Årsbok Yearbook 2006

Polarforskningssekretariatet

Swedish Polar Research Secretariat

Årsbok Yearbook 2006

Polarforskningssekretariatet

Swedish Polar Research Secretariat

+

Omslag ***Cover***
Datakabel till en solfotometer som används för att registrera aerosolers optiska egenskaper.

Data cable for sun-photometers, used to derive optical properties of aerosols.

Innehållsförteckning ***Table of content***
En gruv- och prospekteringsstation från tidigt 1900-tal vid Camp Millar, Bellsund, Svalbard, som användes av det brittiska företaget Northern Exploration Company.

An early 20th century mining and prospecting station in Camp Millar, Bellsund, Spitsbergen, used by Northern Exploration Company.

+

Redaktör
Sofia Rickberg

Produktion och grafisk form
Jerhammar & Co Reklambyrå AB

Tryck
Elanders Tofters AB

Polarforskningssekretariatet
Box 50003
104 05 Stockholm

Tel 08-673 96 00
Fax 08-15 20 57

office@polar.se

www.polar.se

Foto

Torbjörn Karlin	Omslag, s. 47, 48, 49
Dag Avango	s. 2-3
Barbara Wohlfarth	s. 4
Lars Hanning	s. 4, 10
Bertil Strandell	s. 5
Tomas Gustafsson	s. 8
Johan Ström	s. 5, 7, 8, 9, 10, 48
Flygvapnet	s. 11, 12-13, 15, 16
Norsk Polarinstitutt	s. 14

Kartor del 1
Stig Söderlind

Engelsk språkgranskning del 3
Derek Logan

Översättning del 1
Proper English AB

ISSN 1402-2613

ISBN 978-91-973879-6-5

Del ett Part one Verksamheten 2006 Activities 2006

Innehåll Content

Del två Part two Årsredovisning 2006 Annual Report 2006

Del tre Part three Forskarrapporter Cruise Reports

Förord

Britt-Marie Danestig
Styrelseordförande
Polarforskningssekretariatet

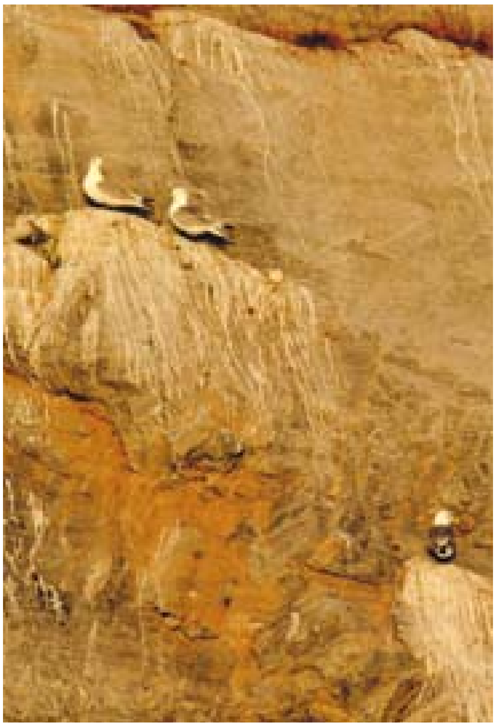
År 2006 kan betecknas som ett mellanår för Polarforskningssekretariatet. Uppföljningen av Beringia 2005, den hittills största expeditionen i sekretariatets historia, och planeringen av det kommande Internationella polaråret (International Polar Year, IPY 2007–2008), har under året varit viktiga arbetsuppgifter. För att Sveriges medverkan i IPY ska bli framgångsrik fordras att forskningsfinansiärerna går från ord till handling och tar ett gemensamt ekonomiskt ansvar för de projekt som är planerade.

I början av november avreste de första deltagarna i årets svenska Antarktisexpedition, SWEDARP 2006/07, till forskningsstationen Wasa för att bl.a. förbereda den svensk-japanska glaciologiska traversen nästa år. Isbrytaren Oden, som chartrats av USA:s National Science Foundation, avgick ungefär samtidigt från Göteborg för att för första gången bryta is i Antarktis. På Sydpolen, vid Amundsen-Scott-stationen fortsätter det internationella partikelfysikprojektet IceCube. Där arbetar svenska forskare och borrare med att montera ljusdetektorer i den klara isen för att kunna fånga upp det ljus som kan uppstå när neutrinos från rymden går igenom isen, och utifrån det få en bättre bild av hur vårt universum ser ut. En av svenskarna kommer att övervintra på stationen och totalt tillbringa 15 månader på Sydpolen i ljus och mörker. Han är den andra svensken någonsin att göra detta; det var 49 år sedan sist.

Under våren 2007 kommer Oden att utrustas med ett nytt avancerat ekolodssystem, ett sk. ”multibeam”. Detta kommer att göra fartyget ännu mer attraktivt på den internationella marknaden, viket vi är både glada och stolta över. Oden blir därmed ett av världens bäst utrustade isgående fartyg för forskningsändamål.

Svensk polarforsknings framtida organisation utreds för närvarande av Polarforskningssekretariatets föreståndare, Anders Karlqvist. Anders kommer att lämna sin utredning till Vetenskapsrådet innan 2006 års slut. Utredningen kan förhoppningsvis ge inspiration för den framtida utvecklingen av svensk polarforskning, och kanske kan den användas som ett inlägg till den kommande forskningspropositionen som väntas under våren 2008.

Vi ser med glädje och tillförsikt tillbaka på polaråret som gått och med spänning fram emot starten av det Internationella polaråret 1 mars 2007.



← Övre vänster *Top left*
Jonas Hagström letar fossil på Trehøgdene, Svalbard.

Jonas Hagström searching for fossils on Mount Trehøgdene, Spitsbergen.

← Nedre *Bottom*
Tältplats i Eskerdalen, Svalbard.

Camp site in Eskerdalen Valley, Spitsbergen.

← Övre höger *Top right*
Kungspingviner, *Aptenodytes patagonicus*,på stranden vid Bahía Colnett, Isla de los Estados, Argentina.

King Penguins, *Aptenodytes patagonicus*, on the beach in Bahía Colnett on Isla de los Estados, Argentina.

↑ Vänster *Left*
Fåglar på klippa i Kungsfjorden, Svalbard.

Bird on a cliff in Kungsfjorden, Spitsbergen.

↑ Höger *Right*
Övergivet och frostigt koltåg i Ny-Ålesund, Svalbard.

Abandoned and frosty coal train in Ny-Ålesund, Spitsbergen.

Foreword

2006 could be described as an off year for the Swedish Polar Research Secretariat. Important projects during the year included following up on Beringia 2005, the largest expedition in the history of the Secretariat to date, and planning for the upcoming International Polar Year (IPY 2007–2008). For Sweden's involvement in IPY to be successful, those funding the research must move from word to deed, and assume collective financial responsibility for the projects that have been planned.

The first participants in this year's Swedish Antarctic Expedition, SWEDARP 2006/07, left for the Wasa research station in the beginning of November to prepare for a Swedish/Japanese glaciological traverse next year. Meanwhile, the icebreaker Oden, which was chartered by the US National Science Foundation, sailed from Gothenburg to break ice in Antarctica for the first time. The IceCube international particle physics project continues at the South Pole, at Amundsen-Scott Station. Swedish researchers and drillers there are working to install light detectors in the clear ice in order to capture the light that can be emitted when neutrinos from outer space pass through the ice, which will enable us to obtain a better picture of our universe.

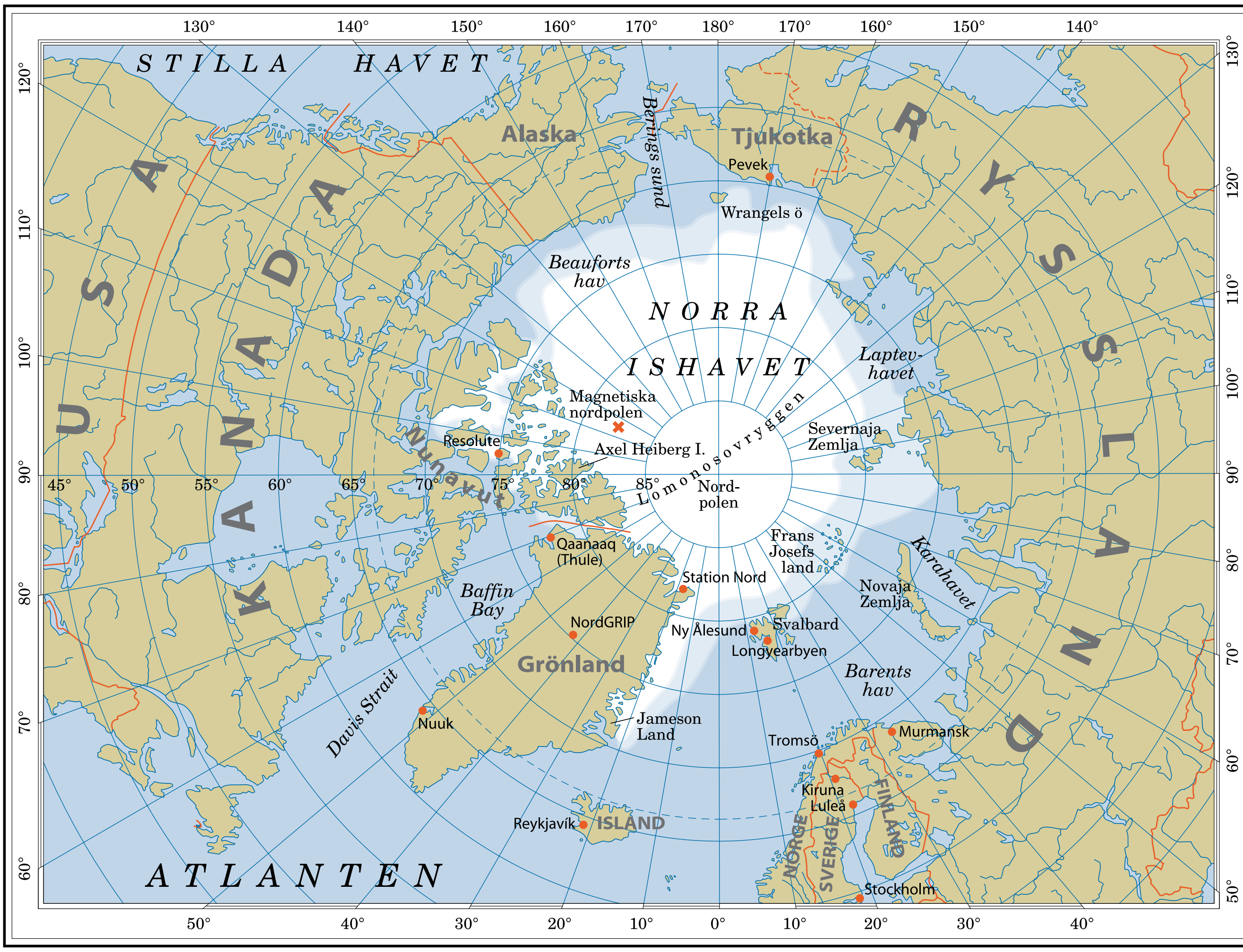
One of the Swedes will winter at the station, and will spend a total of 15 months at the South Pole, in light and darkness. He is the second Swedish person ever to do this, and it has been 49 years since the last time.

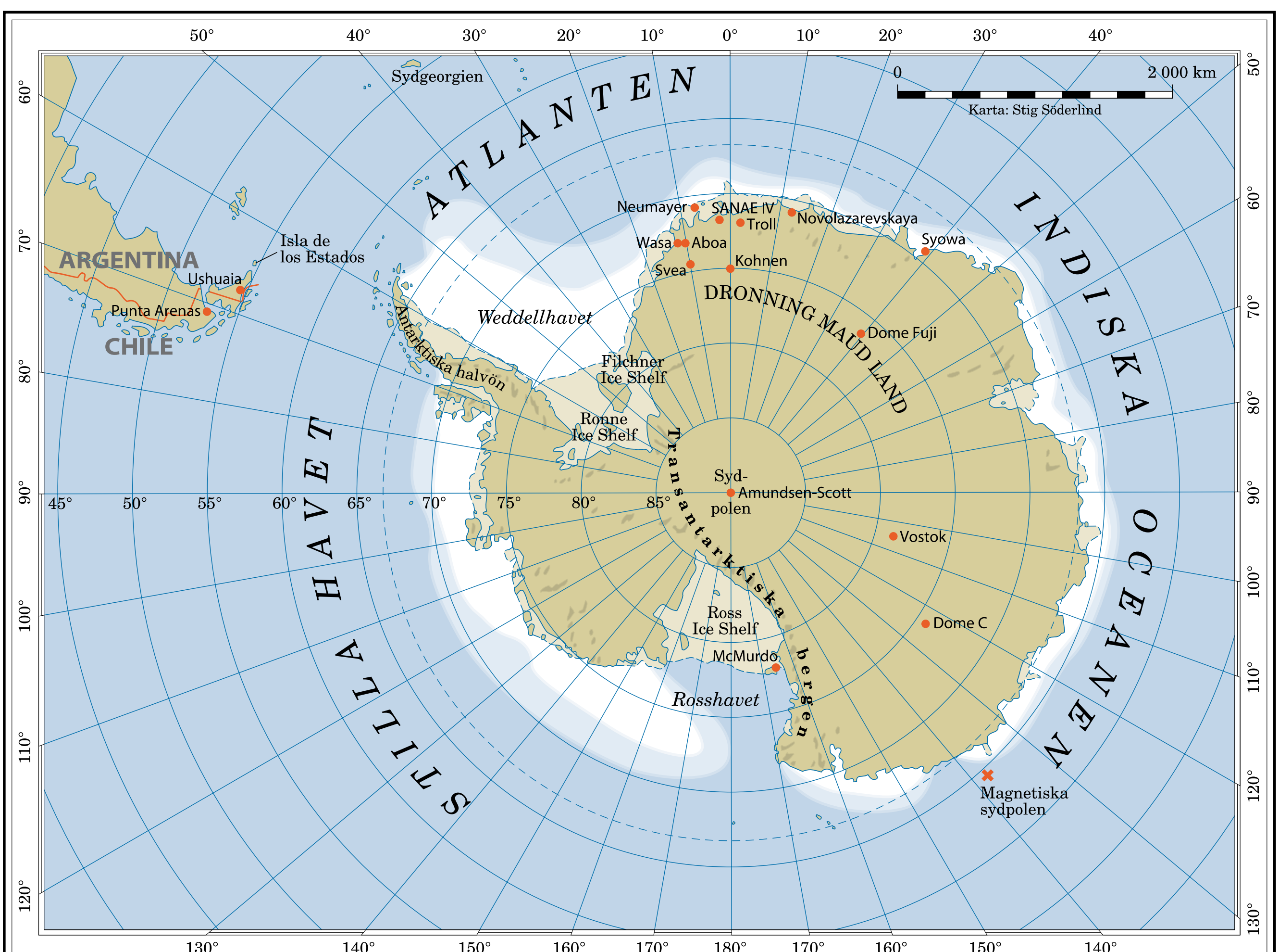
Oden will be fitted with a new and advanced multi-beam echo sounding system during the spring of 2007. We are both pleased and proud to note that this system will make the vessel even more attractive on the international market. It will make Oden one of the best-equipped ice-going research vessels in the world.

The current head of the Swedish Polar Research Secretariat, Anders Karlqvist, is now studying the future organisation of Swedish polar research. Anders will present his report to the Swedish Research Council by the end of 2006. The study will hopefully provide inspiration for the future development of Swedish polar research, and may serve as part of the upcoming parliamentary research bill that is anticipated in the spring of 2008.

We look back on the past Polar Year with joy and satisfaction, and are looking forward with excitement to the start of the International Polar Year on March 1, 2007.

Britt-Marie Danestig
Chairwoman of the Board
Swedish Polar Research Secretariat


STILLA HAVET
ATLANTEN
USA
KANADA
RYSSLAND
Alaska
Tjukotka
Pevek
Berings sund
Wrangels ö
Beauforts hav
NORRA ISHAVET
Laptev-havet
Magnetiska nordpolen
Severnaja Zemlja
Resolute
Nunavut
Axel Heiberg I.
Lomonosovryggen
Nord-polen
Frans Josefs land
Qaanaaq (Thule)
Station Nord
Karahavet
Novaja Zemlja
Baffin Bay
NordGRIP
Ny Ålesund
Svalbard
Longyearbyen
Grönland
Barents hav
Davis Strait
Nuuk
Jameson Land
Tromsö
Murmansk
Kiruna
Luleå
FINLAND
NORGE
SVERIGE
Reykjavík
ISLAND
Stockholm


Sydgeorgien
ATLANTEN
0
2 000 km
Karta: Stig Söderlind
INDISKA OCEANEN
STILLA HAVET
Isla de los Estados
ARGENTINA
Ushuaia
Punta Arenas
CHILE
Neumayer
SANAE IV
Troll
Novolazarevskaya
Syowa
Wasa
Aboa
Kohnen
Svea
DRONNING MAUD LAND
Weddellhavet
Dome Fuji
Antarktiska halvön
Filchner Ice Shelf
Ronne Ice Shelf
Transantarktiska bergen
Syd-polen
Amundsen-Scott
Vostok
Ross Ice Shelf
Dome C
McMurdo
Rosshavet
Magnetiska sydpolen

Polaråret som gått

För första gången på länge i Polarforskningssekretariatets historia har sommaren gått utan att vi har varit engagerade i en stor expedition. Efter den omfattande årsrapporten för 2005 med Beringia-expeditionen som huvudnummer följer här en tunnare årgång. Därmed inte sagt att året har varit händelselöst. Det har varit ett år fyllt av planering och kontaktverksamhet, det mesta med siktet inställt på Internationella polaråret (International Polar Year, eller helt kort: IPY) som inleds 1 mars 2007. Glädjande nog har Kronprinsessan Victoria accepterat att vara beskyddare av det svenska IPY programmet. IPY-invigningen kommer att uppmärksammas världen över och i Sverige med en ceremoni på Icehotel i Jukkasjärvi.

Isbrytaren Oden har i år legat vid kaj i Luleå efter avslutad isbryterisäsong i Bottenviken, men när det här skrivs är hon på väg mot nya spännande uppgifter. I november påbörjade hon sin första resa någonsin till Antarktis. Ombord finns forskare och lärare från USA, Chile och Sverige. Uppdraget är först och främst att bryta is och eskortera fartyg med leveranser in till den amerikanska stationen McMurdo för National Science Foundations (NSF, USA:s största forskningsfinansiär) räkning, men vi passar också på att utnyttja resan för forskning. Detta samarbete mellan Polarforskningssekretariatet, NSF och Sjöfartsverket kommer förhoppningsvis att fortsätta flera år framöver, och i och med det öppnas helt nya möjligheter till forskningssamarbete med USA i Antarktis. Odens rutt, som går via sydspetsen på Sydamerika till Rosshavet, ger forskarna tillfälle till upprepade mätningar i ett havsområde som är sparsamt trafikerat.

Den svenska Antarktisverksamheten pågår annars i begränsad omfattning vid station Wasa med omnejd. Ett forskningsprojekt med koppling till rymdfysik i Kiruna har inletts. I övrigt har det förberetts för den stora glaciologiska traversen under IPY-året 2007–2008 i samarbete med Japan. Utrustning har tagits ner och bandvagnar ställts i ordning. DROMLAN-samarbetet (Dronning Maud Land Air Network) för flygningar till och från Antarktis har fått en systerorganisation i DROMSHIP. Syftet är att samla intressenterna i denna del av Antarktis kring gemensamma tranportlösningar med fartyg. Det första steget togs med transport av tung utrustning till Antarktis i november–december 2006. Det ryska fartyget Papanin hyrdes in och fraktade ner gods från Oslo till stationerna i Dronning Maud Land.

Anders Karlqvist
Chef
Polarforskningssekretariatet

Bild *Figure*
Kanten av Moore-glaciären, Blissbukten, norra Grönland.

The margin of Moore Glacier in Bliss Bugt, North Greenland.

Bild *Figure*
Läraren Ruben Fritzon och maringeologen Martin Jakobsson, som arbetade tillsammans under forskningsexpeditionen Beringia 2005, höll ett gemensamt föredrag på Skolforum-mässan i november.

Teacher Ruben Fritzon and marine geologist Martin Jakobsson worked together during the research expedition Beringia 2005, and held a joint lecture at the educational exhibition Skolforum in November.

Bild *Figure*
Sven Lidström blir andre svensk någonsin att övervintra på den geografiska Sydpolen.
Sven Lidström will be the second Swede ever to overwinter at the geograpical South Pole.

Bild *Figure*
Zeppelinstationen i Ny-Ålesund, Svalbard, i augusti 2006.
The Zeppelin station at Ny-Ålesund, Spitsbergen, in August 2006.

Polarforskningssekretariatets medarbetare Sven Lidström är detta år i tjänst hos NSF för att arbeta med partikelfysikprojektet IceCube på Sydpolen. Sven ska även tillbringa vintern på Sydpolen, och kommer att vara på Antarktis hela 15 månader i sträck. Det är andra gången någonsin i historien som en svensk övervintrar på Sydpolen. Hans intressanta resebrev med bilder finns till allmän läsning på Polarforskningssekretariatets hemsida.

Även om ingen stor fartygsexpedition har seglat norrut under sommaren 2006 så har enskilda forskare varit ute i fält och arbetat på norra Grönland, Svalbard, Wrangelön m.fl. platser. Rapporter om detta finns förstås på annan plats i denna årsbok.

Även om mycket av den operativa verksamheten gått på sparlåga är det aldrig någon risk att sammanträdena, mötena och resandet avstannar. De stora internationella mötena detta år har varit Arctic Science Summit Week i Potsdam i april; Antarktisfördragets årliga session, detta år i Edinburgh; och SCAR/COMNAP-mötet som hölls i Hobart i juli. SCAR-konferensen var mycket välbesökt med mer än 800 forskare från hela världen. Tyvärr var Sverige dåligt representerat. Dessa möten liksom många andra under året, såsom European Polar Board, ägnar stor uppmärksamhet åt IPY-planeringen. Det faktum att IASC (International Arctic Science Committe) har sitt sekretariat i Stockholm i anslutning till Polarforskningssekretariatet har också inneburit många internationella besökare och en ökad direktkontakt med den polarforskande omvärlden.

Slutligen kan vi berätta att Polarforskningssekretariatets nya verkstads- och lagerlokaler i Kräftriket på Stockholms universitets område står klara. Flytten skedde i september och logistikverksamheten har fått en nystart, när den nu ligger nära såväl Polarforskningssekretariatets huvudkontor på Kungl. Vetenskapsakademien som Stockholms akademiska miljöer.

Nästa år räknar vi med att åter ha en årsbok fylld av rapporter från omfattande forskningsprogram och stor expeditionsverksamhet såväl i norr som i söder. Planering pågår!

The past polar year

For the first time in a long time in the history of the Swedish Polar Research Secretariat, the summer passed without us being involved in a major expedition. Following our rather hefty 2005 yearbook, which featured the Beringia expedition, this year's edition is a bit lighter. But that is not to say that the year has been uneventful. It has been a year filled with planning and contact activities, focused mostly on the International Polar Year, or "IPY," which begins on March 1, 2007. We are delighted that Crown Princess Victoria has consented to be the royal patron of the Swedish IPY programme. The IPY dedication will be marked worldwide, and here in Sweden we will have a dedication ceremony at Icehotel in Jukkasjärvi.

The icebreaker Oden had been docked in Luleå this year since the end of the icebreaking season in Bottenviken, but as of this writing she is en route to exciting new missions. In November she embarked on her first ever voyage to Antarctica. On board are researchers and teachers from the USA, Chile, and Sweden. Her primary mission is to break ice and escort vessels bringing supplies to the American McMurdo Station on behalf of the National Science Foundation (NSF, the USA's biggest research funder), but we are making sure to use the voyage for research as well.

We hope that this cooperation between the Swedish Polar Research Secretariat, NSF, and the Swedish Maritime Administration will continue for many years to come, opening up totally new opportunities for Antarctic research in cooperation with the USA. Oden's route, which takes her past the southern tip of South America to the Ross Sea, will give the researchers on board an opportunity to make repeated measurements in a sparsely trafficked area of ocean.

Otherwise, Sweden's Antarctic operations are continuing to a limited extent at Wasa Station and the surrounding area. A project with ties to space physics research at Kiruna has been started. Preparations have also been made for the major glaciological traverse scheduled for IPY 2007–2008 in cooperation with Japan. Equipment has been brought down, and tracked all-terrain vehicles have been arranged for. The Dronning Maud Land Air Network (DROMLAN) cooperative arrangement for flights to and from Antarctica has gained a sister organisation in DROMSHIP. The aim is to bring stakeholders in this part of Antarctica together to cooperate on collective ship-based transportation solutions. The first step was taken with the shipment of heavy equipment to Antarctica in November–

Anders Karlqvist
Director-General
Swedish Polar Research Secretariat

Bild *Figure*

Den subantarktiska "Fyren vid världens ände", känd genom Jules Vernes roman med samma namn, ligger vid mynningen av Puerto San Juan del Salvamento, på Isla de los Estados, öster om Kap Horn.

The sub-Antarctic "The Lighthouse at the end of the World", famous through Jules Verne's novel of the same name, is situated at the entrance to Puerto San Juan del Salvamento, on Isla de los Estados, east of Cape Horn.

Bild *Figure*
Tältplats i Lusitaniadalen med Marmierfjellet i bakgrunden.

Camp site in Lusitaniadalen with Marmierfjellet in the background.

December 2006. The Russian vessel Papanin was leased to bring cargo from Oslo to the stations in Queen Maud Land.

This year, Swedish Polar Research Secretariat staff member Sven Lidström is working for NSF in connection with the IceCube particle physics project at the South Pole. Sven will also be overwintering at the South Pole, and will spend 15 consecutive months in Antarctica. This marks only the second time in history that a Swede has wintered at the South Pole. His interesting travel letters, with pictures, are available to the public on the Swedish Polar Research Secretariat website.

Although no major expeditions sailed northward in the summer of 2006, individual researchers were out in the field, working in northern Greenland, Svalbard, Wrangel Island, and elsewhere. Reports on this research are naturally included in this yearbook.

Although many of our operational activities have been relatively quiescent, there is never any danger that our conferences, meetings, and travels will stop. The major international conferences this year were the Arctic Science Summit Week in Potsdam in April; the annual session of the Antarctic Treaty Consultative Meeting, held this year in Edinburgh in June; and the SCAR/COMNAP meetings, held in Hobart in July. The SCAR conference was very well attended, with over 800 researchers from around the world taking part. Sweden was, unfortunately, poorly represented. Like many other conferences during the year, such as the European Polar Board, these conferences are devoting major attention to IPY planning. The fact that the International Arctic Science Committee (IASC) has its secretariat in Stockholm, in association with the Swedish Polar Research Secretariat, has also led to numerous international visitors and greater direct contact with the world of polar research.

Finally, we note that the Swedish Polar Research Secretariat's new operational and warehouse facilities in Kräftriket, in Stockholm's university district, are up and running. The move was made in September, and our logistics operations have been revitalised now that they are based in close proximity to both the Swedish Polar Research Secretariat's main office at the Royal Academy of Sciences, and to the academic environments of Stockholm.

We expect next year's yearbook to be filled once again with reports of extensive research programs and major expeditions to both the north and to the south. The plans are being made now!

Bild *Figure*
Jobbpaus i snön för Birgitta Noone och Ann-Christine Engvall, Ny-Ålesund, Svalbard.

A break from work in the snow for Birgitta Noone and Ann-Christine Engvall, Ny-Ålesund, Spitsbergen.

Med Hercules till Antarktis

Att flyga till Antarktis är i sig inget större problem än att flyga någon annanstans på jorden. Väl uppe i luften är allt sig likt. De stora skillnaderna när man planerar för en flygning till en så avlägsen plats är att man måste säkerställa vissa fundamentala saker, t.ex. att man kan fylla bränsle för returresan, att man hela tiden säkrar kommunikation med omvärlden samt att man har god uppföljning av vädersituationen på landningsplatsen.

Uppgiften att genomföra en, eventuellt två flygningar till Troll Airfield, Dronning Maud Land, Antarktis via Kapstaden, Sydafrika med ett C-130 Hercules-flygplan fick Flygvapnets Transportflygdivision, Såtenäs, i augusti 2005. Flygningarna skulle genomföras som stöd till Polarforskningssekretariatet och dess internationella samarbete DROMLAN, Dronning Maud Land Air Network. Elva länder är medlemmar i nätverket som flyger till de flesta forskningsstationerna i Dronning Maud Land (nordvästra Antarktis, från Sveriges håll sett) med personer och gods. Samarbetet inom DROMLAN har betydligt underlättat transporter till och ökat möjligheten att forska i denna del av Antarktis.

Ett omfattande förberedelsearbete startade upp och kontakter etablerades med Norsk Polarinstitutt, som står för driften av landningsflygplatsen Troll Airfield, och Polarforskningssekretariatet, som svarade för last och passagerare. Alla praktiska frågor reddes ut. En underlättande faktor var att undertecknad varit på plats på Antarktis två gånger tidigare i Polarforskningssekretariatets regi i samband med utvärdering och projektering av landningsplatsen.

Den 2 januari 2006 startade så flygningen från Såtenäs mot Kapstaden, via Iraklion på Kreta och Nairobi i Kenya. Ombord fanns förutom besättningen om åtta man, även två representanter för Polarforskningssekretariatet, en tekniker från Norge som skulle underhålla markutrustningen på Antarktis samt en representant för DROMLAN-organisationen. Även en del teknisk utrustning för tankning etc. medfördes. Mellanlandningarna på Kreta och i Kenya förlöpte rutinmässigt. Väl nere i Kapstaden fortsatte de sista förberedelserna inför ”det stora lyftet”. Bl.a. genomfördes noggranna genomgångar med passagerarna om den säkerhetsutrustning som fanns ombord, samt kontroller att den tillkommande lasten var packad och korrekt dokumenterad.

Klockan 22:00 lokal tid den 6 januari lättade vi så från Cape Town International, med planen att genomföra flygningen på 8 timmar och 50 minuter med goda väderutsikter. Ett 30-tal passagerare av olika nationaliteter – bl.a. officiella representanter för norska och tyska myndigheter – och några ton reservdelar och förnödenheter fanns ombord. Efter halvannan timme försvann de sista ljusen från Afrika bakom oss, och stjärnhimmeln var det enda ljus som kunde urskiljas utanför flygplanet. Därefter förflöt tiden rutinmässigt, med positionsrapporter till flygtrafikledningen i Johannesburg på kortvågsradio, samt väderuppdatering med meteorologen på den tyska forskningsstationen Neumayer på Antarktis via satellittelefon. Passagerarna hade vid det laget gjort det så bekvämt som möjligt för sig och de flesta passade på att få några timmars sömn.

Göran Wästhed
Befälhavare
F 7 – Skaraborgs flygflottilj
Flygvapnet

Bild *Figure*
Midnattssol under inflygningen till Antarktis.
Midnight sun during the inflight to Antarctica.

Efter ca 4 timmars flygning kunde vi skönja den första gryningen rakt söderut, vilket piggade upp besättningen betydligt. Efter 6 timmar var det dags att passera den punkt där vi senast måste bestämma om vi skulle fortsätta mot destinationen eller återvända till Kapstaden, den s.k. ”point of no return”. Vädersituationen var fortfarande stabil, och eftersom övriga faktorer höll sig inom planeringens ramar var beslutet att fortsätta givet. Efter ytterligare ca 2 timmar framåt såg vi de första isbergen i havet, och strax därefter hade vi Antarktis under oss.

Efter 8 timmar och 53 minuter i luften, precis som planerat, kunde vi slutligen landa i strålande solsken och 10 minusgrader på en mycket välpreparerad landningsbana av blå-is ca 7 km från den norska forskningsstationen Troll. Landningen innebar inga som helst problem, då vädersituationen innebar att kontrastverkan var mycket god, samt att landningsbanan var föredömligt utmärkt med svarta skärmar. Dålig kontrastverkan kan annars vara ett problem över stora obrutna is- och snöytor, då visuella referenser med marken helt kan förloras. Prepareringen av isen gjorde vidare att ytan på landningsbanan kan jämföras med dom s.k. ”vinterbanor” av packad snö som vi normalt opererar på i norra Skandinavien vintertid.

Passagerare och last spreds därefter till sina slutdestinationer med mindre flygplan och helikoptrar, och besättningen inkvarterades på Troll station för några timmars välbehövlig sömn. De följande dagarna ägnades åt tillsyn och tankning av flygplanet, vilket tog några timmar extra pga. lite primitivare hjälpmedel än normalt. Ca 22 000 liter flygbränsle, som

fraktats dit först med båt och de sista 300 kilometrarna från kusten med bandvagn, gick åt (man vill helst inte veta literpriset). Tid fanns även för att göra mindre utflykter runt stationen för att studera den vidunderliga naturen som bjöd på allt ifrån djupa glaciärsprickor till snöfria bergsformationer. Förekomsten av ett par fågelarter förundrade oss också, då födotillgången torde vara begränsad.

Efter tre dagar på Troll var det dags för återresan till Kapstaden. Väl utvilade och uppfyllda av unika intryck av Antarktis startade vi norrut med 35 passagerare: samma VIP-grupp som åkte med ner, några forskare av olika nationalitet och dessutom några norska byggnadsarbetare som arbetat på forskningsstationen. Vidare lite teknisk utrustning som skulle till Sydafrika respektive Norge för översyn och reparation. Returflygningen förlöpte även den utan några problem, och efter knappt 9 timmar kunde vi åter landa i Sydafrika.

I Kapstaden summerade vi våra erfarenheter med berörda personer och efter ett par dagar började resan tillbaka till Sverige. Även den kunde genomföras helt rutinmässigt, och efter samma route som vägen ner: Nairobi–Iraklion–Såtenäs.

Att flyga långt ut i ödemarken, som ju har naturliga begränsningar gällande support om man råkar ut för tekniska störningar, krävde sina särskilda och noggranna förberedelser, trots våra tidigare erfarenheter av flygning i Arktis och andra ensligt belägna områden. Vi insåg t.ex. vikten av att etablera kontakter med andra nationer som flyger med samma flygplanstyp på Antarktis. Många nyttiga erfarenheter drogs av denna, även för oss, extraordinära flygning.

+

Bild *Figure*

Urlastning på den norska Antarktisstationen Trolls flygfält.

Unloading at the Norwegian antarctic station Troll's airfield.

By Hercules to Antarctica

Göran Wästhed
Pilot in command
F 7 – Skaraborg Wing
Swedish Air Force

Bild *Figure*
Ett svenskt Hercules-plan landar för första gången på Antarktis.

A Swedish Hercules aircraft lands for the first time on Antarctica.

Flying to Antarctica is, in and of itself, no more problematic than flying anywhere else in the world. It's all the same once you are up in the air. The big differences in planning for a flight to such a remote location involve taking care of certain basics, such as being able to refuel for the return trip, always ensuring reliable communications with the outside world, and keeping close tabs on the weather situation at the landing site.

In August 2005 the Swedish Air Force's Air Transport Squadron, Såtenäs AFB (Air Force Base), was given the mission of making one or possibly two flights to Troll Airfield, Queen Maud Land, Antarctica, by way of Cape Town, South Africa, using a C-130 Hercules aircraft. The flights were to be made in support of the Swedish Polar Research Secretariat and its international cooperative programme, DROMLAN (Dronning ["Queen"] Maud Land Air Network). There are eleven member nations in the network, which flies people and material to most of the research stations in Queen Maud Land (northwest Antarctica from Sweden's perspective). The DROMLAN cooperative programme has significantly facilitated shipments to this part of Antarctica, making research there more feasible.

Comprehensive preparations were begun, and contacts were established with the Norwegian Polar Institute, which is responsible for operating the landing field, Troll Airfield, and with the Swedish Polar Research Secretariat, which was responsible for the passengers and cargo. All the practical issues were studied and worked out. One facilitating factor was that I, the undersigned had been on site in Antarctica twice before under the auspices of the Swedish Polar Research Secretariat in connection with the evaluation and planning of the landing site.

On 2 January 2006 we set out from Såtenäs toward Cape Town by way of Heraklion, Crete and Nairobi, Kenya. In addition to the crew of eight people, we had on board two representatives from the Swedish Polar Research Secretariat, an engineer from Norway who was to maintain the ground equipment in Antarctica, and a representative from the DROMLAN organization. Some technical equipment for refuelling, etc. was also brought along. The intermediate stops in Crete and Kenya proceeded routinely. After we landed in Cape Town, the final preparations for ”the big lift” continued. They included a detailed review of the onboard safety equipment with the passengers, and checks to ensure that our additional cargo had been packed and properly documented.

We took off from Cape Town International at 10 p.m. local time on 6 January, planning to make the flight in 8 hours and 50 minutes, with a forecast calling for favourable weather. On board were some 30 passengers of various nationalities, including official representatives from the Norwegian and German governments, and several tonnes of spare parts and essential materiel. After an hour and a half the last lights from Africa disappeared behind us, and the starry skies offered the only discernible light outside the aircraft. The time passed routinely, with position reports to air traffic control in Johannesburg via shortwave radio, and weather updates from the meteorologist at the German Neumayer research station in Antarctica transmitted by satellite telephone. By that time the passengers had settled in as comfortably as they could, and most of them made sure to catch a few hours of sleep.

We saw the first glimmers of dawn due south after about four hours, which cheered the crew considerably. After six hours we reached the “point of no return,” our last chance to decide whether we were to continue on to our destination or turn back to Cape Town. The weather situation remained stable and, since the other factors involved were within the planning framework, the decision to carry on was a given. After about two more hours we spotted the first iceberg in the sea, and Antarctica appeared beneath us very shortly thereafter.

+

Bild *Figure*
Trolls flygfält sett från ovan.

Troll Airfield from above.

+

Bild *Figure*

Besättningen med en extra linslus på vänstra flanken.

The crew, and an extra lens louse on the left flank.

After 8 hours and 53 minutes in the air, right on schedule, we were finally able to land in brilliant sunshine and ten degrees below zero on a very well prepared blue-ice runway about 7 km from the Norwegian research station, Troll. The landing went off without a hitch, since the contrast was excellent, due both to the weather and to the fact that the runway had been marked out with black screens in exemplary fashion. Poor contrast can otherwise be a problem over large unbroken ice and snow surfaces, where visual ground references can become lost entirely. In addition, the preparation of the ice made the runway surface comparable with the winter runways made of packed snow on which we normally operate in northern Scandinavia during the winter months.

The passengers and cargo were then dispersed to their final destinations using smaller aircraft and helicopters, and the crew was billeted at Troll Station for a few hours of much needed sleep. The days that followed were spent maintaining and refuelling the aircraft, which took a few extra hours because the equipment there is a little more primitive than usual. We took on about 22,000 litres of aviation fuel, which had been brought there first by ship, with the last 300 kilometres from the coast being traversed by tracked all-terrain vehicles (the cost per litre is better left unknown). There was also time to make minor excursions around the station to study the wondrous natural surroundings, which offer everything from deep glacial crevasses to snow-free rock formations. The presence of several species of birds also amazed us, as the food supply must be very limited.

After three days at Troll, it was time for the return trip to Cape Town. Well rested and filled with unique impressions of Antarctica, we set off northward with 35 passengers: the same VIP group that had come down with us, several researchers of various nationalities, and also a number of Norwegian construction workers who worked at the research station. We also took along a small cargo of technical equipment which was to be transported to South Africa or Norway for inspection and repair. The return flight also proceeded without problems, and we landed in South Africa in just under 9 hours.

In Cape Town we summarised our experiences with the relevant parties, and after a few days began our return trip to Sweden. This also proceeded in entirely routine fashion, following the same route as we used on the way down, i.e. Nairobi–Heraklion–Såtenäs.

Flights made deep into remote wastelands, which are naturally subject to limitations in terms of support if you encounter technical problems, require special and careful preparations, despite our previous experience flying in the Arctic and other remote, isolated regions. We perceived, for instance, the importance of establishing contacts with other nations that are flying to Antarctica using the same type of aircraft. A great deal of useful experience was gained from this flight, which was an extraordinary one, even for us.

+

Bild *Figure*

Tankning och kallprat.

Fuelling and small talk.


Forskarrapporter Cruise Reports

Innehåll Content

Forskarrapporter Cruise Reports

SWEDARP 2005/06

Forskarrapporter Cruise Reports

Project leader

Svante Björck
Geobiosphere Science Centre
Quaternary Sciences
Lund University

Project participants

Christian Hjort
Karl Ljung
Per Möller
Geobiosphere Science Centre
Quaternary Sciences
Lund University

Barbara Wohlfarth
Department of Physical Geography
and Quaternary Geology
Stockholm University

Isla de los Estados – Quaternary geology and palaeoclimatology at the end of the world

Introduction

The expedition in November–December 2005 to Isla de los Estados (Staten Island) off the south-eastern tip of South America (Fig. 1) was a cooperative venture between Lund University (LU) and Stockholm University (SU) in Sweden and the CADIC-CONICET institute in Ushuaia, Argentina. The size of the island is ca. 65 × 35 km, its geographical position roughly 54°45'S, 64°30'W and its highest peaks reach approx. 800 m a.s.l. (Fig. 1). Its bedrock geology and general morphology have been described by Dalziel et al. (1974) and Caminos and Nullo (1979).

The expedition travelled to the island with the chartered ketch *Ocean Tramp*. It left Ushuaia on Tierra del Fuego on 28th November and returned there on 16th December. The total number of field workdays was 16, carried out from one field camp in Bahía Colnett and, based on the boat, from anchorages in Puerto Basil Hall, Puerto Cook (Fig. 2), Puerto San Juan del Salvamente and Bahía Crossley. A one day visit was also made to the small Isla Observatorio north of the main island.

The scientific crew consisted of five Swedish researchers (Svante Björck, Christian Hjort, Karl Ljung and Per Möller from LU, and Barbara Wohlfart from SU) and five Argentinians (Jorge Rabassa, Juan Federico Ponce and Adrian Schiavini from CADIC-CONICET in Ushuaia, Fidel Roig from IANIGLA-CONICET in Mendoza, and Oscar Martinez from Universidad Nacional de la Patagonia-San Juan Bosco in Esquel). In addition to this the ketch had a crew of three (with captain Charlie Porter) and an Argentinian medical doctor (Enrique Pianzola).

The expedition's aim was threefold;

(1) to anchor the Swedish palaeoclimatic "ATLANTIS"-project (Greenland, Iceland, Faroe Islands, Azores, Grenada, Tristan da Cunha, e.g. see Björck et al. 2002, Andresen et al. 2004, Andresen and Björck 2005, Björck et al. 2006, Andresen et al. 2006, Ljung et al. 2006) onto the southern parts of the South American continent;

(2) to connect earlier Swedish and Argentinian glacial- and climate history reconstructions from the Antarctic Peninsula (e.g. Björck et al. 1996, Hjort et al. 2003, Ingolfsson et al. 2003) with equivalents from north of the Drake Passage, in southernmost South America;

(3) to extend this type of palaeo-information such as that already available from the Tierra del Fuego mainland (see references

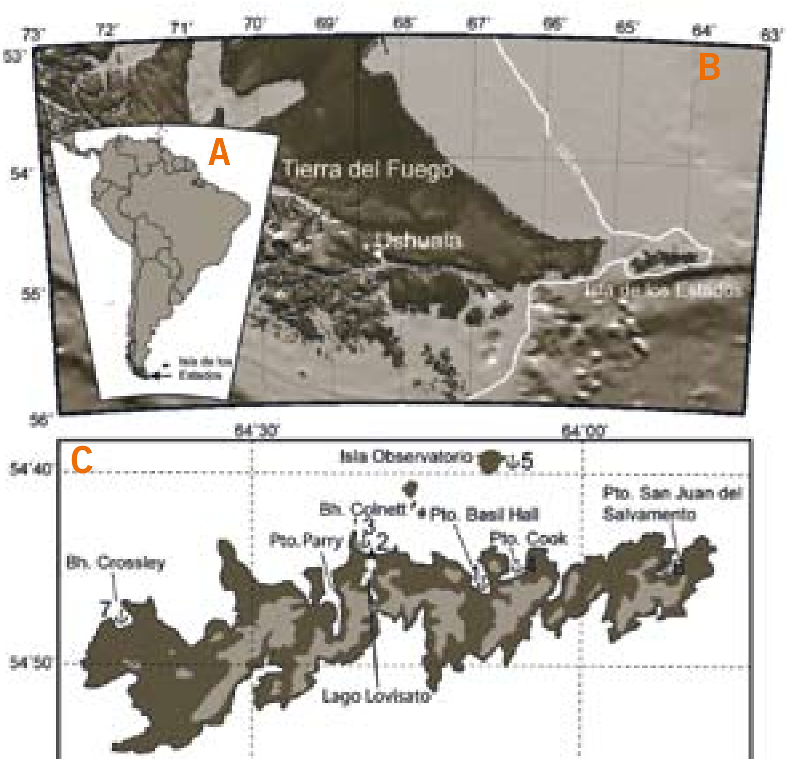


Figure 1
A. Overview map of South America.
B. Tierra del Fuego with Isla de los Estados (Staten Island) and with the 100 m depth-curve approximating the coastline of the eustatically lowered sea at the Last Glacial Maximum (LGM) ca. 20,000 years ago.
C. Isla de los Estados with our field camp and working anchorages, used the following dates: 1: 29.11–8.12., 2: 30.11–8.12., 3: 8–9.12., 4: 9–10.12., 5: 10.12., 6: 10–13.12. and 7: 13–15.12. The paler shade approximates areas over 300 m a.s.l.

Figure 2
The north coast of Isla de los Estados at Puerto Cook as seen from the approaching *Ocean Tramp*. Photo: Svante Björck.

below) to the peripherally situated and in this context only superficially studied Isla de los Estados.

Earlier studies have shown that at one time glaciers originating in the southernmost Andes reached east to and beyond the present Atlantic coast (e.g. Nordenskjöld 1898, Caldenius 1932, Auer 1956, Malagnino and Olivero 1999, Rabassa et al. 2000, Sugden et al. 2005). However, the last time they did so on a broad front may have been 1 million years ago – and the ice-fronts did not reach the Atlantic at all during the so-called Last Glacial Maximum (LGM) around 20,000 years ago (Rabassa et al. 2000, Sugden et al. 2005). On the first glaciation map ever published for southern South America, Otto Nordenskjöld (1898) envisaged an ice cap which, covering the Andes and much of the (due to lower sea level) dry shelf areas southeast of Tierra del Fuego, also included Isla de los Estados. A study of topographic maps, satellite images and aerial photos of the island also show it pitted with glacial cirques and truncated by overdeepened glacial basins (mini-fjords) – in contrast to which its higher areas (above ca. 300 m) show a distinct nunatak topography. Thus the island seemed a promising working area for a glacial geologist.

As for the vegetation history of Isla de los Estados, which today is covered below the treeline at approx. 300 m by a combination of primeval *Nothofagus* forest and bogs, not too much is known. The flora and vegetation of the island were described by Dudley and Crow (1983) and included in Moore's *Flora of Tierra del Fuego* (1983), but the only palaeobotanical work so far available from here is by Johns (1981). This was based on three undated peat cores from the Bahía Crossley area. However, from mainland Tierra del Fuego much palaeovegetational work has been done over the years, e.g. by Auer (1958), Heusser (1989, 1998) and Markgraf (1993a, b). The development can be said to start with the post-LGM deglaciation around 17,000 years ago (e.g. Hulton et al. 2002) and thereafter includes climatically based fluctuations between steppes, forests and so called Magellanic moorlands.

On Isla de los Estados our expedition studied the glacial history, as illustrated in the field by glacial erosion and various forms of deposition, through geomorphological and stratigraphical work, including the sampling for dating. Palaeoclimatic records were sampled by coring lake sediments and peat bogs and through dendrochronological work on both living *Nothofagus* trees and old logs preserved in the peat.

Glacial geomorphology and sedimentology

Our main work on glacial geomorphology and sedimentology was conducted at Bahía

Colnett (Fig. 3). Here four moraines form highly arched ridges, 5–15 m high, one of them damming Lago Lovisato (moraine C, Fig. 3). The small Lago Galvarne to the north is, however, dammed by a pronounced beach ridge. Moraines A and B are eroded by the sea at the recent shoreline, and their tentative former continuation out into Bahía Colnett is indicated in Figure 3. The configuration of these moraines show that they were formed at temporary stillstands during the recession of an outlet glacier emanating in the mountains to the south, thus representing only local glaciation on Isla de los Estados. Minimum ages for the moraines, and thus for the deglaciation, are given by the lowermost ^{14}C datings of organic deposits from lake cores. For Lago Galvarne it is 16,500 cal yr BP (calculated years before present) (Fig. 3: coring point 1), which gives the minimum age for moraine B. For the small lake southwest of Lago Lovisato it is 16,000 cal yr BP (Fig. 3: coring point 3), which then possibly gives the minimum age for moraine D. The moraine indicated on the western shore of the Cabo Colnett peninsula (Fig. 3) is a lateral one, from an outlet glacier flowing out of Puerto Parry into Bahía San Antonio.

Eastward, in the direction of Puerto Roncagli (Fig. 3), wave erosion has formed a 10–25 m high cliff, exposing the glacigenic sediments of the area (Fig. 5). Documented sedimentary sequences (triangles at the coast in Fig. 3) give a local stratigraphy of the area, which at sea level starts with laminated silt and clay, probably representing annual varves. These glaciolacustrine sediments are overlain by thick diamict units, being both massive and shear laminated. The diamicton is frequently interbedded with sorted sediments, often showing glacial deformation structures. The lower part of the diamicton also has large inclusions of silt and clay in its lower part, interpreted to derive from the underlying glaciolacustrine sediments. The long-axis orientation of pebble clasts shows a transport direction from SSW, suggesting that the diamicton was deposited beneath a glacier that came out of the Lago Lovisato valley, thus a product of local glaciation. Maximum ages of this glaciation will be given by pending OSL (Optically Stimulated Luminescence) datings, and its minimum age by ^{14}C datings of the blanketing peat.

Another important locality with Quaternary sediments was located in the inner part of Bahía Crossley. Here sequences of interbedded fluvial and aeolian sediments are draped by a diamicton with a strong long-axis orientation of elongated stones in it. However the genetic interpretation of this diamicton is not clear; it could either be interpreted as a glacial till or as a colluvium, i.e. a debris flow from adjacent high areas. The age of the fluvial and aeolian sediments will be determined by ^{14}C datings on organic remains and by OSL dating on the sediment itself, and a minimum age of the covering diamicton should be given by ^{14}C dating the peat on top of it.

Lake sediment and peat stratigraphy

To reconstruct the palaeoclimatic development of Isla de los Estados since the last ice retreat, four main peat bog/lake sites were cored and sampled with a so-called Russian chamber corer. Three of these are situated in the Bahía Colnett area (Fig. 3) and the fourth one in Bahía Crossley.

The northernmost site, Lago Galvarne, was cored from several points in the lake and from the peat bog surrounding it. The most complete stratigraphy was found in the bog south-west of the lake, where 7.5 m of sediments were retrieved (Fig. 3: coring point 1). The stratigraphy is complex, with

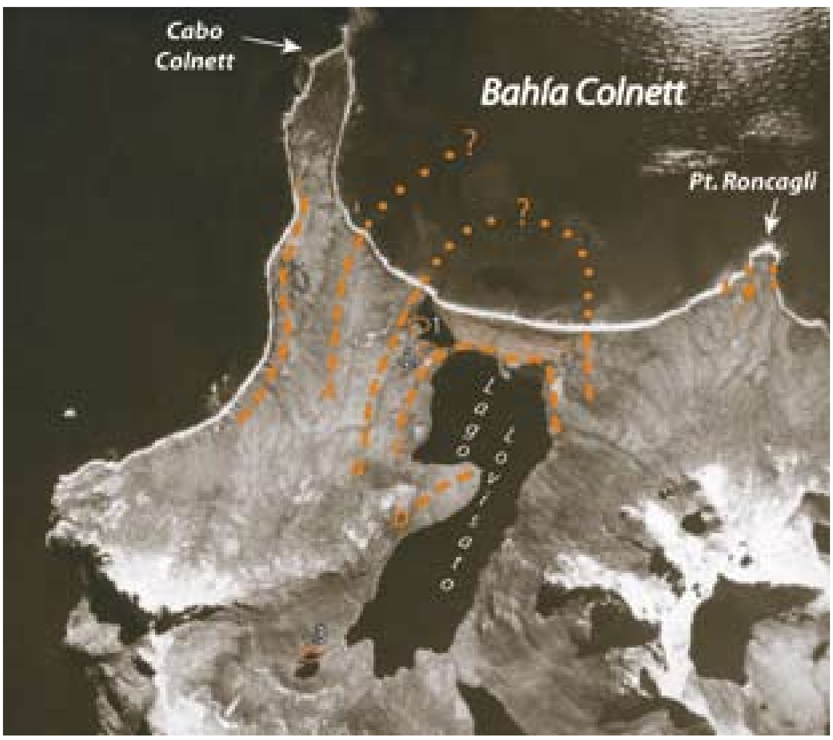


Figure 3
Air photo of the Bahía Colnett–Lago Lovisato area with its succession of moraines. The configuration of the four successively younger ice-marginal moraines (A–D; hatched–punctuated lines) suggest that the Lago Lovisato valley was once occupied by an outlet glacier from ice fields in the mountains to the south. Stratigraphic sections in the shore cliffs are marked by triangles; glacial tills in the sections indicate an ice-flow direction (arrow) out of the Lago Lovisato valley. Thin stippled lines parallelling the present shore and towards Lago Lovisato indicate the position of a series of beach ridges with crests situated some 3–4 m above the present shoreline. Coring points 1–3 are indicated with open circles. The camp was situated close to the beach, northeast of coring point 1.

a mix of peat, lake sediments and marine sediments, and the peat at the bottom of the cored profile is dated to 16,500 cal yr BP. The high bottom age and the complexity of the sediments imply that this key site can be used both for dating the deglaciation and for unfolding the general palaeoenvironmental development thereafter, including the sea level history. Because of the highly variable character of the deposits, an array of different methods will be used to analyse these sediments.

Moraine ridge C (Fig. 3) is covered by 4 m of peat at the crest of the ridge, but a more than 7 m thick peat sequence was found on its northern slope. A complete sequence (7.1 m) of it was cored at coring point 2 (Fig. 3). The stratigraphy implies that peat humification has varied considerably over time and ^{14}C dating shows that the bottom of the sequence is older than 13,000 cal yr BP. Such a high bottom age for a peat profile is rare, and in combination with the variable stratigraphy this may turn into a unique palaeohydrological archive.

Echosoundings of the large Lago Lovisato basin, carried out from our Zodiak rubber dinghy, showed that the northern part of the lake is shallow, only ca. 3 m deep, and that the southern part has several sub-basins, of which the deepest is 26 m. These were regarded impossible to core due to the high wind fetch from the south and the water depth. Therefore a small lake southwest of Lago Lovisato, here called Laguna Cascada, was cored instead (Fig. 3: coring point 3). Since the coring was performed from the quagmire that surrounds the lake, the uppermost part of the sequence consists of peat. Below the peat we cored >4 m of lake sediments with a glacial varved clay at the bottom. The transition between the varved clay and the organic lake sediments is dated to ca. 16,000 cal yr BP. Considering the relatively thin sequence in relation to the old bottom age, one would suspect that some sediments are lacking. However there are no signs of any clear hiatuses or erosional discordances, which instead implies a low sedimentation rate, in the order of only 0.25–0.3 mm/year. The lithology is very variable, with different types of gyttja units, some clearly laminated, others rich in gravel/sand clasts and tephra layers. The sequence is highly interesting from a palaeoclimatic viewpoint and detailed geochemical analyses are under way, as well as diatom analyses.

The fourth cored and sampled sequence is from 0.5 km inside the eastern part of Bahía Crossley (Fig. 6), where Johns (1981) had reported the occurrence of an almost 10 m thick peat sequence, but without age control. After reconnaissance corings in the area a promising spot was found. Here it was possible to penetrate approx. 11 m into swamp peat, variably humified, including a few metres at the bottom with a mix of peat and reworked fluvial sediments. The oldest age obtained from this sequence is ca. 9 000 cal yr BP, but the upper 8 m of undisturbed stratigraphy comprises only ca. 7 500 cal years. Detailed analyses of organic matter and magnetic susceptibility have already been carried out and will be complemented by pollen and macrofossil analyses.

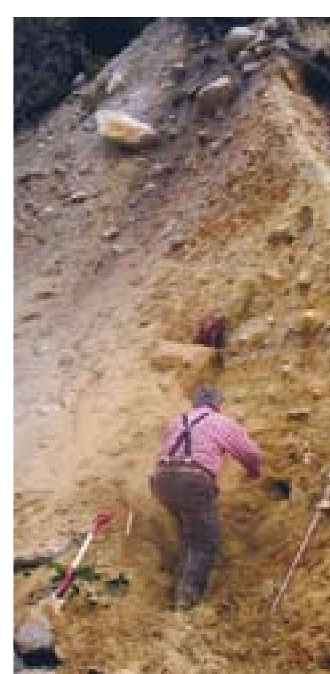
Summary

To sum up, the results of the 2005 expedition to Isla de los Estados look very promising. The different data sets imply that we will be able to reconstruct a more or less complete history of climatic, glacial, vegetational and sea level development from the Last Glacial Maximum until the present time. The sampled material is being analysed both in Sweden and in Argentina, and a group of Swedish and Argentinian senior researchers are directly involved in the project, as well as an Argentinian PhD student, Marilen Fernandez, and a German post-doc, Ingmar Unkel.

We think that this work will further strengthen the long history of Swedish-Argentinian scientific cooperation, originating from Otto Nordenskjöld's expedition to Tierra del Fuego and Patagonia in 1895–97.

+
Figure 4
The storm-ridden beach, the windswept *Nothofagus*-forest and the rugged mountains at the camp by Bahía Colnett. Photo: Karl Ljung.

+
Figure 5
Per Möller excavating the thick glacial deposits on the eastern side of Bahía Colnett. Photo: Svante Björck.



References

Andresen, C.S., Björck, S., Bennike, O. and Bond, G. 2004. Holocene climate changes in southern Greenland: evidence from lake sediments. *Journal of Quaternary Science* 19, 783–795.

Andresen, C.S. and Björck, S. 2005. Holocene climate variability in the Denmark Strait region – a land-sea correlation of new and existing climate proxy records. *Geografiska Annaler* 87 A (1), 157–172.

Andresen, C.S., Björck, S., Rundgren, M., Conley, D. and Jessen, C. 2006. Rapid Holocene climate changes in the North Atlantic: evidence from lake sediments from the Faroe Islands. *Boreas* 35, 23–34.

Auer, V. 1956. The Pleistocene of Fuego-Patagonia. Part I: The Ice and Interglacial Ages. *Annales Academia Scientiarum Fennicae, Series A III*, 45, 1–22.

Auer, V. 1958. The Pleistocene of Fuego-Patagonia. Part II: The history of the flora and vegetation. *Annales Academia Scientiarum Fennicae, Series A III*, 50, 1–239.

Björck, S., Olsson, S., Ellis-Evans, C., Håkansson, H., Humlum, O. and De Lirio, J.M. 1996. Late Holocene palaeoclimatic records from James Ross Island, Antarctica. *Palaeogeography, Palaeoclimatology, Palaeoecology* 121, 195–220.

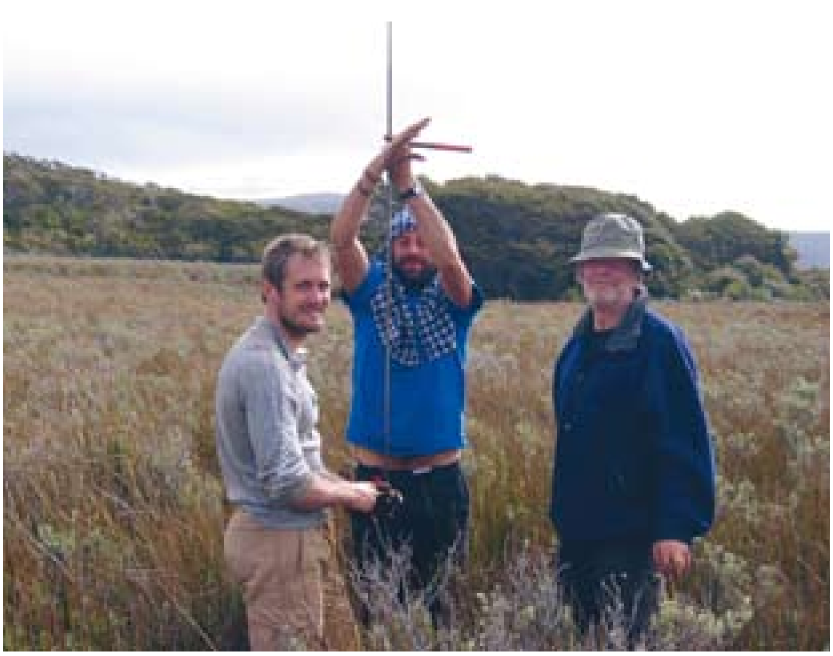
Björck, S., Bennike, O., Rosén, P., Andresen, C.S., Bohncke, S., Kaas, E. and Conley, D. 2002. Anomalously mild Younger Dryas summer conditions in southern Greenland. *Geology 30* (5), 427–430.

Björck, S., Rittenour, T., Rosén, P., França, Z., Möller, P., Snowball, I., Wastegård, S., Bennike, O. and Kromer, B. 2006. A Holocene lacustrine record in the central North Atlantic: proxies for volcanic activity, short-term NAO mode variability and long-term precipitation changes. *Quaternary Science Reviews* 25, 9–32.

+

Figure 6

Kalle Ljung, Juan Federico Ponce and Svante Björck coring the swamp bog inside Bahía Crossley. Photo: Barbara Wohlfarth.



Caldenius, C. 1932. Las glaciaciones cuaternarias de la Patagonia y Tierra del Fuego. *Geografiska Annaler* 14, 1–164.

Caminos, R. and Nullo, F. 1979. *Descripción Geológica de la Hoja 67 e, Isla de los Estados.* Buenos Aires: Servicio Geológico Nacional.

Dalziel, I.W.D., Caminos, R., Palmer, K.F., Nullo, F. and Casanova, R. 1974. South Extremity of Andes: Geology of Isla de los Estados, Argentine Tierra del Fuego. *American Association of Petroleum Geologists Bulletin* 58 (12), 2502–2512.

Dudley, T.R. and Crow, G.E. 1983. A contribution to the flora and vegetation of Isla de los Estados (Staten Island), Tierra del Fuego, Argentina. *Antarctic Research Series, Terrestrial Biology II*, 37, 27 pp.

Heusser, C.J. 1989. Late Quaternary vegetation and climate of Tierra del Fuego. *Quaternary Research* 31, 396–406.

Heusser, C.J. 1998. Deglacial paleoclimate of the American sector of the Southern Ocean: Late Glacial – Holocene records from the latitude of Canal Beagle (55°S), Argentine Tierra del Fuego. *Palaeogeography, Palaeoclimatology, Palaeoecology* 141, 277–301.

Hjort, C., Ingólfsson, Ó., Bentley, M.J. and Björck, S. 2003. The Late Pleistocene and Holocene glacial and climate history of the Antarctic Peninsula region as documented by the land and lake sediment records – a review. *Antarctic Peninsula Climate Variability, Antarctic Research Series* 79, 95–102.

Hulton, N.R.J., Purves, R.S., McCulloch, R.D., Sugden, D.E. and Bentley, M.J. 2002. The Last Glacial Maximum and deglaciation in southern South America. *Quaternary Science Reviews* 21, 233–241.

Ingólfsson, Ó., Hjort, C. and Humlum, O. 2003. Glacial and climate history of the Antarctic Peninsula since the Last Glacial Maximum. *Arctic, Antarctic and Alpine Research 35* (2), 175–186.

Johns, W.H. 1981. *The vegetation history and paleoclimatology for the Late Quaternary of Isla de los Estados, Argentina*. Michigan State University, Dept. of Geology, MSc thesis.

Ljung, K., Björck, S., Hammarlund, D. and Barnekow, L. 2006. Late Holocene multi-proxy records of environmental change on

the South Atlantic island Tristan da Cunha. *Palaeogeography, Palaeoclimatology, Palaeoecology* 241, 539–560.

Malagnino, E.C. and Olivero, E.B. 1999. New evidence of the total glaciation of the Isla Grande de Tierra Del Fuego. *Journal of South American Earth Sciences* 12, 343–348.

Markgraf, V. 1993a. Younger Dryas in southernmost South America – An update. *Quaternary Science Reviews* 12, 351–355.

Markgraf, V. 1993b. Paleoenvironments and paleoclimates in Tierra del Fuego and southernmost Patagonia, South America. *Palaeogeography, Palaeoclimatology, Palaeoecology* 102, 53–68.

Moore, D.M. 1983. *Flora of Tierra del Fuego*. Oswestry: Anthony Nelson.

Nordenskjöld, O. 1898. Geologie, Geographie und Anthropologie. In: *Wissenschaftliche Ergebnisse der schwedischen Expedition nach den Magellansländern 1895–1897, unter Leitung von Otto Nordenskjöld*. Stockholm: Norstedt & Söner.

Rabassa, J., Coronato, A., Bujalesky, G., Salemme, M., Roig, C., Meglioli, A., Heusser, C., Gordillo, S., Roig, F., Borromei, A. and Quattrocchio, M. 2000. Quaternary of Tierra del Fuego, southernmost South America: an updated review. *Quaternary International* vol. 68–71, 217–240.

Sugden, D.E., Bentley, M.J., Fogwill, C.J., Hulton, N.R.J., McCulloch, R.D. and Purves, R.S. 2005. Late-glacial glacier events in southernmost South America: a blend of “northern” and “southern” hemispheric climatic signals? *Geografiska Annaler* 87A, 273–288.

Figure 7
A sediment core with lake sediments (the grey siltgyttja) on top of the brown peat. This is evidence for a significant hydrologic change: the peat bog environment is replaced by a lake. Photo: Barbara Wohlfarth.

Isla de los Estados – kvartärgeologi och paleoklimatologi vid världens ände

En svensk-argentinsk expedition till Isla de los Estados (Staten Island) utanför Sydamerikas sydostspets – på Kap Horn-seglatsernas tid känd som skeppskyrkogård – genomfördes under november och december 2005. Syftet var geologiskt; att genom studier av glaciala avlagringar, sjösediment, torvlagerföljder och årsringsvariationer på träd rekonstruera glaciations-, vegetations- och klimathistorien på denna perifert belägna ö. Den ligger på nordsidan av det blåsiga Drakes sund, som skiljer Sydamerika från Antarktis. Det svenska arbetet härnere ingår i det s.k. ATLANTIS-projektet, som undersöker klimatutvecklingen och dess tidsmässiga synkronitet eller fasförskjutning från norr till söder i Atlanten. Tidigare har man arbetat inom projektet på öarna Grönland, Island, Färöarna, Azorerna, Grenada och Tristan da Cunha. Dessutom anknyter studierna på Isla de los Estados direkt till tidigare forskningsexpeditioner, både svenska och argentinska, till Antarktiska halvön på sydsidan av Drakes sund. En tredje uppgift var, naturligtvis, också att anknyta till den avsevärda kunskap som redan finns om södra Sydamerikas, och då särskilt Tierra del Fuegos (Eldslandets) glaciationshistoria, samt klimat- och vegetationsutveckling.

Expeditionen utgick från Ushuaia, världens sydligaste stad och tillika huvudort på den argentinska delen av Tierra del Fuego. Vi färdades med en inhyrd kombinerad segel- och motorbåt och fältarbetet genomfördes dels från ett läger i land i bukten Bahía Colnett på öns nordsida, dels direkt från båten utifrån olika strategiskt valda ankarplatser inne i andra bukter och fjordar. Ett avsevärt material hembragtes; stratigrafiska loggar från kustklintar eroderade i glaciala och relaterade sediment, borrkärnor från sjö- och torvlagerföljder, samt dendrokronologiska (årsrings)serier från både döda och levande träd. Dateringar visar redan att dessa olika typer av data för oss tillbaka till den senaste omfattande nedisningen. Då nådde glaciärer från bergen på öns inre långt utanför den nuvarande kusten och ut på den – genom den globala havsytesänkningen – då delvis torrlagda kontinentalsockeln. Denna nedisningsperiod avslutades för ungefär 17 000 år sedan, direkt efter det som i ett globalt perspektiv brukar kallas för det ”senaste glaciala maximat” (Last Glacial Maximum, LGM) och som kulminerade för ungefär 20 000 år sedan. Hela vegetations- och klimatutvecklingen härnere sedan dess, inklusive marina nivåförändringar och nederbördsrelaterade vattenståndsförändringar i sjöarna, bör kunna rekonstrueras med hjälp av det hembragta materialet!

Project leader

Per Olof Hulth
Department of Physics
AlbaNova University Center
Stockholm University

Project participants

Tomas Gustafsson
Eleonora Lind
Tomas Oppelstrup
Stephan Hundertmark
Department of Physics
AlbaNova University Center
Stockholm University

Adam Bouchta
Department of Radiation Sciences
Uppsala University

The neutrino telescopes AMANDA and IceCube at the South Pole

The aim of the telescopes

The feasibility of using transparent ice at large depth in Antarctica for neutrino telescopes was shown by the AMANDA collaboration in the 1990's. The scientific goals for these telescopes are e.g. to use the neutrino particles to investigate the question of the "dark matter" of the Universe and to search for the sources of the highest energy cosmic rays. The neutrino particles are extremely penetrating and interact very rarely with matter. They are expected to be produced through different violent processes in the Universe, and the possibility to detect high-energy neutrino sources will open a new window to study the Cosmos. In order to compensate for the extremely low probability for the neutrino to interact with matter one has to use very large detectors. The neutrino telescopes are sensitive to the emitted Cherenkov light from electrically charged particles created by neutrino interactions deep in the ice. The transparent ice at the South Pole is a very suitable detector medium for a neutrino telescope. The ice sheet is 2 900 m deep and extremely transparent at large depths (Askebjer et al. 1997, Askebjer et al. 1998). The AMANDA neutrino telescope was constructed between the years 1995 and 2000 deep in the ice at the Amundsen-Scott base at the South Pole. Owing to the success of AMANDA the large IceCube Neutrino Observatory is now under construction at the same location.

The AMANDA detector consists of 677 optical modules deployed in 19 holes in the ice. The holes were made using a hot water drilling technique and the modules were frozen in during a period of about one week. The optical modules are photomultipliers contained in pressure vessels (glass spheres) deployed at depths between 1 200 m and 2 300 m. The central part of the detector, with the highest density of optical modules, is situated between 1 500 m and 2 000 m below the surface. The diameter of the detector is 200 m. The photomultipliers are sensitive to single photons in the wavelength range from 330 nanometres (nm) to 600 nm and have a diameter of 20 cm. The signal from each photomultiplier is transmitted via cables up to the surface and read by on-line computers. The American Polar Ice Core Office (PICO) performed the hot water drilling with the help of drillers from the Swedish Polar Research Secretariat.

The AMANDA detector has been fully operational and taking data since February 2000.

The construction of a much larger telescope, the new IceCube Neutrino Observatory, began at the South Pole in January 2005. The complete observatory will consist of 4 800 optical modules deployed between depths of

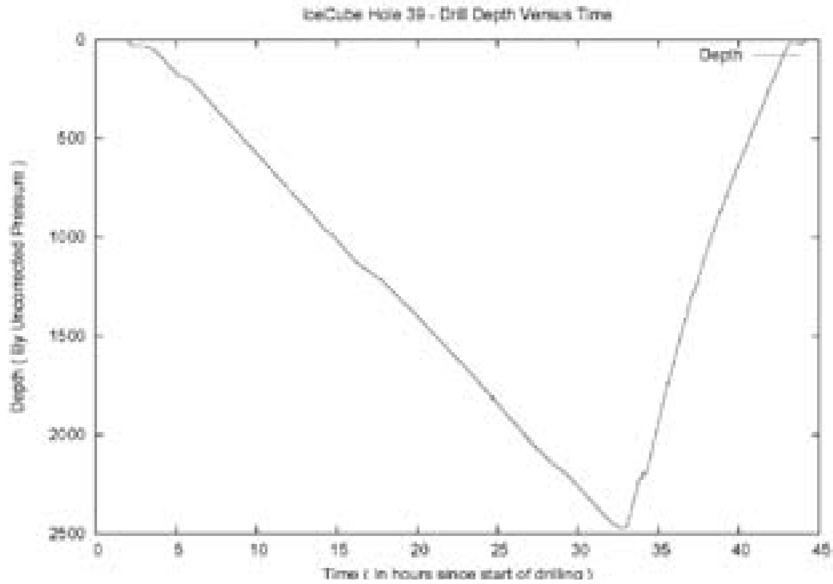
Figure 1
The hot water drill camp and the MAPO laboratory (right) with AMANDA at the Amundsen-Scott base at the South Pole. The drill tower at the hole can be seen at the top of the figure. Photo: National Science Foundation.

1 450 and 2 450 m in 80 holes covering an instrumented volume of about 1 km³. The optical modules for IceCube are much more advanced than those for AMANDA; they digitize the photomultiplier signals and transmit all information in digital form to the surface. The timing calibration, which was done manually and took several weeks for AMANDA, is done automatically every two seconds for the whole IceCube array. On the surface above the neutrino telescope an air shower array, IceTop, will detect air showers from cosmic rays interacting in the atmosphere. The combination of IceTop and the detectors in the ice will allow calibration of IceCube using the atmospheric muons, as well as studying the chemical composition of the incoming cosmic rays. The AMANDA telescope will be an integrated part of the IceCube Neutrino Observatory; the AMANDA collaboration merged with the new IceCube collaboration in 2005.

The IceCube project is a collaboration between Aachen University, Germany; University of Alaska, Anchorage, USA; University of Gent, Belgium; MPI Heidelberg, Germany; Chiba University, Japan; IAS Princeton, USA; Clark-Atlanta University, USA; University of Maryland, USA; University of Alabama, USA; Université Libre de Bruxelles, Belgium; Vrije Universiteit Brussel, Belgium; University of Mons-Hainaut, Mons, Belgium; University of California, Berkeley, USA; Lawrence Berkeley National Laboratory, Berkeley, USA; Bartol Research Institute, University of Delaware, USA; University of Kansas, USA; Southern University, Baton Rouge, USA; Humboldt University Berlin, Germany; University of California, Irvine, USA; Pennsylvania State University, USA; University of Mainz, Germany; University of Dortmund, Germany; Stockholm University, Sweden; Uppsala University, Sweden; DESY-Zeuthen, Hamburg, Germany; University of Wisconsin, Madison, USA; University of Wisconsin-River Falls, USA; University of Wuppertal, Germany; Imperial College, London, UK; Oxford University, UK; Utrecht University, The Netherlands; University of Canterbury, New Zealand.

The fieldwork

People and scientific equipment are transported by air from Christchurch, New Zealand to the American antarctic base McMurdo on Ross Island, and then to the Amundsen-Scott station at the geographical South Pole.



Heavy equipment can also be transported by cargo vessel once a year, arriving at McMurdo in January–February.

The construction of the new IceCube Neutrino Observatory continued this season. In the previous season the new hot water drill was installed and tested. The drill for IceCube has a heating power of 5 MW compared with 2 MW for the AMANDA drill. It is more advanced and is designed to drill a 60 cm diameter hole down to 2 500 m in less than 40 hours. Despite the higher power and the larger depth of the holes the consumption of fuel is less than for the AMANDA holes. The drilling camp for IceCube is shown in Figure 1. One IceCube string with 60 optical modules was successfully deployed at the end of last season in January 2005. That string worked well during 2005, and a summary from the first year of running has been published (Achterberg et al. 2006a) showing that the equipment performed as expected. This season the hot water drill was slightly modified based on the experience from last season. After a slow start the deployment rate at the end of the season approached a speed of one deployed string in less than four days. Figure 2 shows the drilled depth as a function of time for one of the holes. Eight new strings were deployed, giving a total of nine IceCube strings in the ice out of the planned 80. In addition twelve IceTop stations were successfully deployed. The equipped ice volume of the new IceCube strings is already larger than the volume of AMANDA. Figure 3 shows a reconstructed descending high-energy muon from cosmic ray interaction in the atmosphere in the nine-string IceCube detector. The telescope is modular and any newly deployed string will be commissioned as soon as it is in place.

+

Figure 2
Drilling depth as a function of time for hole 39.

+

Figure 3
A muon bundle passing from above through the nine-strings IceCube array.

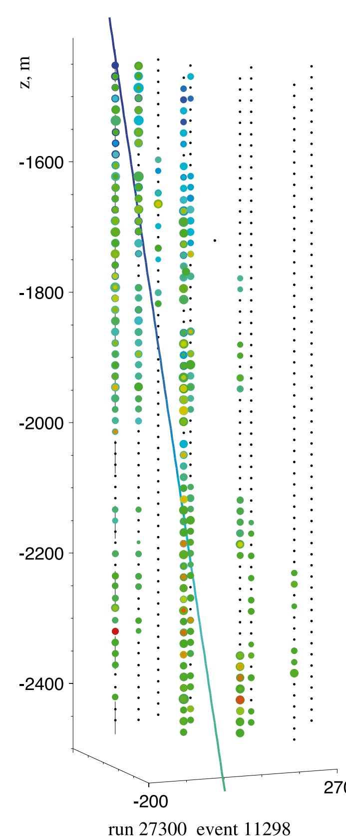


Figure 4
Preparing to start deployment of one IceCube string by bringing the end of the Ericsson cable to the drill hole. The large drill hose winch can be seen in the background. Photo: National Science Foundation.

The sensitivity of the observatory to detect neutrinos will thus increase continuously during the deployment period. The last string of IceCube is planned to be deployed in January 2011.

During the season 2005/06 Sweden contributed with three technicians for the drilling operation and two scientists for testing and deployment of the modules. Two more Swedes were hired by the US as drillers.

Preliminary results

The nine IceCube strings are performing very well and commissioning and verification has been performed. The results so far are mainly technical.

The AMANDA telescope is working very well and detects about five atmospheric neutrinos per day. The atmospheric neutrinos are produced in the collisions between cosmic rays and atoms in the atmosphere of the Earth. More than 4 000 neutrino candidates have been recorded, but so far no evidence for extraterrestrial neutrinos has been found. Analysis of the AMANDA data is ongoing and about 25 scientific papers in refereed journals have been published. A general paper on principles and first results was published in *Nature* (Andrés et al. 2001). Papers on the search for supernova neutrinos and dark matter particle-annihilations in the centres of the Earth and Sun have also been published (Ahrens et al. 2002a, Ahrens et al. 2002b, Ackermann et al. 2005a), as have searches for point sources of neutrinos (Ahrens et al. 2004a, Ackermann et al. 2005b) and neutrino-induced cascades (Ahrens et al. 2003). The composition of the cosmic rays has been studied, using AMANDA data in combination with the air shower detector SPACE situated on the ice surface above AMANDA (Ahrens et al. 2004b). Limits from AMANDA for high-energy gamma and neutrino fluxes from the giant flare of the Soft Gamma-Ray Repeater 1806-20 in December 27 2004 have recently been published (Achterberg et al. 2006b). A paper about the ice properties in the AMANDA volume has been published (Ackermann et al. 2006a).

References

Ackermann et al. 2004. Search for Neutrino-Induced Cascades with AMANDA. *Astroparticle Physics* 22, 127–138.

Ackermann et al. 2005a. Limits to the Muon Flux from Neutralino Annihilations in the Sun with the AMANDA Detector. Accepted for publication in *Astroparticle Physics*.

Ackermann et al. 2005b. Search for extra-terrestrial point sources of high energy neutrinos with AMANDA-II using data collected in 2000–2003. *Physical Review* D71, 077102.

Ackermann et al. 2006a. Optical Properties of Deep Glacial Ice at the South Pole. *Journal of Geophysical Research* 111, D13203.

Achterberg et al. 2006a. First Year Performance of the Icecube Neutrino Telescope. *Astroparticle Physics* 26, 155–173.

Achterberg et al. 2006b. Limits on the High-Energy Gamma and Neutrino Fluxes from the SGR 1806-20 Giant Flare of 27 December 2004 with the AMANDA-II Detector. *Physical Review Letters* 97, 221101.

Ahrens et al. 2002a. Search for Supernova Neutrino-Bursts with the AMANDA Detector. *Astroparticle Physics* 16.

Ahrens et al. 2002b. Limits to the Muon Flux from WIMP Annihilation in the Center of the Earth with the AMANDA Detector. *Physical Review* D66, 032006.

Ahrens et al. 2003. Search for Neutrino-Induced Cascades with the AMANDA Detector. *Physical Review* D67, 012003.

Ahrens et al. 2004a. Search for extraterrestrial point sources of neutrinos with AMANDA-II. *Physical Review Letters* 92, 071102.

Ahrens et al. 2004b. Measurements of the Cosmic Ray Composition at the Knee with the SPASE-2/AMANDA-B10 detectors. *Astroparticle Physics* 20, 565–581.

Andrés et al. 2001. Observation of High-Energy Neutrinos Using Cherenkov Detectors Embedded Deep in Antarctic Ice. *Nature* 410, 441–443.

Askebjer et al. 1995. Optical Properties of the South Pole Ice at Depths Between 0.8 and 1 km, AMANDA Collaboration. *Science* 267, 1147–1150.

Askebjer et al. 1997. Optical Properties of Deep Ice at the South Pole: Absorption, AMANDA collaboration. *Applied Optics* 36, 4168–4180.

Figure 5
Two of the IceCube crew with one optical module at the ceremonial South Pole. The new South Pole station can be seen in the background. Photo: National Science Foundation.

Neutrinoteleskopen AMANDA och IceCube på Sydpolen

Konstruktionen av det nya neutrinobservatoriet IceCube pågår intensivt vid Amundsen-Scott stationen vid den geografiska sydpolen på Antarktis. Observatoriet byggs på samma plats som neutrinoteleskopet AMANDA, som färdigställdes år 2000 och kommer att kopplas ihop med IceCube. Teleskopen består av en mängd ljusdetektorer nedsänkta i isen på 1 500–2 500 meters djup (med hjälp av en varmvattenborr). Totalt kommer en kubikkilometer av isen att instrumenteras med 4 800 ljusdetektorer, som detekterar den mycket svaga ljusblixt som bildas då neutrinopartiklar kolliderar med en atom nere i isen. Teleskopen kan avgöra riktningen på den inkommande neutrinon med någon grads noggrannhet. Målsättningen är att observera neutriner från kosmiska källor som aktiva galaxer, gammablixtar och universums mörka materia. Under säsongen 2005/06 installerades åtta nya detektorsträngar med 60 ljusdetektorer vardera. När säsongen avslutades bestod IceCube av nio strängar av de planerade 80. De installerade ljusdetektorerna fungerar mycket bra och atmosfäriska neutriner har redan observerats. IceCube beräknas vara färdig-installerat 2011.

Sverige bidrog med tre borrare och två forskare vid årets expedition. Ytterligare två svenskar var anställda av USA som borrare.

Project participants

Torbjörn Karlin
Margareta Hansson*
(Swedish project leader)
Department of Physical Geography and Quaternary Geology
Stockholm University

*not participating in the field

EPICA to the bottom in Dronning Maud Land

The deep ice core drilling project at the German Kohnen Station in Dronning Maud Land (DML) is part of the European Project for Ice Coring in Antarctica (EPICA) which started one decade ago. The drilling at Kohnen Station reached the bedrock in the season 2005/06 after four seasons of drilling. The final depth was recorded as 2 774 m.

Aims of the project

Advanced simulations of our future climate call for increased understanding of the complex climate system. Only records of climate variations in the past can provide us with information about the total response of the climate system when influencing factors are changed with all the various feedback mechanisms in action. The knowledge achieved from analyses of ice cores from Antarctica and Greenland has been revolutionary in the field of climate research. The Vostok ice core, drilled one decade ago in Antarctica by a Russian-French team, revealed the variations in atmospheric greenhouse gas concentrations over several glacial cycles. The ice core data verify that the anthropogenic contribution of greenhouse gases has increased the global concentrations far beyond any natural variations seen the last 420,000 years. The EPICA ice core drilling effort at Dome C extended the length of the existing records by a factor of two. It also provided a wealth of new information due to new analysis techniques developed during the last few years. The EPICA-Dome C ice core thus far represents a continuous record of past climate and environmental changes over eight glacial cycles (EPICA community members 2004). The records of greenhouse gases have been extended to the last 650,000 years (Siegenthaler et al. 2005, Spahni et al. 2005). The EPICA-DML ice core together with the NGRIP (North Greenland Icecore Project) ice core have for the first time revealed a one-to-one interhemispheric coupling for the shorter climate variations during the glacial period, the so called Dansgaard-Oeschger events (EPICA community members 2006). EPICA has been funded by the EU and by

Figure 1
Ilyushin 76 on Novolazarevskaya airbase. Photo: Torbjörn Karlin.

national contributions from Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom. The programme consisted of two deep drillings in Antarctica at sites with different characteristics. The first drilling started in the season 1996/97 at Concordia Station, Dome C, in the Indian Ocean sector of Antarctica (75°06'S, 123°21'E). The aim of the EPICA-Dome C drilling was to recover an ice core reaching as far back in time as possible. The second drilling started a few years later, in 2001/02, at Kohnen Station in Dronning Maud Land (75°00'S, 00°04'E). The EPICA-DML drilling aimed to retrieve a high-resolution record of a few complete glacial–interglacial cycles at a site facing the Atlantic Ocean.

EPICA-DML fieldwork

During the season 2005/06 PhD student Torbjörn Karlin represented Sweden in the EPICA-DML drilling team at Kohnen Station. EPICA personnel and part of the cargo were flown in and out within the framework of DROMLAN (Dronning Maud Land Air Network), using an Ilyushin 76 TD (Fig. 1) aircraft. The feeder flights from Novolazarevskaya airbase to Kohnen Station were carried out using a Basler Turbo 67 (Fig. 2). The first group (logistics) landed at Novolazarevskaya airbase on 3rd November and the second group (drilling and science) landed on 11th November. Feeder flights started immediately to Kohnen Station. The days following arrival were used for acclimatization to cold conditions and altitude. Meanwhile light work was performed, such as preparing the drill tower, setting up logging systems, communication systems and installing science facilities. Preparatory work – such as logging and reshaping of the borehole and maintenance of the drill winch – took another three weeks, and the drilling started at a depth of 2 565 meters on 7th December. The drilling reached bedrock on 17th January at a depth of 2 774 meters. The station was occupied for a period of 98 days until 8th February 2006. Altogether 26 people (ten drillers, six scientists, ten logistics) worked at the station. One traverse from the German station Neumayer supplied Kohnen Station with fuel, drill liquid, heavy equipment and food. At the end of the season the scientific group left Kohnen Station for Novolazarevskaya airbase with a Basler Turbo 67 and arrived in Cape Town on 5th February 2006. On 9th January a group of five Germans, nine Norwegians and one Swede visited Kohnen Station as part of a presentation tour of Dronning Maud Land research stations for representatives from the German Government and the Norwegian ministries of Education and Research, Environment and Foreign Affairs. The group came by Basler aircraft from the Norwegian station Troll and returned there afterwards. The Swedish visitor was Ann-Sofie Rickby from the Swedish Polar Research Secretariat.

The Kohnen Station (Fig. 3) is situated at an elevation of 2 892 m a.s.l. The mean annual temperature is -44.6°C and the mean annual accumulation rate is above 6 cm (water equivalent) per year. The drill trench is located a few metres under the snow surface (Fig. 4). The temperature in the drill trench never exceeds -25°C during the field season. The

Figure 2
Feeder flight to Kohnen with Basler Turbo 67. Photo: Torbjörn Karlin.

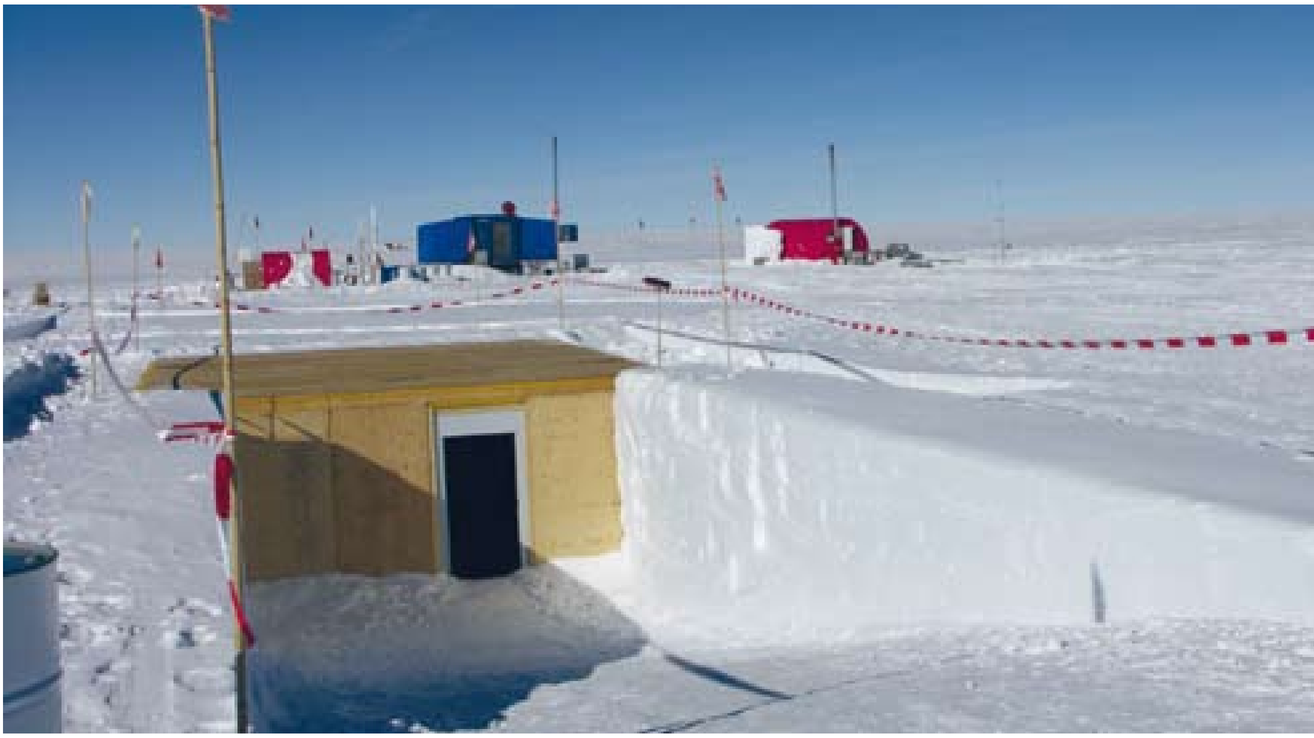
Figure 3
The German antarctic station Kohnen.
Photo: Torbjörn Karlin.

ten drillers in three shifts kept the drilling operation running for 24 hours per day since the field season is short and work has to be done in the most efficient way. The weekly production decreased towards the end of the season due to the increasingly difficult penetration. This was due to the higher temperature of the ice and the pressure melting of the ice. At 2 550 m depth the recorded temperature of the ice is as high as -7.5°C, which can be compared to temperatures of -44.5°C close to the surface of the ice sheet. With increasing temperature the ice cuttings contain more water and tend to stick together. The ice itself gets tougher, less brittle and thus harder to break. By the end of the drilling, at the depth of 2 774 m, the ice temperature was at the pressure-melting point and the bore hole was partly refilled with water (Fig. 5).

The electro-mechanical drill produces 98 mm diameter ice cores, typically in unbroken lengths of 0.5 m–1 m for each run. Each run takes about 2.5 hours to complete. After the newly retrieved ice core has been physically measured and marked, its electrical properties are measured by dielectric profiling (DEP). Next the ice core is packed for transport to the freeze room facilities at Alfred Wegener Institute (AWI) in Bremerhaven. After each field season a large group of European scientists gather for several weeks in the freeze rooms at AWI in a post-field sample preparation campaign. A processing line is build up where the ice core cross-section is dissected into pieces for different measurements in various laboratories by a series of cuts with band saws. Changes in crystal size and orientation along the core are detected. A second electrical conductivity measurement (ECM) is also performed on the cut core. The remaining parts are sectioned for transport to different European laboratories for analysis of stable isotopes in the water itself (oxygen and deuterium used as proxies for temperature variations), gases (carbon dioxide, methane etc.), dust, ions, mechanical properties and many other parameters. At least a quarter of the ice core is packed and kept at AWI as an archive for future analyses with new techniques.

Analysis at Stockholm University

We perform chemical analysis of the two deep ice cores drilled within EPICA. The analysis of the EPICA-DML ice core has partly been performed during the post-field sample preparation campaigns at AWI. One section of the ice core was cut into squared (3 × 3 cm) 100 cm long pieces and used for continuous flow analysis (CFA). The 100 cm long ice bar was mounted in a tray and lowered down on a heated melt head. Only the melt water from the inner, clean part of the ice section was sucked into a warm laboratory where it was analysed directly at very high resolution for liquid conductivity, dust content, hydrogen peroxide, formaldehyde and six ions. One line with melt water was not used for direct measurements. Instead the melt water was collected in small bottles and later analysed by ion-chromatography at four different laboratories in Europe. At Stockholm University



we are analysing one quarter of these samples and we are measuring ten different ions by means of ion-chromatography (eg. Wolff et al. 2006).

We aim to increase knowledge on the impact of aerosols on the radiation balance of the atmosphere by studying the natural variations of aerosols and climate over glacial cycles. We use the information contained in the ice cores on concentration changes with time in model simulations of the past. We test which processes are most important in yielding the record present in the ice. We learn how these processes have changed with climate change and how the chain of different climate feedbacks has acted. The different sources of sulphate aerosols and their potential to provide climate feedback mechanisms are in focus. This knowledge will enable an assessment of the role of anthropogenic sulphate aerosols in future climate development.

Latest results

Palaeoclimate records from Antarctic and Greenland ice cores showed different temperature patterns during the last glacial period. The latest results from the EPICA-DML ice core show that these changes are not independent. We have been able to synchronize precisely climate records from Antarctica and Greenland using the common information on global changes in methane concentrations archived in air bubbles in the ice. Even shorter and smaller temperature variations in the south were directly linked to the rapid temperature variations in the north via changes in the ocean circulation in the Atlantic. The results show that, for any period in the time between 55,000 to 20,000 years BP, Antarctica gradually warmed when the North was cold and warm water export from the Southern Ocean to the North Atlantic was reduced. In contrast the Antarctic started to cool every time more warm water started to flow into the North Atlantic during warm events in the north. Data shows that the degree of warming in the south is linearly related to the duration of cold periods in the North Atlantic. This result suggests a general linkage between long-term climate changes in both hemispheres via a "Bipolar Seesaw" when the overturning circulation of the Atlantic changes (EPICA community members 2006).

References

EPICA community members (incl. M. Hansson). 2004. Eight glacial cycles from an Antarctic ice core. *Nature* 429, 623–628.

EPICA community members (incl. M. Hansson and T. Karlin). 2006. One-to-one coupling of glacial climate variability in Greenland and Antarctica. *Nature* 444, 195–198.

Siegenthaler, U., Stocker, T.F., Monnin, E., Lthi, D., Schwander, J., Stauffer, B., Raynaud, D., Barnola, J.-M., Fischer, H., Masson-Delmotte, V., Jouzel, J. 2005. Stable Carbon Cycle-Climate Relationship During the Late Pleistocene. *Science* 310, 1313–1317.

+

Figure 4
The underground drill trench at Kohnen Station. Photo: Torbjörn Karlin.

+

Figure 5
The melted ice at the end of the core.
Photo: Torbjörn Karlin.

Spahni, R., Chappellaz, J., Stocker, T.F., Loulergue, L., Hausammann, G., Kawamura, K., Flückiger, J., Schwander, J., Raynaud, D., Masson-Delmotte, V., Jouzel, J. 2005. Atmospheric Methane and Nitrous Oxide of the Late Pleistocene from Antarctic Ice Cores. *Science* 310, 1317–1321.

Wolff, E.W., Fischer, H., Fundel, F., Ruth, U., Twarloh, B., Littot, G.C., Mulvaney, R., Röthlisberger, R., de Angelis, M., Boutron, C.F., Hansson, M., Jonsell, U., Hutterli, M., Lambert, F., Kaufmann, P., Stauffer, B., Stocker, T.F., Steffensen, J.P., Bigler, M., Siggaard-Andersen, M.L., Udisti, R., Becagli, S., Castellano, E., Severi, M., Wagenbach, D., Barbante, C., Gabrielli, P., Gaspari, V. 2006. Southern Ocean sea ice extent, productivity and iron flux over the past eight glacial cycles. *Nature* 440, 491–496.

+

EPICA till botten av Dronning Maud Land

Tio nationers samarbete inom EPICA (European Project for Ice Coring in Antarctica) har resulterat i två djupiskärnor borrade genom den antarktiska inlandsisen ner till berggrunden. Iskärnorna ger unik information om gångna tiders atmosfär och klimatvariationer. Borrningen vid den fransk-italienska forskningsstationen Dome Concordia (EPICA-Dome C) avslutades säsongen 2004/05 och den 3 270 meter långa iskärnan sträcker sig över mer än åtta istidscykler (EPICA community members 2004). Borrningen vid den tyska forskningsstationen Kohnen (EPICA-DML) i Atlantsektorn av Antarktis avslutades säsongen 2005/06 på ett djup av 2 774 meter. Sverige representerades denna säsong i fält av forskarstuderanden Torbjörn Karlin. Iskärnan från EPICA-DML har efter varje fältsäsong transporterats till frysrum vid Alfred Wegener Institute (AWI) i Bremerhaven, där en stor grupp forskare från de olika deltagande nationerna har samlats i en provprepareringskampanj. Vissa analyser har utförs direkt och andra prover har preparerats och sänts för analys till olika laboratorier runt om i Europa. Vid Stockholms universitet utför vi jonkromatografianalyser på dessa prover. Den högupplösta iskärnan från EPICA-DML har synkroniserats med dess motsvarighet från Grönland, NGRIP (North Greenland Icecore Project) och visat på en generell koppling mellan klimatvariationerna på de båda halvkloten via en ”gungbrädesmekanism” där cirkulationen i Atlanten är avgörande (EPICA community members 2006).

GPS site Svea – a Swedish reference station in Heimefrontfjella, Dronning Maud Land

Project leader

Lars E. Sjöberg*
Division of Geodesy
Royal Institute of Technology
Stockholm

Project participant

Erick Asenjo*
Division of Geodesy
Royal Institute of Technology
Stockholm

*not participating in the field

Backgound

Since the beginning of the 1990's the SCAR working group on Geodesy and Geoinformatics has devoted much effort to establishing and measuring a GPS geodetic network over Antarctica with connection to other continents. The primary goal of the project, a part of the Geodetic Infrastructure of Antarctica (GIANT), is to estimate possible crustal motions and plate motions in the region. The network points also serve as accurate reference points for various scientific expeditions on the continent. Most GPS stations were primarily observed epoch-wise, as was the case with the Swedish site Wasa. However, permanent observation stations were also established early at permanently manned antarctic stations.

The program GIANT is responsible for the establishment and maintenance of a precise geodetic reference network linked to the International Terrestrial Reference Frame (ITRF). The research stations participating in the SCAR GPS epoch campaign of the antarctic summer 2004/05 were Base Artiga (supervised by Uruguay), Maitri (India), Mirny (Russia and Germany) and Svea (Sweden). Svea (Fig. 1), like some other stations, operated with a permanent GPS receiver all year round. At present the GIANT GPS network consists of 42 sites. The Department of Planetary Geodesy at the Technical University of Dresden has the responsibility of serving as a computing centre, and of maintaining the database of the SCAR Epoch Crustal Movement Campaigns.

In 2004/05 we established the unmanned GPS station Svea. This report describes the experiences we gained from this station after one year of observation.

The monitoring of the GPS site Svea

On 14th November 2004 we started GPS measurements at the permanent GPS reference station Svea in Heimefrontfjella. About one year later, on 29th November 2005,

Figure 1
The permanent GPS site Svea in Heimefrontfjella. Photo: Erick Asenjo.

the Finnish antarctic expedition (FINNARP) 2005/06 – in cooperation with the Swedish Polar Research Secretariat – visited the Svea station to collect the data stored during the first year of observations. They did so by manual replacement of the memory card, and they also controlled the functioning of the instrument. This inspection and the following data analysis showed that the functionality of the instrument during its first year of life was excellent. The power supply to the receiver from six 12 V batteries, totally 600 Ah, functioned perfectly. It charged using solar panels and used a wind generator during the period of winter darkness. Site Svea has thereby been upgraded into a permanent reference GPS point in the GIANT network, and its first year data has been delivered to the international scientific community to be included in the joint analyses of the network. The quality of the stored data is very high.

The site location of Station Svea is: latitude 74°34'33.8''S, longitude 11°13'30.8''W and elevation 1 261.2 m (ellipsoidal height) in ITRF. Technical specifications are as follows: Receiver type is Trimble R7 and antenna type is Ashtech Dorne & Margolin with snow radome. More information about the site definition, observations, instrument used, description of the antenna, the antenna mount and the surveyed data can be found at www.tu-dresden.de/ipg/service/scargps/SVEA.

Acknowledgements

We want to thank Dr. Jaakko Mäkinen from the Finnish Geodetic Institute for collecting the data and performing the site inspection at Svea in the antarctic summer 2005/06.

References

Andersson, I. 2001. Geodetiska mätningar vid Station Wasa, Antarctica, 1990–2000. *TRITA-GEOFOTO* 2001:8. Mars 2001.

Pan, M. and Sjöberg L.E. 1996. *Positioning of Station Wasa from the SCAR GPS Campaign* 1992. Royal Institute of Technology, Division of Geodesy, Stockholm.

Sjöberg, L.E. and Asenjo, E. 1997. *The Swedish Geodetic Survey in Antarctica in 1997*. Royal Institute of Technology, Division of Geodesy, Stockholm.

Sjöberg, L.E., Andersson, I. and Asenjo, E. 1998. A Swedish Geodetic Survey in Antarctica in 1997. In: Grönlund, E. *Polarforskningssekretariatet årsbok* 1997. 47–49. Stockholm: Polarforskningssekretariatet.

Sjöberg, L.E. and Asenjo, E. 2006. Continuous GPS-monitoring at Station Svea. In: Rickberg, S. *Polarforskningssekretariatets årsbok* 2005. 62–64. Stockholm: Polarforskningssekretariatet.

GPS-mätningar vid Svea – en svensk referensstation i Heimefrontfjella, Dronning Maud Land

Sedan 1990-talets början har SCAR:s arbetsgrupp för Geodesi och Geoinformatik genomfört årliga GPS-kampanjer över Antarktis (med anslutning till mätningar på andra kontinenter) med syfte att bestämma såväl plattektoniska rörelser som eventuella regionala deformationer i det fasta berget. Med tiden har mätningarna utökats med observationer vid permanenta, kontinuerligt mätande stationer. Samtliga av dessa GPS-stationer ingår i GIANT (Geodetic Infrastructure of Antarctica), och levererar årligen mätningar till beräkningscentrat vid Tekniska Högskolan i Dresden.

I november 2004 startade vi kontinuerliga GPS-mätningar vid station Svea, Dronning Maud Land. Syftet med stationen är dels att ge data till GIANT för den geodynamiska analysen enligt ovan, dels att utgöra en noggrant bestämd referenspunkt för allehanda vetenskapliga expeditioner i området. Ett exempel är användning av realtidsbestämning av position med GPS-mottagare med centimeternoggrannhet. GPS-mottagaren mäter kod och fas på båda frekvenserna L1 och L2 med mätningsintervallet 15 s som standard. Mottagarens minneskapacitet är begränsad till 512 dagar. Stationen får sin elkraftsförsörjning från solpaneler och en liten vindgenerator. Efter ett års mätningar kan konstateras att stationen fungerar utmärkt med mycket goda mätresultat. Fr.o.m. 2006 har station Svea därför uppgraderats till en officiell permanent GPS-station i GIANT.

SWEDARCTIC 2006

Forskarrapporter Cruise Reports

Project leaders

Dag Avango
School of Architecture and
Built Environment
Division of History of Science and
Technology
Royal Institute of Technology (KTH)
Stockholm

Louwrens Hacquebord
Arctic Centre/Groningen Institute of
Archaeology
University of Groningen
The Netherlands

Project participants

Ulf Gustafsson
Ben Bekooy
Wouter Ytsma
Arctic Centre/Groningen Institute
of Archaeology
University of Groningen
The Netherlands

Cameron Hartnell
Industrial Archaeology, Department of
Social Sciences
Michigan Technological University
Houghton, Michigan, USA

LASHIPA 3 – Industry and its impacts in the polar areas from 1600 till present

Introduction – research problems, methods and theoretical approaches

The circumpolar north has become increasingly important as a supply area for fossil energy, partly as a result of rising world market prices for crude oil and partly because of the possibilities for extraction and transport in the high north that global warming might offer. In the wake of this development, attempts have been made by states to establish exclusive rights to natural resources in the Arctic (AHDR 2004). No doubt national rights and sustainable resource management will stay on the agenda of international negotiations in the future. This is an important subject of the LASHIPA project – these developments call for research efforts on how actors have dealt with the natural resources, territorial rights and environmental issues in the polar regions in the past.

The LASHIPA project (Large Scale Historical Industrial exploitation of Polar Areas) is an endorsed and financed research project within the International Polar Year 2007–2008 (IPY), with participants from the Netherlands, Sweden, USA, Great Britain, Norway and Russia (www.lashipa.nl, www.ipy.org). It is multidisciplinary, with the emphasis on disciplines as Historical Archaeology and Industrial Archaeology. The aim of the project is to explain the development of industry in the polar areas from the 17th century until today and to analyse the natural and geopolitical consequences of that development.

The LASHIPA project will analyse a set of research problems pertaining to industrial development in the Arctic and Antarctic. The first problem concerns the *driving factors* behind industrial development in the polar areas. We want to know what the primary driving forces were and what the necessary preconditions were. The focus here is on actors and changing historical contexts in the industrial centres of the world, from the 17th century until today.

Of great importance for general explanations is also the design of industrial activities in the polar areas. Thus a second research problem concerns *transfer of technology* and the *design of technology*. We want to know what strategies were used to adapt technology from the temperate zone to the harsh natural conditions of the polar areas. Also, why did the various national actors design their industrial activities differently? Was it a response to diverse natural conditions or a result of diverging industrial cultures? Why did some companies manage to adapt to polar area conditions and why did some fail?
A third and closely related problem concerns the *design of industrial communities* and the

Figure 1
Fieldwork locations in the Isfjorden region: 1) Kokerineset (17th cent. whaling station, 18th cent. hunting station), 2) Finneset (20th cent. mining and whaling), 3) Heerfjellet (20th cent. mining), 4) Bohemanneset (Rijspburg, 20th cent. mining), 5) Gipsdalen (20th cent. mining).

social organisation of production. We are interested in how different national actors tried to establish social order under no-mans land conditions and harsh environmental circumstances. How did their strategies differ from each other and why? Did the design of company towns and the social organisation of production have an impact on the success or failure of industrial projects in the polar areas?

Since the 17^{th} century, there has been a heavy competition over the control of natural resources of the polar areas. Therefore a fourth research problem concerns the *strategies of different actors to establish and legitimize claims on natural resources* – by using symbols and rituals of possession in the polar landscapes and in negotiations with competitors and between national governments. We believe that the choices of strategy had an impact on how successful the industrial projects were.

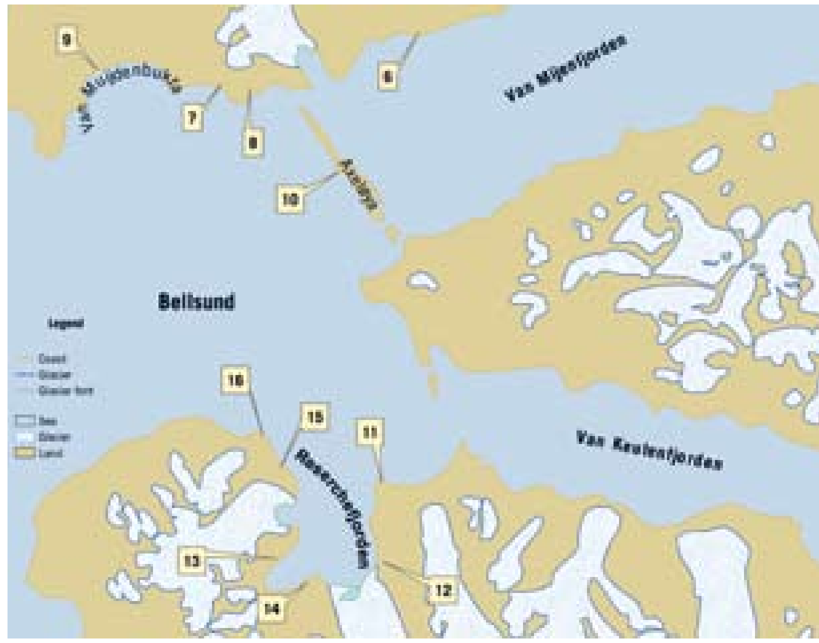
A fifth and closely related research problem concerns the *consequences of polar industries for the geopolitical development* in the polar areas. How were the activities of industrial companies used by national governments in struggles over the political status of the polar areas at different times? How did the industrial companies interact with the governments in their countries to strengthen territorial control? What was the role of rituals of possession and symbols of occupation in international negotiations? What was their impact on the international power relations in the polar areas?

Finally, an important research problem concerns the *impacts of industrial activities on the local natural environment*. We want to investigate and compare the local environmental impact of whaling, hunting, coal mining and oil extraction. With a comparative approach we will look at different attitudes towards natural resources before and after the industrial revolution, and different approaches to the natural environment between actors from different nations. What was the impact of these dissimilar approaches to the environment, and what can we learn from it?

LASHIPA consists of several subprojects that are carried out on different locations in both polar regions. LASHIPA will use two overarching theoretical approaches that will hold the different subprojects together – a core-periphery model and Actor Network Theory. The core-periphery model offers a general framework for understanding industrial activities in the polar areas. According to this model the polar areas can be seen as *resource frontier regions* because of their remote location and their production of raw materials for the industrial centres of the world. The activities in the resource frontier regions are always dependent on actors and historical contexts in the industrial cores (Sugden 1982, Hacquebord 1984, Duhaime 2004). However, since this model tends to focus attention on the core regions when explaining industry in the polar areas, we will also use a second theoretical approach – Actor Network Theory (ANT) (Latour 1987, Law and Callon 1992, Avango 2005). ANT can be used to put the activities at the resource frontier into focus – human factors such as labour and knowledge, but also non-human factors such as geography, climate and material objects like technology, settlements and symbols. With this theoretical approach we can compare industrial projects within different branches, time periods, national origins, as well as in both polar regions, in a common analytical language. Moreover, the approach allows for symmetrical analyses of both traditional historical sources and archaeological data, thus allowing for synthesis and general conclusions.

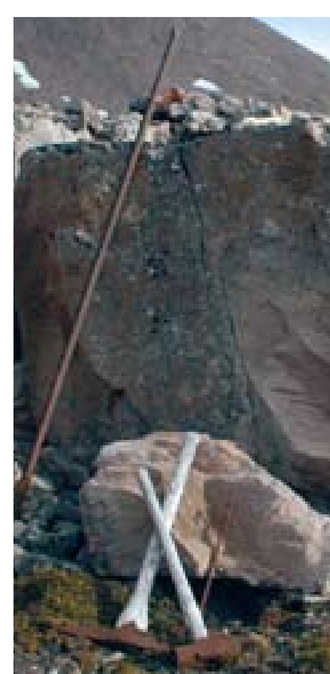
Fieldwork

The research problems of the LASHIPA project cannot be dealt with solely by relying on analyses of written sources in archives, the traditional source of historical research. Analyses of archaeological data, environmental



+
Figure 2
Fieldwork locations in the Bellsund region: 6-8) NEC mining camps, 20^{th} cent., 9) Van Muijdenbukta (17^{th} cent. whaling), 10) Axeløya, 11) “Edge point” (17^{th} cent. whaling and 19^{th} cent. NEC activity), 12) Iron range (20^{th} cent. mining), 13), Camp Smith (20^{th} cent. mining, 17^{th} cent. whaling), 14) Asbestodden (20^{th} cent. mining), 15) Calypsobyen (20^{th} cent. mining) and 16) Renardodden (17^{th} cent. whaling).

+
Figure 3
Remains in Gipsdalen of a Scottish Spitsbergen Syndicate (SSS) mining- and claim marking site (from 1919). The remains of SSS activities on Bünsow land reveal both the industrial and colonial practices of this company. Photo: Dag Avango.



+

Figure 4
Bohemanneset – the site of the Dutch mining settlement of Rijpsburg, containing remains of mines, transportation systems and buildings. The site was mapped with total station in LASHIPA 3, August 2006. Photo: Dag Avango.

conditions and interviews with actors in the polar areas are of equal importance for understanding and explanation. This is especially true for the research problems concerning technology transfer, design of technology and of industrial communities, the social organisation of production and strategies for control over natural resources. Through archaeological investigations we can study how technological systems and industrial communities were designed and how these designs were influenced by local natural conditions. We can also analyse how natural resources were claimed through the use of symbols in the polar landscapes.

From this methodological point of departure the LASHIPA project will conduct several historical-archaeological field campaigns in the polar areas. Although the project will deal with polar industries in a circumpolar perspective, two areas have been selected for case studies – Svalbard in the Arctic ("The Green Harbor project") and South Georgia in the Antarctic ("The South Georgia project"). These areas have been focal points for international competition for both natural resources and political influence over the course of their history, and they contain rich historical remains. Thus these are areas where the research problems of the LASHIPA project can be addressed in a limited geographical context.

In line with this research plan a series of archaeological field surveys have been done on Svalbard – in August 2004 with a focus on the remains of American mining in the Longyearbyen and Isfjorden regions (LASHIPA 1), in August 2005 at Bohemanneset and Grønfjorden (LASHIPA 2) and in 2006 in various locations in the Isfjorden and Bellsund regions (LASHIPA 3).

The objective of the LASHIPA 3 survey in August 2006 was to find, identify and select sites on Svalbard that can be used for archaeological investigations during the International Polar Year. Our focus area was the great fjords of Western Spitsbergen – Isfjorden, Bellsund, Van Mijenfjorden, Van Keulenfjorden and Recherchefjorden. During the first half of the field campaign, the research team worked in two separate groups. One group surveyed and documented mining camps in Gipsdalen (Bünsow land) and the areas around Heerfjellet and Finneset at Grønfjorden. A second group mapped the remains of a coal mining settlement on Bohemanflya and a whaling/fur hunting station at Kokerineset at Grønfjorden. During the second half of the field campaign the two groups worked together in the Bellsund area. Field camps were successively established at Gipsvika, Gipsdalen, Bohemanneset and Kokerineset. A ship, *Farm*, was used as field camp at Heerfjellet, Finneset and in the Bellsund area.

The surveys were performed in a pedestrian reconnaissance mode: the researchers formed a line and searched a given areas for remains of industrial activities. All features and structures were recorded with either a TRIMBLE GPS (a highly accurate GPS unit with software adapted for mapping historical remains) or a total station (a very efficient mapping device with centimetre accuracy). Moreover, hand measure and hand drawn detail sketches were made of foundations, buildings and more prominent remains of industrial activities. All finds were photo-documented with Nikon digital cameras.

Preliminary results

The survey results provided the basis for a detailed plan for the field efforts during the International Polar Year. At Kokerihamna a highly detailed map of a whaling station and a hunting camp was made with the total station. The site contains the remains of two blubber ovens, several hut foundations and a number of graves. Our hypothesis is that the site was first established by whalers, most likely British or Dutch, in the 17th century and again reused by Russian fur hunters (Pomors) during the 18th century. During the IPY, in the summer of 2007, the plan is to excavate parts of the site with a team of Dutch, Russian and Swedish archaeologists.

A detailed plan for coming field efforts was also made for the eastern coastline of Grønfjorden. The remains of a 20th century whaling station at Finneset was surveyed and the results revealed a complex industrial structure with great potential for comparative analyses with contemporary whaling stations on South Georgia (archaeological investigations at Prince Olav Harbour are planned in the Austral summer of 2007–2008 or 2008–2009). In the summer of 2007 the site will be carefully mapped with a total station and interpreted with the help of written documents, site plans and historical photographs for establishing specific functions and for reconstructing the production line. The site will also be analysed in relation to the remains of a multitude of coal mines from the early 20th century along the same coastline – industrial facilities used as tools in the pre-Spitsbergen treaty struggle for control over the archipelago. Moreover, a major effort will be made in documenting the present mining town of Barentsburg – the settlement, the production line and its social organisation.

The LASHIPA 3 field campaign also gave conclusive data that can already now be used within the research project. In the Isfjorden region, at Gipsdalen on Bünsow land, we found and documented remains of transportation systems, several prospecting camps and a number of prospecting sites. These emanated from the activities of two different mining companies (and nations) and time periods – the Scottish Spitsbergen Syndicate (SSS) was active there in the early 20th century and the Finn Coal Development (FCD) was active in the mid 1980's. One of the SSS sites was seriously threatened by erosion – a situation reported to the Norwegian heritage management authority on Svalbard. At Bohemanneset a detailed map was made of the remains from the early 20th century Dutch coal mining town of Rijpsburg.

In the Bellsund region we mapped the remains of several mining camps and whaling stations. At Recherchefjorden we mapped the residues of a number of camps erected or just used by the Northern Exploration Company (NEC) from the UK, active in the 1910's and 1920's:

- the Iron range camp (built to investigate and mine supposed iron ore deposits in Martinfjella),
- Camp Smith (most likely used for the sole purpose of claiming the entire Recherchefjorden area for the NEC, since there is hardly anything to mine there), and
- Camp Calypso (a settlement for coal mining and radio communication).

Remains of NEC activities were also mapped at Edge point. Moreover, two whaling sites were mapped in the area, at Camp Smith and at Renardodden. In Van Keulenfjorden an attempt was made to map a NEC prospecting camp (originally a hunters' hut). However the effort was hampered by the presence of no less than four polar bears in the vicinity.

On the northern side of Bellsund several prospecting and mining camps, also emanating from NEC activities, were mapped – Camp Bell and Camp Millar. At Camp Millar a previously unknown mine was documented. At the mouth of Van Mijenfjorden, a detailed map was made over the Camp Morton coal mine (NEC) with the total station – including a transportation system and several mine openings situated in a very steep and unstable location high up in the south face of Kolfjellet. The archaeological data from the sites investigated during the LASHIPA 3 expedition provided the project with important data for comparative analyses on several of its research problems – technology transfer, the design of technology, the shaping of industrial

+

Figure 5

Wouter Ytsma, University of Groningen, mapping a mining camp with total station – a highly accurate instrument used for mapping archaeological sites. Photo: Dag Avango.

+

Figure 6
Camp Morton, a Northern Exploration Company coal mine at Van Mijenfjorden. Here we could study a British view on how coal mining in the Arctic should be designed. The site contains a production line with a coal mine high up in the mountain, a rail transportation system, coal stockpiles and reloading stations, a shipping area and living quarters for management, engineers and mine workers. The site was also used during spring time by Swedish workers in transit between the ice edge in Bellsund and the Svea mine (Sveagruvan) during the 1920's. Photo: Dag Avango.

settlements and the strategies for claiming and controlling natural resources. The cases provide data for international comparison between different time periods, between different national actors and between different regions in the polar areas. Last but not least, the results of archaeological surveys are not only what you find but also what you do not find. During the surveys, we expected to locate the remains of 17th century whaling sites in at least two areas in the Bellsund region, where written sources seem to indicate that whale hunting was performed – the Van Muijden Bay and the west coast of Axeløya. Despite thorough reconnaissance efforts, no traces of whaling remains were found. However observations of landscape settings and other natural conditions gave important insights into both the physical realities of 17th century whaling and into the natural processes eroding cultural remains in the vicinity of coastlines, thus providing important data for dealing with the research problems of the LASHIPA project.

References

AHDR *(Arctic Human Development Report)*. 2004. Akureyri: Stefansson Arctic Institute.

Avango, D. 2005. *Sveagruvan: Svensk gruvhantering mellan industri, diplomati och geovetenskap*. Stockholm: Jernkontoret.

Duhaime, G. 2004. Economic Systems. In: *Arctic Human Development Report*, 69–84. Akureyri: Stefansson Arctic Institute.

Hacquebord, L. 1984. *Smeerenburg: het verblijf van Nederlandse walvisvaarders op de westkust van Spitsbergen in de zeventiende eeuw = The sojourn of Dutch whalers on the westcoast of Spitsbergen in the seventeenth century (with a summary in English)*. Amsterdam.

Latour, B. 1987. *Science in Action – How to Follow Scientists and Engineers Through Society*. Cambridge, Massachusetts: Harvard University Press.

Law, J. and Callon, M. 1992. The Life and Death of an Aircraft: A Network Analysis of Technical change. In: Bijker, W.E. and Law, J. (eds.) *Shaping technology/building society: studies in sociotechnical change*. Cambridge, Massachusetts: MIT Press.

Sugden, D. 1982. *Arctic and Antarctic: a Modern Geographical Synthesis*. Oxford: Blackwell.

+

LASHIPA 3 – Industrin och dess påverkan i polartrakterna från 1600 till idag

LASHIPA (Large Scale Historical Industrial exploitation of Polar Areas) är ett internationellt historiskt-arkeologiskt forskningsprojekt inom ramen för Internationella polaråret 2007–2008 (IPY). Projektets syfte är att förklara utvecklingen av industri i polartrakterna från 1600-talet till idag och industrins konsekvenser för de geopolitiska förhållandena och för naturmiljön där. Projektet fokuserar på ett antal problemområden/delteman: drivkrafter bakom utvecklingen av industri i polartrakterna, samspelet mellan industri och polarpolitik, tekniköverföring, sociala förhållanden, kontroll över naturresurser och miljökonsekvenser. De fyra sistnämnda problemområdena kräver fältstudier av industrilämningar i polartrakterna, vid sidan av arkivstudier. Målsättningen med LASHIPA 3-expeditionen i augusti 2006 var att göra en utförlig fältstudie inför dessa fältundersökningar, som skall genomföras på bl.a. Svalbard under IPY 2007–2008.

Fältundersökningarna genomfördes på olika lokaler kring de stora fjordarna på Västra Spetsbergen – Isfjorden, Bellsund, Van Mijenfjorden, Van Keulenfjorden och Recherchefjorden. Målsättningen var att finna och dokumentera lämningar efter valfångst och gruvdrift, från 1600-tal till 1980-tal. Undersökningarna inleddes med avsökningar av terrängen, med utgångspunkt i historiskt kartmaterial och fotografier. Lämningar som påträffades dokumenterades med en TRIMBLE GPS och/eller totalstation, samt med handritade skisser och digitalkamera. Ett betydande antal valfångst- och gruvanläggningar dokumenterades, varav ett antal valdes ut för fortsatta undersökningar under IPY 2007–2008, de flesta belägna vid Grønfjorden.

Palaeontological fieldwork on Spitsbergen – in the footsteps of Erik Stensiö

Project leader

Jonas Hagström
Department of Palaeozoology
Swedish Museum of Natural History
Stockholm

Accompanying persons

Fredrik Berg
Lars Hanning
Stockholm

Background

For a long period (1923–1959) the Department of Palaeozoology at the Swedish Museum of Natural History was led by professor Erik Stensiö (1891–1984), at the time a world leading expert on the history of fishes. His interest in early vertebrates started at Uppsala University, where he began his scientific studies in 1910 at the age of 23. His chosen topics were zoology and geology. In the latter his teacher, professor Carl Wiman, made a strong impression on young Stensiö – or Andersson as was his name before 1917. Wiman had participated in de Geer's scientific expedition to Spitsbergen in 1908 to collect Triassic vertebrates. Driven by a desire for adventure and inspired by Wiman, Stensiö organized an expedition himself in 1912. The aim was to collect Triassic vertebrates in the Isfjorden area in central Spitsbergen. Stensiö and one of the three accompanying students paid the expenses. This was to be the first trip to the island in a series of six led by Stensiö between the years 1912–1918. Various coal companies for whom Stensiö did geological work usually provided the logistics. In the years 1912, 1913, 1915 and 1916 he worked in Sassendalen, situated in the inner part of Isfjorden. This beautiful valley is some 30 km long and 5 km wide with a flat valley floor where the sluggish, sediment laden Sassenelva River runs. The surrounding mountains consist of strata from the Permian, Triassic and Jurassic periods. In Triassic times, some 240 million years ago, the area was covered by sea, bordered in the west by land. The remains of several species of fish, amphibians and reptiles became embedded and later turned into fossils in the deltaic to coastal sediments. What caught Stensiö's attention was the large number of peculiar fishes, which would eventually lead to his thesis *Triassic fishes from Spitzbergen*, published in 1921.

One of the aims of the current project was to revisit some of the localities Stensiö sampled to fix their GPS-positions and search for fossils. Since Stensiö was affiliated to Uppsala University at the time of his fieldwork on Spitsbergen, all his collections were deposited there. Information on these

Figure 1
Left: Axel Stensiö and Erik Asplund at subcamp 15 km up Sassendalen Valley in 1913. Photo: Erik Stensiö.

Right: On bear watch at the darkest hour of night. Eskerdalen Valley. Photo: Jonas Hagström.

+

Figure 2
Left: Stensiös camp with Mount Templet and Sassenfjorden. Photo: unknown.

Right: Our camp with Mount Templet and Sassenfjorden. Photo: Jonas Hagström.

localities will hopefully serve as a first step on a future expedition to collect specimens for the collections at the Swedish Museum of Natural History in Stockholm. Stensiö also took photos of the area but often neglected to note where they were taken. New pictures taken by us will aid in the identification of these historically interesting glass plates housed at the museum.

Another aim of the project was to get experience of how it is to do field work in arctic conditions, to establish contacts with the Norwegian Polar Institute on Spitsbergen and to see what range of logistics were available. Although the equipment has improved dramatically since Stensiö worked there almost a century ago, first hand experience is needed.

Fieldwork

Our original plan was to walk the whole length of Sassendalen before going back to Longyearbyen via Eskerdalen and Adventdalen. However, shortly after being put ashore at the mouth of Sassendalen it became evident that we would not make enough progress per day to reach the inner part of the valley within the time limit carrying all our equipment. The ground is to a large extent covered with rocks, tussocks and mires. There are also rivers to ford. The average distance covered to establish a new camp was therefore less than 7 km. As a test we established a base camp halfway up the valley, and carrying only daypacks we managed to walk more than twice the distance and reached the Vendomdalen Valley ("Turnback Valley").

Due to very active erosion the slopes are covered by scree in which the fossils lay scattered. Where the strata are more resistant, they form almost vertical cliffs to steep to climb. As a result of this we never saw the specimens *in situ* during our searches. The most productive stratum, the "Fish Horizon", was therefore only tentatively located. However, the specimens were easily spotted due to the original calcium phosphate of the bones being replaced by the bluish mineral vivianite. Most common were fragments of Ichtyosaur vertebrae and ribs. In addition a few labyrinthodont plates were found as well as specimens belonging to several invertebrate groups. We also located a Triassic "bone bed" with microvertebrate fauna.

In Enerdalen, south of Longyearbyen, we tried to reach the Tertiary strata where fossil plants could be found. Eventually we encountered well-preserved specimens of Palaeogene plants in the debris of a glacier. The genera are tentatively identified as *Ushia, Metasequoia, Phragmites* and *Equisetum.*

To ward off polar bear attacks during the night, one can either post a guard outside or surround the tent with tripwires. We chose the first option. This proved to be a mistake, since the 3-hour shifts disrupted our much needed sleep.

Preliminary results

Valuable information was obtained in relation to Stensiö's work in Sassendalen. The condition of the localities and their positions were noted. Photos of the valley were taken for comparison with the historical material. I also feel that I have come closer to both the scientist and the person Stensiö after my time in the valley.

For future expeditions covering large

areas, it is essential to leave the heavier equipment in a base camp and push further by establishing sub-camps. This is especially important if one plans to bring out heavy fossils. To use expensive helicopter transports is of course an alternative. A more economical way to bring out the collections could be to establish depots of collected material, determine the coordinates and then retrieve the material using snowmobiles the following winter. Stensiö had to go back and forth repeatedly to transport his fossils to the coast. Still he had to leave part of the collections behind. Half a century later, the French Palaeontological Expedition of 1969 retrieved these specimens with the help of helicopters.

The temperature during our stay in mid-July was between +6–8° C. The chill factor from the more or less constant wind should be added to this. It became evident that one needs absolutely windproof clothes for comfort. Other equipment that proved valuable were the cover boots used when fording and the hiking poles that gave extra support when passing rough terrain.

Contact was established with the Norwegian Polar Institute in Longyearbyen, which is essential for the organization of future expedition logistics.

The overall impression from the expedition is that there are no obstacles to reviving Swedish palaeontological fieldwork on Spitsbergen. The Swedish Museum of Natural History has great traditions in this scientific field to live up to. A century ago pioneers working or coming to work for the museum such as Sven Lovén, A.E. Nordenskiöld, A.G. Nathorst and of course Erik Stensiö brought large collections of fossils back to Sweden for the benefit of visiting scientist from all over the world.

And yes, there are mosquitoes on Spitsbergen, lots of them, contrary to what we were told before we left Sweden and our mosquito repellents!

Acknowledgements

Thanks to the Swedish Polar Research Secretariat and the Norwegian Polar Institute for loan of equipment. Thanks also to Nordenskiöldska Swedenborgfonden (at the Royal Swedish Academy of Sciences) and Riksmuseets Trygghetsfond for economic support.

Figure 3
Left: Two members of Stensiö's expedition at the Triassic "Fish horizon" on Mount Trehøgdene, Sassendalen Valley. 1912. Photo: unkown.

Right: Fossil hunting on Mount Vikinghøgda, Sassendalen. Photo: Lars Hanning.

Figure 4
Left: Logistics at the beginning of the 20th century. One of Stensiö's expeditions with Sassenfjorden and Mount Templet in the background. Photo: unkown.

Right: Logistics at the beginning of the 21st century. Sassenfjorden and Von Post-breen Glacier in the background. Photo: Jonas Hagström.

References:

Andersson (Stensiö), E. Spetsbergsexpeditionen 1912. *Ymer* 1912, pp. 390–391.

Andersson (Stensiö), E. Svenska geologiska expeditionen till Spetsbergen sommaren 1913. *Ymer* 1913, pp. 448–449.

Andersson (Stensiö), E. Svenska geologiska Spetsbergsexpeditionen 1915. *Ymer* 1915, pp. 383–387.

Andersson (Stensiö), E. Svenska Spetsbergsexpeditionen 1916. *Ymer* 1917, pp. 196–197.

A:son Stensiö, E. 1921. *Triassic fishes from Spitzbergen, part 1*. Vienna: Adolf Holzhausen. 307 pp.

Dallmann, W.K. (ed.). 1999. *Lithostratigraphic lexicon of Svalbard*. Tromsø: Norsk Polarinstitutt. 318 pp.

Dallmann, W.K. et al. 2000. *Geological map of Svalbard 1:100 000, C9G Adventdalen*. Tromsø: Norsk Polarinstitutt.

Liljequist, G.H. 1993. *High Latitudes*. Stockholm: Polarforskningssekretariatet. 607 pp.

Stensiö, E. 1980. *Självbiografiska anteckningar* ("Autobiographical notes", unpubl.). 91 pp.

Stensiö's field diaries for the years 1912, 1913, 1915 and 1917, kept at The Center for History of Science at the Royal Swedish Academy of Sciences.

Paleontologiskt fältarbete på Spetsbergen – i Erik Stensiös fotspår

Under mitten av 1900-talet leddes den paleozoologiska avdelningen på Naturhistoriska Riksmuseet i Stockholm av professor Erik Stensiö – en då världsledande expert på fiskarnas tidiga historia. Han hade som ung student i Uppsala inspirerats att börja forska på fossila fiskar från Spetsbergen, eller Svalbard. Forskningsmaterialet samlades in under flera expeditioner ledda av honom själv under åren 1912–1918. Resultatet blev så småningom en avhandling om triassiska fiskar från ögruppen. Vårt projekt sommaren 2006 gick ut på att besöka ett av Stensiös insamlingsområden, Sassendalen, längst in i Isfjorden på Spetsbergen. Här lokaliserades och undersöktes några av hans fyndplatser. Dessutom togs foton av området som hjälp för identifiering av motiven på Stensiös gamla glasplåtar. Erfarenhet samlades om hur det är att arbeta i fält i ett arktiskt klimat samt vad som krävs av utrustningen. Kontakter togs även med Norsk Polarinstitutt på plats för samarbete vid framtida insamlingsresor.

Lärdomar för kommande expeditioner var bl.a. vikten av att ha absolut vindtäta kläder, att man bör arbeta utifrån basläger för att slippa bära både tung utrustning och fossil långa sträckor. För att få sova ut ordentligt bör man förlita sig på larmminor runt tältet för att skrämma bort eventuella isbjörnar, att turas om med vakthållning var alltför tröttande. Som slutsats kan dras att det finns inget som hindrar att Riksmuseet ånyo organiserar insamlingsresor till Spetsbergen i samma anda som då de stora polarfararna besökte ögruppen för ett sekel sedan. Men glöm inte myggmedel!

Did ice-free areas exist in Northeast Greenland during the peak of the last ice age?

Project leader

Lena Håkansson
Geobiosphere Science Centre
Quaternary Sciences
Lund University

Project participants

Elizabeth Thomas
Paleoclimate Laboratory
Department of Geology
University of Buffalo
New York, USA

Scientific background

Along the presently ice-free Northeast Greenland continental margin, upland plateaus and coastal lowlands are often strongly weathered, in contrast to fjords and valleys, which are characterised by fresh-looking surfaces of glacial erosion. Based on the degree of weathering and on the lack of identified deposits from the last glaciation, it has been suggested that the areas between fjords were ice-free during the Last Glacial Maximum (LGM), ca. 20,000 years ago (Funder and Hjort 1973, Hjort 1981). During the past decades considerable effort has been put into both onshore and offshore investigations of the Late Quaternary glacial history of Northeast Greenland. One large step was taken through the ESF programme "Polar North Atlantic Margins" (PONAM), with most of the investigations focusing on Jameson Land (Fig. 1C). This work led to the reconstruction of outlet glaciers restricted to the fjords during the LGM, leaving interfjord areas free from ice (e.g. Möller et al. 1994, Funder et al. 1998). However, the concept of a restricted LGM glaciation in Northeast Greenland has recently been challenged by marine geological studies, suggesting grounded ice on the shelf at this time (Evans et al. 2002, Ó Cofaigh et al. 2004).

To examine these minimum versus maximum concepts, fieldwork has been carried out along the Northeast Greenland coast since the summer of 2003 as part of a PhD project at Lund University (Hjort et al. 2005, Alexanderson and Håkansson 2006). Field sites are shown in Figure 1B.

Was LGM ice indeed more extensive than in earlier reconstructions, covering the presently ice-free coastal areas and the shelf, or was it only the outlet glaciers from the main fjords that inundated parts of the shelf, leaving the adjacent coast and shelf areas with only limited glaciation? Our main aim is to test these two conflicting hypotheses of ice-sheet extent by using cosmogenic exposure dating along the differentially weathered Northeast Greenland continental margin.

Cosmogenic exposure dating

The analysis of cosmogenic isotopes like ^{10}Be and ^{26}Al provides a measure of the time a rock surface has been exposed to cosmic radiation. When cosmic rays interact with the nucleus of an atom, cosmogenic isotopes can be produced (Gosse and Phillips 2001). Most of this production takes place in the atmosphere, but it also occurs in the uppermost few meters of the lithosphere. When accumulated within a rock, two processes act to reduce the amount of these isotopes: radioactive decay and erosion of the rock surface. The accumulated amounts of cosmogenic isotopes can be used as a measure for the time elapsed since the last deglaciation. This assumption is valid if the ice once covering the sampled

Figure 1
A) Overview map; B) map of Northeast Greenland showing sites visited during field seasons 2003–2006,
C) Dark areas show Quaternary sediment cover and coloured areas show the 2006 field sites.

+

Figure 2
Sampling weathered bedrock at Fynselv (Area 2). Photo: Elizabeth Thomas.

rock surface eroded away enough material to erase the accumulation from earlier ice-free periods. However this is not always the case. If the erosion was not sufficient to achieve "zeroing" then the rock will be left with a nuclide inheritance from earlier exposures, which will make the apparent age of our sample older than it is. By using two isotopes with different half-lives (^{10}Be and ^{26}Al) it is possible to conclude whether a sampled surface has been "zeroed" or not. Thus the use of multiple cosmogenic isotopes not only provides a means of dating former ice-margins but also indicates whether the ice cover was eroding its substrate or not.

Jameson Land 2006

The Jameson Land peninsula (70–71°N) is situated on the northern side of the Scoresby Sund fjord, a major drainage path for the eastern part of the Greenland ice sheet (Fig. 1). Jameson Land is ice-free today, but is partly covered by glacial deposits containing rocks of a western provenance, which indicate that the Greenland Ice Sheet has earlier advanced across the peninsula.

The fieldwork of 2006, following up on work done within the same project in 2004 and 2005, was carried out during four weeks in August, when we revisited two of the field areas from 2005 (Alexanderson and Håkansson 2006). From small base camps we made daily excursions and 2–3 day hikes sampling boulders and bedrock, studying landforms and digging into sediment exposures.

Area 1: the Central Plateau (3–14 August)

The central plateau of Jameson Land (400–550 m a.s.l.) is covered with ground moraine that has previously been mapped using satellite imagery and aerial photographs and is referred to as the "Older Drift" (Ronnert and Nyborg 1994, Fig. 1C). Earlier studies suggest that this drift pre-dates the Weichselian (last glacial cycle) and originates from the last extensive ice sheet advance over Jameson Land (Möller et al. 1994). The western boundary of the "Older Drift" has been interpreted as a result of postglacial erosion.

We walked along this sediment boundary to ground-truth the previous mapping efforts and we can confirm the interpretation of the boundary as an erosional boundary. Additionally, samples for cosmogenic exposure dating were collected from the central plateau with the aim of documenting further at what time the ice sheet last covered central Jameson Land.

Area 2: Fynselv (16–31 august)

In the area around Fynselv the bedrock is exposed as weathered sandstone remnants more or less eroded by glacial meltwater (Fig. 2). Erratic boulders and patches of ground moraine are found, especially in lower parts of the terrain. The patchy distribution of glacial deposits and the pattern of melt water erosion in combination with the softness of the sandstone led to the interpretation that the weathered rock formations were formed by a combination of subglacial erosion and postglacial weathering (Hjort and Salvigsen 1991).

During the field season of 2006 rock samples were collected from glacial deposits (erratics on bedrock and ground moraine) and from weathered bedrock surfaces with different imprints of meltwater erosion (Fig. 3). In addition clay mineral samples were collected from weathering pits to test whether the weathering remnants of the Jameson Land sandstone have formed since the last deglaciation, as earlier anticipated, or if they are much older than that.

Preliminary results

At present 27 boulder samples from Jameson Land have been dated, giving ^{10}Be-ages between 8 000–250,000 years. These dates fall within one older group of pre-Weichselian ages and roughly three groups of Weichselian ages (around ca. 14,000, 35,000 and 70,000 years). Due to the large spread of ages and the complexity of the method a larger dataset is needed before we can draw any firm conclusions about the timing of ice sheet advances over Jameson land. However more ^{10}Be-ages from Jameson Land and the field sites north thereof are pending.

Acknowledgements

Thanks to the Danish Polar Centre, the Swedish Polar Research Secretariat, Helge Ax:son Johnson Foundation and Granholm's Foundation for logistic and economic support. Jason Briner at the Department of Geology in Buffalo, NY, USA is acknowledged for letting me use his cosmogenic isotope laboratory. I also thank my PhD advisors Christian Hjort, Svante Björck, Per Möller and Johan Kleman.

Figure 3
Weathered sandstone remnants eroded by glacial meltwater at Fynselv (Area 2). Photo: Elizabeth Thomas.

References

Alexanderson, H. and Håkansson, L. 2006. Did ice-free areas exist on East Greenland during the peak of the last ice age? In: Rickberg, S. (ed.) *Polarforskningssekretariatets årsbok 2005*. 70–73. Stockholm: Polarforskningssekretariatet.

Evans, J., Dowdeswell, J.A., Grobe, H., Niessen, F., Stein, R., Hubberten, H.-W. and Whittington, R.J. 2002. Late Quaternary sedimentation in Kejser Franz Joseph Fjord and the continental margin of East Greenland. In: Dowdeswell, J.A. and Ó Cofaigh, C. (eds.) *Glacier-Influenced Sedimentation on High-Latitude Continental Margins*. Geological Society, London, Special Publications 203. 149–179.

Funder, S. and Hjort, C. 1973. Aspects of the Weichselian chronology in central East Greenland. *Boreas* 2, 69–84.

Funder, S., Hjort, C., Landvik, J.I., Nam, S-I., Reeh, N. and Stein, R. 1998. History of a stable ice margin – East Greenland during the Middle and Upper Pleistocene. *Quaternary Science Reviews* 17, 77–123.

Gosse, C.J. and Phillips, F.M. 2001. Terrestrial in situ cosmogenic nuclides: theory and application. *Quaternary Science Reviews* 20, 1475–1560.

Hjort, C. 1981. A glacial chronology for northern East Greenland. *Boreas* 10, 259–274.

Hjort, C., Håkansson, L. and Alexanderson, H. 2005. A cosmogenic approach to the glacial history of Greenland. In: Viidas, J. (ed.) *Polarforskningssekretariatets årsbok 2004*. 103–108. Stockholm: Polarforskningssekretariatet.

Hjort, C. and Salvigsen, O. 1991. The channel and tor landscape in southeastern Jameson Land, East Greenland. *LUNDQUA Report* 33, 23–26.

Möller, P., Hjort, C., Adrielsson, L. and Salvigsen, O. 1994. Glacial history of interior Jameson Land. *Boreas* 23, 320–348.

Ó Cofaigh, C., Dowdeswell, J.A., Evans, J., Kenyon, N.H., Taylor, J., Mienert, J. and Wilken, M. 2004. Timing and significance of glacially influenced mass-wasting in the submarine channels of the Greenland Basin. *Marine Geology* 207, 39–54.

Ronnert, L. and Nyberg, M.R. 1994. The distribution of different glacial landscapes on southern Jameson Land, East Greenland according to Landsat Thematic Mapper data. *Boreas* 23, 294–311.

Fanns det isfria områden i nordöstra Grönland under den senaste istiden?

I den östgrönländska fjordzonen är dalar och fjordar kraftigt eroderade av is, medan de flacka höjdområdena där emellan ofta är starkt förvittrade. Under de senaste decennierna har ingående undersökningar av detta områdes nedisningshistoria genomförts, men det råder fortfarande vitt skilda meningar om den grönländska inlandsisens utbredning under det senaste nedisningsmaximat för ca. 20 000 år sedan. Var utlöparglaciärer som nådde ut på kontinentalsockeln begränsade till fjordar och större dalar eller täcktes de idag isfria kustområdena av en stor och tjock inlandsis?

Med hjälp av kosmogen exponeringsdatering vill vi åldersbestämma den senaste vidsträckta framstöten av den grönländska inlandsisen och utforska vilket inflytande den haft på landskapets utveckling. Fältarbetet 2006 utfördes under drygt fyra veckor i augusti. Tidigare fältarbete inom projektet har genomförts 2003, 2004 och 2005.

Swedish team

Per Möller (SWEDARCTIC PI)
Nicolaj Krog Larsen
Anders Schomacker
Geobiosphere Science Centre
Quaternary Sciences
Lund University

Danish team and other project participants

Svend Funder (LongTerm project PI)
Kurt Kjær
Geological Museum
Natural History Museum
University of Copenhagen, Denmark

Eske Willerslev
Centre for ancient Genetics and Evolution
Niels Bohr Institute and Biological Institute
University of Copenhagen, Denmark

Henriette C. Linge
Bjerknes Centre for Climate Research
Bergen University, Norway

Claus Andreasen
Greenland National Museum and Archives
Nuuk, Greenland

David Mazzuchi
Royal British Columbia Museum
Earth History
Victoria, British Columbia, Canada

Where the northernmost world ends – fieldwork in Johannes V. Jensen Land on its glacial and palaeoenvironmental history

Background

The importance of the Arctic region for global change has often been stressed in recent years, both in the scientific community and in the media. A cold arctic region with an ice covered Arctic Ocean has been suggested to be crucial for a North–South climate gradient sufficiently steep to drive the meridional energy exchange, which again is an integral part of the Earth's climate today. The risk is that rapid greenhouse warming may destroy this. However the case for rapid change rests to a large extent on satellite observations and – in the case of rapidly diminishing sea ice – from measurements made by nuclear submarines over the last 30 years. There is therefore a need for an assessment of the long-term "natural" variability of such complex and powerful agents as sea ice and glaciation along the Arctic Ocean coast.

Greenland's north coast is the northernmost land in the world, and one of the few remaining coastlines still facing permanent sea ice cover. Owing to its inaccessibility it is also among the world's least explored regions. The *LongTerm* project has been launched in order to perform a broad spectrum investigation of the interactions between climate, sea ice cover, and glaciation over a time scale ranging from the Holocene and back through the last glacial cycle, aiming to contribute to a long-term record of the variability and sensitivity of this extreme environment. The changing conditions for Greenland's earliest cultures are also considered in the project.

LongTerm was initiated by Svend Funder at the Geological Museum in Copenhagen, Denmark, who also is the principal project leader. Due to the long-standing cooperation between the Geological Museum, the Department of Geology at Copenhagen University and the Department of Geology at Lund University, the Swedish group of glacial geologists was invited to take part in the project's work in 2006, which is also a part of SWEDARCTIC 2006 (the Swedish Arctic Research Programme). The *LongTerm* project is a precursor to the *APEX* project (Arctic Palaeoclimate and its EXtremes), which has been named a 'lead project' for International Polar Year 2007–2008 (IPY). The *APEX* project is planned to unfold in and along the Eurasian and Greenland Arctic Ocean in 2007 and 2008.

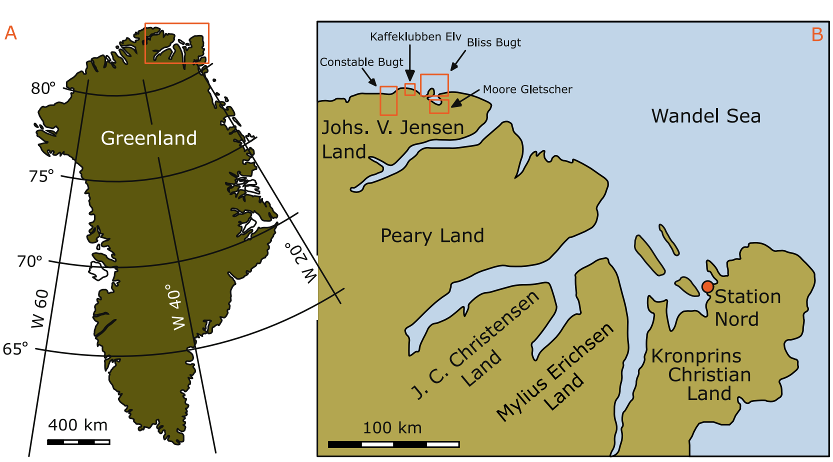


Figure 1
Overview map of Greenland. A) Coloured box indicates insert map, B) shows our four principal investigation areas on the northern coast of Johannes V. Jensen Land.

Aim and scope

The target for fieldwork was the coastal plain along the Arctic Ocean, its tributary valleys and valley glaciers (Fig. 1). With altitudes below 100 m and a width up to 20 km, this coastal plain fringes the Arctic Ocean for ~100 km in Johannes V. Jensen Land. Unique to Greenland, the plain probably originated as an ancient marine abrasion terrace. It is covered by a continuous blanket of Quaternary sediment, and reconnaissance fieldwork in the snow-melt season has indicated that it contains a record of glacial and marine events and sea level change going back more than 40,000 years (Funder and Hjort 1980, Funder and Larsen 1982, Dawes 1986). The aim of the *LongTerm* project is to study sediments, landforms and lakes – but also remains of former human habitation – on the coastal plain and along valleys leading into the alpine mountains to the south, supplemented with studies on processes along present glaciers. More specifically the project aims at:

- The establishment of a glaciation record for northernmost Greenland and investigation of the dynamic interplay between alpine and ice sheet glaciations and their sensitivity to changes in sea ice cover.

This will be achieved by surveying present valley glaciers and sedimentological processes along their margins, combined with installation of data loggers. Additionally traditional field mapping of landforms and logging of sediment sections combined with analyses of glacial geomorphological elements in satellite imagery and aerial photographs will provide a record of past glacier behaviour.

- Reconstructing the sea ice and sea level history of northernmost Greenland.

This will be achieved by studies of raised marine sediments on the coastal plain and on wave- to non-wave generated beaches. Important information on these aspects is also obtained from the dating of driftwood, as this is an indication of both open water along the coasts and of partially open water along the passage in the Arctic Ocean.

- The establishment of a precise chronology of the environmental change.

Precise dating is a prerequisite for all types of records. Here we use the same methods that we developed during our QUEEN project in northern Russia for dating similar records: AMS ^{14}C-dating of organic remains, OSL (Optically Stimulated Luminescence) datings of sediments, and exposure datings of rock and boulder surfaces by ^{10}Be and possibly other cosmogenic nuclides.

- Tracing the human environment in the extreme north.

In spite of an arctic desert environment and a five month polar night, the area has an archaeological record showing all major phases of human habitation in Greenland, going back approx. 4 500 years (Grønnow and Jensen 2003). The plans were to professionally excavate some observed palaeoeskimo ruins and reconnoitre for new ones. Further the aim was to trace human DNA in frozen soil to show ethnic roots of early immigrants and to carry out exposure datings on ruins and tools.

Figure 2
Our first camp in the Constable Bugt valley. Photo: Per Möller.

The fieldwork

The *LongTerm* expedition in 2006 was part of a larger field campaign set up by the Danish Polar Centre under the name of "Forskning i Nord" (Research in the North), with a logistic platform based on Station Nord (81°43'N and 17°50'W, Fig. 1B). The *LongTerm* field party went by regular flight on 6th July from Copenhagen to Longyearbyen, Svalbard. Due to bad weather the group had to stay in Longyearbyen for a couple of days, but was eventually flown across the Greenland Sea to Station Nord in the evening of 9th July by a Canadian-chartered Twin Otter. Due to bad weather, helicopter operations from Station Nord had not been possible for a week and the station was thus quite crowded with field parties waiting to get out. Logistical problems increased as the helicopter crashed while returning from the first delivery of researchers to the field. Though the helicopter was totally wrecked, the pilot was fortunately unhurt. Lacking any helicopter replacement until 29th July, we had to depend on Twin Otter transport which, together with unusually large snow cover on the terrain, meant a rethink of the possible landing/camp sites as compared to the original expedition plan.

After seemingly endless waiting at Station Nord, the whole group was deployed on 13th July in two Twin Otter flights to the first field camp at Constable Bugt, the camp situated some 3 km from the coast at 83°34.36'N, 32°1.55'W (Fig. 1B). Camp was set up on a gravel bar close to the river (Fig. 2). However

Figure 3
Twin Otter landing at the Constable Bugt camp before transfer to the Bliss Bugt camp. Photo: Per Möller.

one question dominated our minds: What on earth are we doing in a place like this? It was +2°C with a bitter northern wind carrying snow in our faces, and the clouds were just 50 m above us. We were supposed to stay in this area for some five weeks, being the absolutely most northern men and woman with land beneath their feet, around 700 km from the North Pole. And we all knew that southern Scandinavia had the best summer for decades with temperatures around +30°C, week after week! However, as it turned out we repeatedly got periods of 3–6 days with very stable weather conditions including lots of sun and nice "summer" temperatures between +6–10°C, interspersed with low-pressure passages of rain and/or snow for a few days. The Constable Bugt valley also turned out to be the 'garden of Eden' of the expedition, compared to the truly arctic deserts of our other field camp sites. After some days of sun the barren ground exploded in the colours of arctic poppy, *Dryas* and different kinds of *Saxifaga*. Muskoxen, geese and arctic hare were abundant everywhere, and the arctic tern with its nest on our landing strip fought us courageously on our way to the toilet.

Our group of glacial geologists was really kept busy: numerous sections along the river valley exposed glaciolacustrine sediments terminating on the proximal side of a large terminal moraine from a valley glaciation. River-cut cliffs in this moraine in turn exposed a complex sequence of tills and sorted sediments deposited in interaction between a valley-based glacier and a shelf-based glacier to the north. Along the coast numerous sections exposed raised marine sediments and beach deposits.

Still having no helicopter replacement, our plans had to be changed. Instead of a split into two different camps the whole group was shipped by Twin Otter some 60 km eastwards to the eastern side of Bliss Bugt (Fig. 1B) on 23rd July (Fig. 3). After serious reconnaissance the plane landed on the only possible landing strip(?) – shaken, not stirred – far from any sections of interest to a glacial geologist! For the following ten days there was plenty of time to study a ground moraine landscape most probably formed by an east-flowing shelf-based ice sheet. The till surface was loaded with large boulders, some of them from a clearly western source area, carrying striae from the west. With a lot of time to spare, glacial geologists turned to the lake coring programme. This had so far met with little success, having encountered only shallow lakes with very little sediment. However at Bliss Bugt we localized a lake with water depths up to 9 metres. From this lake, but not without some effort, a 3.4 m long sediment core was retrieved, containing laminated sediments (probably glacial varves) with a substantial content of organic detritus (Fig. 4). Pending ^{14}C-dates will show the importance of this, for these High Arctic conditions, very long core!

After a period of stormy weather and snow, the helicopter finally arrived and lifted the expedition to new and final sites on 2nd August. The glacial geologists were split into two different camps at Moore Glacier and along the Kaffeklubben Elv, respectively (Fig. 1B), while the rest of the expedition members were flown with Twin Otter to successive camps at Kap Ole Chiewitz and at Mågefjeld on Holm Land in the quest for palaeoeskimo ruins. At Moore Glacier we studied glaciological and geological processes along the margin of a modern high-arctic glacier, as well as processes on pro-glacial outwash fans. Climate stations were also set up for monitoring air, surface and below surface temperatures, and precipitation. The area around the Kaffeklubben Elv revealed rich records of deglacial geomorphological and sediment sequences and very well-exposed sections of raised marine and beach deposits. Thick sequences of marine silt of yet unknown stratigraphic position were also encountered. Pending datings will probably resolve this.

The whole expedition party was successively reunited at Station Nord on 12th–13th August. After sorting out the samples and packing all expedition gear, we were flown to Longyearbyen on 15th August and finally back to Copenhagen the day after. And the 42 day long expedition was over!

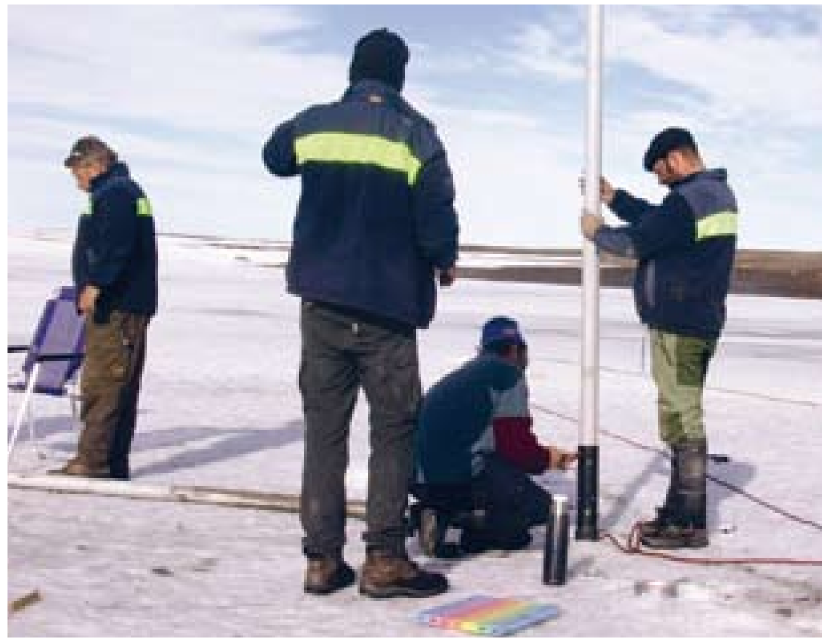


Figure 4
Preparing lake coring in Bliss Lake; a 3.4 metre long sediment core was retrieved from this lake – a Greenland high-arctic record. From left to right: Per Möller, Nicolaj Krog Larsen, David Mazzuchi and Kurt Kjær. Photo: Svend Funder.

Some conclusions

Even though the expedition did not follow the initial plans due to the difficulties in transport logistics and unusual snow coverage at some sites, the geological investigations carried out were a success. The sediment sequences investigated from the Constable Bugt, Kaffeklubben Elv and Bliss Bugt areas will give us information on the interaction between local mountain/valley-based glaciers and more regional ice sheet coverage on the plain/shelf areas to the north. However, as no datings have yet been received, it is premature to put the environmental history into a chronological framework. One of the most interesting observations is the occurrence of fossil high-energy beach systems. These suggest open water during period(s) of the Holocene, as opposed to the present day conditions with permanent sea ice along the North Greenland coast. This puts the present-day discussion of fast ice degradation over the Arctic Ocean into perspective. It has been argued that the possible disappearance of sea ice from the Arctic Ocean due to global warming will be an irreversible environmental change. However, our findings indicate that open-water conditions along the North Greenland coast has at least once during Holocene time flipped back into frozen Arctic Ocean conditions! Even if not yet dated, we presently suppose that these open-water conditions occurred in the early Holocene, thus tied to the insolation maximum at that time.

References

Dawes, P. 1986. Glacial erratics on the Arctic Ocean margin of North Greenland; implications for an extensive ice-shelf. *Geological Society of Denmark, Bulletin* 35, 59–69.

Funder, S. and Hjort, C. 1980. A reconnaissance of the Quaternary geology of eastern North Greenland. *Grønlands Geologiske Undersøgelse, Report* 99, 99–105.

Funder, S. and Larsen, O. 1982. Implications of volcanic erratics in Quaternary deposits of North Greenland. *Geological Society of Denmark, Bulletin* 31, 57–61.

Grønnow, B. and Jensen, J.F. 2003. The northernmost ruins of the globe. *Meddelelser om Grønland, Man and Society* 29, 403 pp.

Där jorden tar slut i norr – fältarbete på Johannes V. Jensen Land om dess glaciala historia och paleologiska miljö

Löpsedlarna ropar: Den arktiska bassängens havsis smälter på grund av den globala uppvärmningen och isbjörnarna är hotade! Mer viktigt är hur en eventuellt i framtiden isfri arktisk bassäng påverkar det globala klimatet och kanske förstärker faktorerna bakom den globala uppvärmningen. Vår forskning på-visar en troligen isfri arktisk ocean under den tidiga delen av vår nuvarande mellanistid, och detta klarade björnarna av. Det gäller emellertid att förstå den naturliga variabiliteten av så komplexa saker som utbredningen av havsis och dess samverkan med landbaserade istäcken för att kunna skilja ut den människopåverkade komponenten. För detta måste vi ha kunskap om, och förståelse för, utvecklingen över en längre tidsperiod. Data för detta finns i våra geologiska arkiv, t.ex. i sedimentsekvenser blottade i flod- och kustskärningar eller i sjöbassängernas sediment. Vårt projekt *LongTerm* syftar till att samla information om just dessa saker. Projektet genomförde sin första expedition under sommaren 2006 till det nordligaste landområdet på Moder Jord: Johannes V. Jensen Land på nordligaste Grönland (83.5° nordlig bredd; bara en 700 km lång promenad över havsisen från Nordpolen). Syftet med expeditionen var:

1. att få data i tid och rum över variationerna av nordligaste Grönlands istäcken och det dynamiska samspelet mellan alpina och landisbaserade glaciationer och deras sensitivitet i förhållande till havsisutbredningen,
2. att rekonstruera förändringar över tiden i havsnivåer och havsisutbredning för nordligaste Grönland, samt
3. att genom många och noggranna dateringar tidsbestämma dessa förändringar.

Expeditionen genomfördes med den danska Station Nord (81°43’N och 17°50’W) som bas, varifrån expeditionsmedlemmarna transporterades ut och senare omgrupperades med flygplan (Twin Otter som kan landa på helt osannolika platser med 150 m start/landningssträcka, se Figur 3) och helikopter. Den glacialgeologiska forskningen utfördes inom fyra olika områden (se Figur 1), och all insamlad data håller nu på att bearbetas.

The development of the Arctic Ocean

Project leader

Victoria Pease
Department of Geology and Geochemistry
Stockholm University

Project participants
Wrangel Island expedition

Elizabeth Miller
Department of Geological and Environmental Sciences
Stanford University
Stanford, California, USA

Sergei Sokolov
Marianna Tuchkova
Geological Institute
Russian Academy of Sciences
Moscow, Russia

Vladimir Verzhbitsky
Department of Geology
Lomonosov Moscow State University
Moscow, Russia

Greenland expedition

Chris Kirkland
Laboratory for Isotope Geology
Swedish Museum of Natural History
Stockholm

John Peel
Evolutionsmuseet/Institutionen för geovetenskaper, Uppsala University

Peter Frykman
Jon Ineson
Lars Stemmerik
Geological Survey of Denmark and Greenland
Copenhagen, Denmark

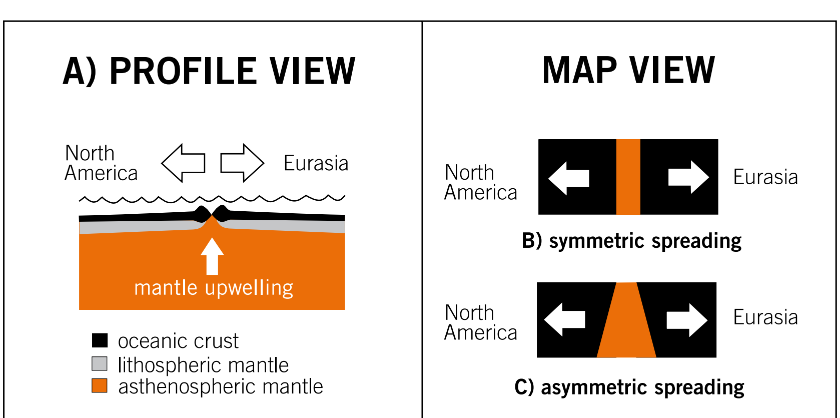
Project aims

The surface of the Earth is made of many rigid pieces known as *plates*. The margins between these plates are either *constructive* (adding material to the plate), *destructive* (removing material from the plate), or *conservative* (material is neither gained nor lost) (Fig. 1). In the Arctic region, the boundary between the North American plate and the Eurasian plate is a *constructive margin* – these two plates are spreading apart from one another and new oceanic crust is being created and added to the outer shell of the planet along the Gakkel Ridge (Fig. 2A). The Gakkel Ridge has been active for the last 55 million years or so (Jackson and Gunnarsson 1990). Before this, a different constructive margin orthogonal to the Gakkel Ridge existed and this 'proto-Arctic' Ocean was much smaller than the Arctic Ocean of today (Fig. 2B). Prior to about 130 million years ago, the Arctic Ocean did not even exist (Fig. 2C).

A widely held theory for the development of the proto-Arctic Ocean, known as the 'rotation' hypothesis, suggests that when North America and Eurasia began spreading apart (rifting), Eurasia rotated away from North America (Lawver et al. 2002). This rotation was anchored around a point (the 'pole of rotation') in the MacKenzie delta of Alaska and rifting was asymmetric, like the opening of a zipper (Figs. 1 and 2). According to the rotation hypothesis Wrangel Island, Chukotka and possibly the New Siberian Islands would all have been derived from the North American Arctic margin.

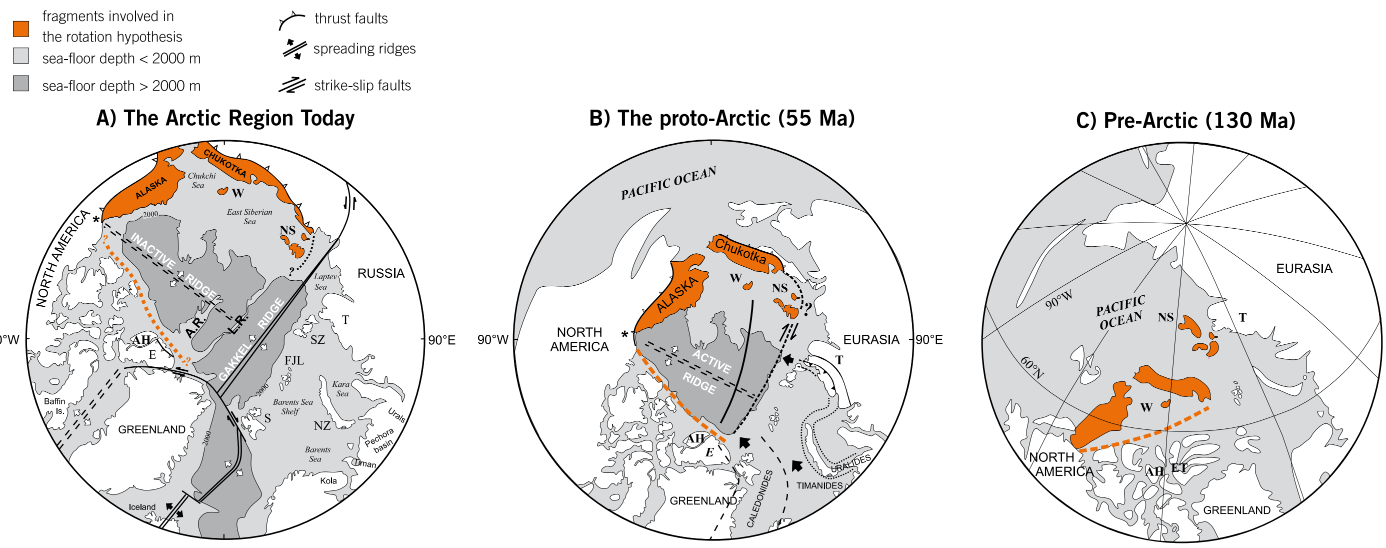
If the rotation hypothesis is correct then signatures of distinctive tectonic processes such as collision, rifting and subsidence should be recorded in the geologic record as orogenic belts, ophiolites, ocean basin sediments, etc. Using these signatures to evaluate the geologic evolution of the greater circum-Arctic region, we are testing the rotation hypothesis and the correlations suggested by it (e.g. Pease 2006). This work is part of international research efforts to understand the regional tectonic evolution of circum-Arctic palaeogeography, i.e. CASP (Circum-Arctic Sediment Provenance), PLATES & GATES (International Polar Year project no. 77: Plate Tectonics and Polar Gateways). This work also has important implications for global economic resources since significant proven and potential reservoir rocks also occur in Arctic shelf regions, as well as for the development of the modern global climate system because cold water flowing from the Arctic and Antarctic Oceans drives global ocean circulation.

Figure 1
Schematic constructive plate margin. A) Cross-section view. B) Map view of symmetric spreading. C) Map view of asymmetric spreading.



Field season 2006

The main target for our fieldwork in 2006 was Wrangel Island in the Russian Arctic, but we also took advantage of unexpected and exciting opportunities to work on Axel Heiberg Island in arctic Canada and in North Greenland. Wrangel Island would have been near Axel Heiberg Island prior to its counter-clockwise rotation from the North American margin (Fig. 2). If the geology and age relationships on Wrangel Island are similar to those on Axel Heiberg Island, this will provide direct confirmation of the rotation hypothesis. Unfortunately the expedition to Axel Heiberg Island was grounded in Resolute; winter never left the island and float planes were unable to land. Work in North Greenland provided an



opportunity to continue developing our reference database: North Greenland has a fantastic, continuous and *in situ* (non-rotated) sedimentary succession to which our other circum-Arctic locales can later be compared.

Wrangel Island

Fieldwork

Our international group (American, Russian, and Swedish participants) met in Moscow and on 10th July flew northeast across Siberia to Pevek. In Pevek, supplies were organized and local geology was investigated while awaiting our 'weather window' to fly by helicopter via Cape Schmidt to Wrangel Island, 120 km north of mainland Russia. We reached Wrangel Island on 27th July and on 29th July arrived at our first base camp in the Tsentralny Mountains. After a few days evaluating the stratigraphy we divided into separate working groups, each operating from several base camps (Fig. 3). We typically hiked 10–15 km per day, either directly from camp or, if the objective was far away, from a vehicle drop-off point. The expedition experienced generally fine weather and motorized vehicle transportation ensured that our original scientific objectives were exceeded!

After two weeks in the field our working groups re-combined along the Mamontovaya River and on 12th August headed to Somnitelnaya to await our return flight to the Russian mainland. Some days were used to work locally and on 21st August the helicopter flew direct from Wrangel Island to Pevek, where we made our connections to Moscow and beyond.

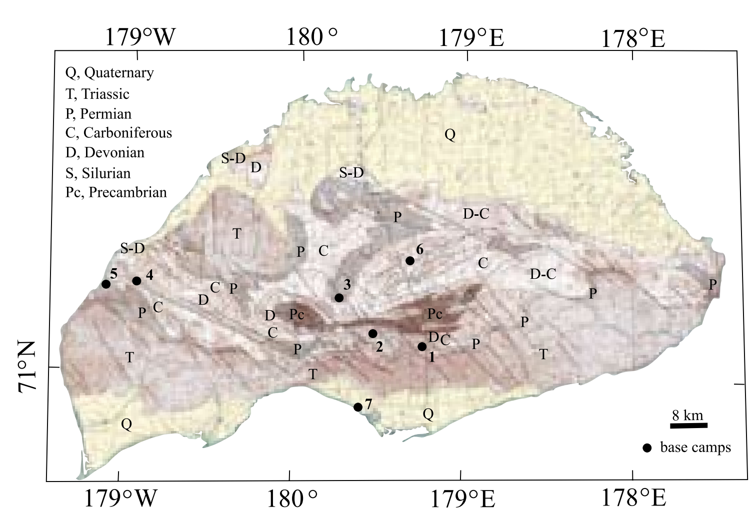
Preliminary results

Wrangel Island represents a north-vergent fold and thrust belt. All rock units, from Precambrian to Triassic in age, are folded at the meso- and macro-scale and thrust faulted. Folding varies from close to isoclinal. Bedding and cleavage generally dip 20–40° to the south, though steeper angles are seen locally. Variable bedding and cleavage relationships have resulted from folding (e.g. upright versus overturned limbs, steeper cleavage-to-bedding intersections in hinges). As a result of this folding and faulting, the stratigraphic section is both duplicated and/or missing! Consequently, though outcrop exposure is good and a general sequence stratigraphy is identifiable (Figs. 4 and 5), determining the original thickness of strata and the detailed relationships between units is difficult.

The geology of Wrangel Island is dominated by Palaeozoic and Mesozoic clastic and shallow water marine sequences, i.e. erosional sediments and shelf carbonates, deposited unconformably on Precambrian basement (Figs. 4 and 5). Though folding and faulting across Wrangel Island has resulted in the widespread out-of-sequence juxtaposition of strata, gradational contacts between Palaeozoic and Mesozoic units are seen locally. These sediments document a change in depositional environment, from a subsiding passive margin to an actively uplifting margin; predominantly terrigenous clastics (Devonian) overlain by shallow marine carbonates (Carboniferous)

+
Figure 2
Tectonic evolution of the Arctic Ocean (after Jackson and Gunnarsson 1990). A) Today. B) 55 million years ago. C) 130 million years ago. Northern Alaska, Chukotka, Wrangel and the New Siberian Islands are thought to have rotated counter-clockwise from the Canadian/Greenland margin along a now inactive spreading ridge, around a pole of rotation (*) in the MacKenzie delta. (A.H.: Axel Heiberg, A.R.: Alpha Ridge, E: Ellesmere Island, ET: Ellesmere Terranes, FJL: Franz Josef Land, L.R.: Lomonosov Ridge, NS: New Siberian Islands, NZ: Novaya Zemlya, S: Svalbard, SZ: Severnaya Zemlya, T: Taimyr Peninsula, W: Wrangel Island.

+
Figure 3
Geology of Wrangel Island (Kosko et al. 1993) superimposed on 1:250 000 topography (compiled by E. Miller). Base camps indicated by black dots.



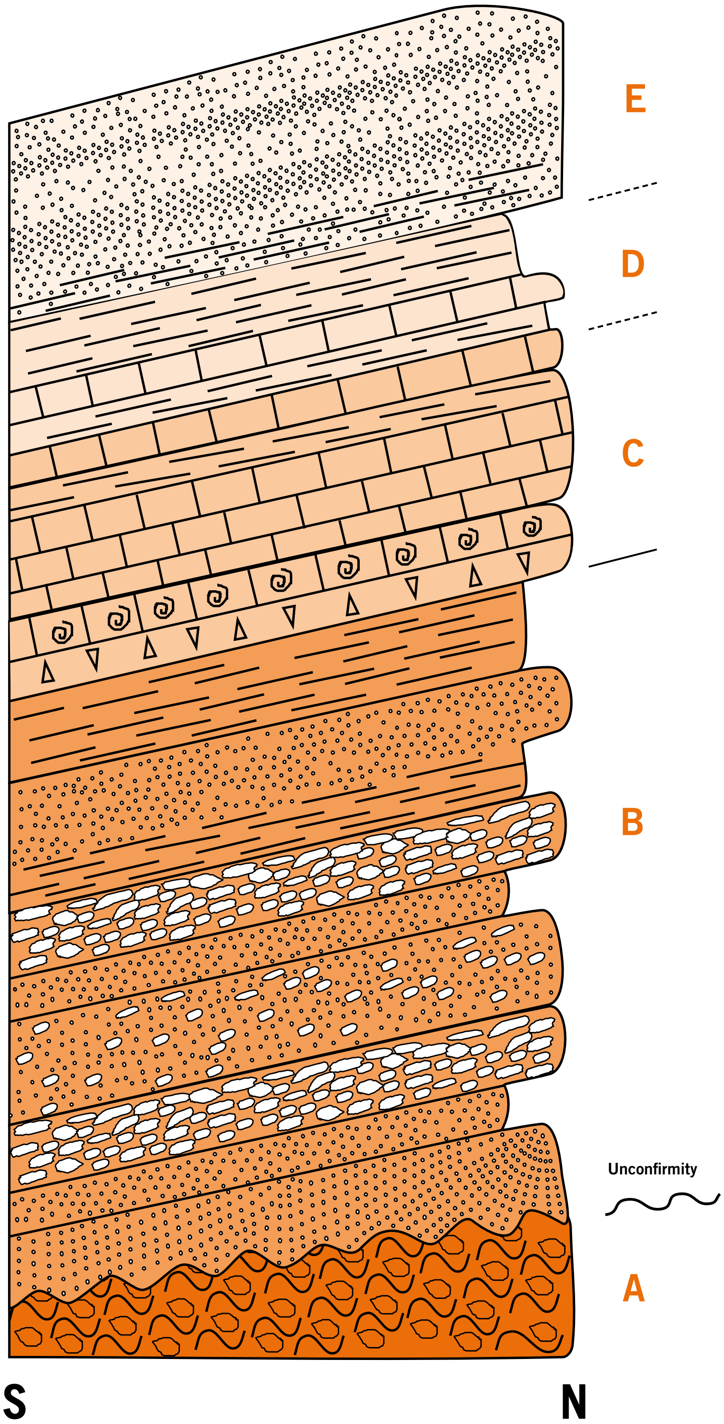


Figure 4
Composite stratigraphy of central Wrangel I land. Duplication of stratigraphy due to folding and thrust faulting not illustrated. Dashed lines (------) indicate transitional boundary between strata.

Composite Stratigraphy
of Wrangel Island
E) Triassic black shale and organic-rich sandstone and siltstone.
D) Permian blach shale with minor carbonate.
C) Carboniferous green pepperite and slate; yellow fossiliferous carbonate with minor black shale.
B) Devonian clastic sequence: orange and green sandstone and shale: purple conglomerate, and slate; green gritstone and sandstone.
A) Precambrian gneiss.

Figure 5
Field photographs
E) Thick Triassic sandstone bed.
D) Permian black shale.
C) Carboniferous limestone forming ledge against the skyline.
B) Polymict Devonian conglomerate with granitic clast indicated by arrow.
A) Polydeformed precambrian ortho-gneiss.
Photos: Victoria Pease, Vladimir Verzhbitsky, Elizabeth Miller.

and deeper marine (basinal) black shale (Permian) record the former, while the immature, organic-rich turbiditic sandstone and shale (Triassic) overlying Permian shale records the latter (Figs. 4 and 5). In the coming months, provenance analysis of Triassic sediment will be important for constraining plate tectonic reconstructions associated with the development of the Arctic Ocean (e.g. Miller et al. 2005).

The nature of the Precambrian basement is poorly understood. Numerous age data exist for these rocks (predominantly K-Ar whole rock analyses), but because they are metamorphosed (greenschist facies) and variably deformed (Figs. 4 and 5), these ages are interpreted to reflect metamorphic resetting. A few conventional U-Pb zircon dates range from 630–700 Ma, with inherited grains suggesting the possible presence of older source material at depth (see Kosko et al. 1993, for a summary of existing work). The geochemistry of these rocks is essentially unknown. Thus a major focus of our work on these rocks will be to define the age and magmatic evolution of this basement using zircon U-Pb, O-, and Hf-isotopic analyses on single crystals at NORDSIM (the Nordic ion-microprobe facility in Stockholm). This information will be used to correlate circum-Arctic Precambrian terranes.

Notable results from work to date include:
1) recognition of highly strained Devonian conglomerates and sandstones, with possible mylonitic deformational fabrics – the verification of mylonitic fabrics is important, as it would suggest thrust faulting occurred at deeper levels than previously thought;
2) identification of Carboniferous pepperite, mixtures of lava and wet sediment (previously reported as basaltic breccia);
3) a sampling cross-section from the central mountains to the southern coast (Precambrian through Triassic) for microfauna, fission-track and provenance analyses. Further work on these topics requires sample processing and laboratory access, which will also begin in the coming months.

North Greenland

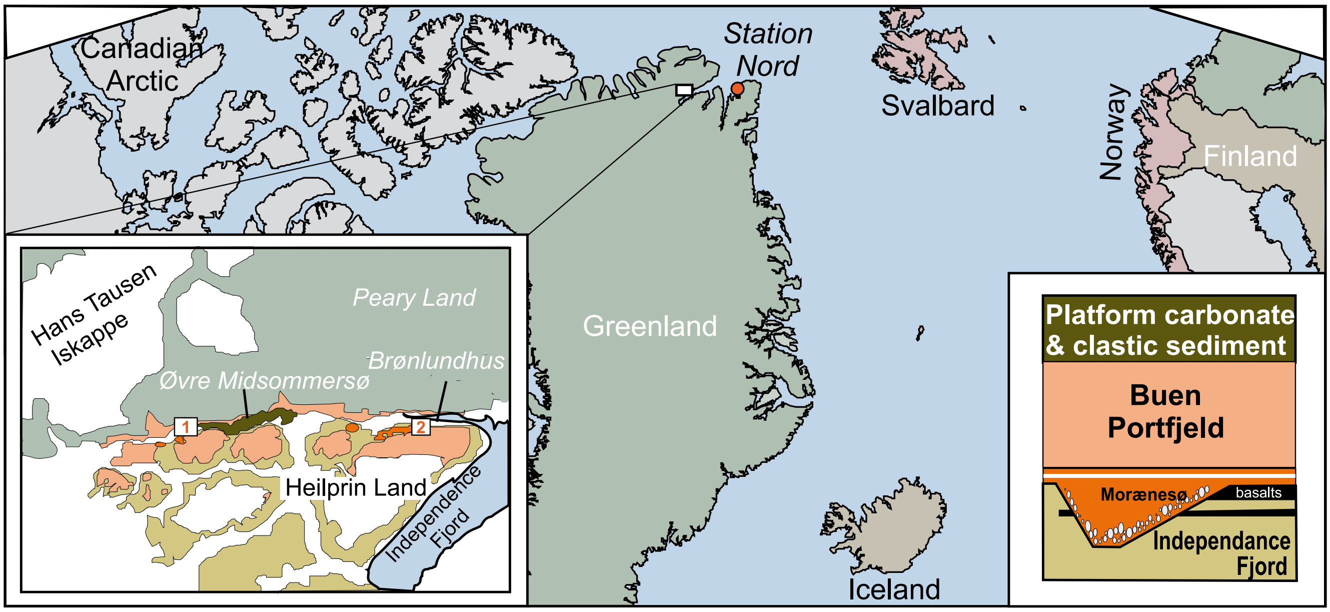
Fieldwork

Our field party of Danish and Swedish scientists assembled in Copenhagen on 17th July and travelled by air to Svalbard. From Svalbard equipment and personnel were loaded into a rugged aircraft (Twin Otter) and transferred to Station Nord, North Greenland. On 18th July we flew to our first base camp at the western end of Ovre Midsommersø (Fig. 6), where we spent ten days mapping, logging and collecting samples. On 27th July we transferred to our second base camp and spent three days near Brønlundhus (Fig. 6) before returning to station Nord. The weather was excellent, permitting a large dataset of field observations and samples to be collected.

Preliminary results

Base camps in North Greenland were selected for access to the late Precambrian–Cambrian stratigraphy, i.e. rocks 1 000–545 million years old. These rocks include an important glacial unit known as tillite, which represents ice-deposited material of *inferred* Neoproterozoic age (Collinson et al. 1989). Such deposits are important for understanding the timescales of climate change and variability on Earth. For example, Hoffman et al. (1998) postulated a global glaciation in the Neoproterozoic with global mean temperatures about -50°C! Constraining the absolute age of the tillite from the Morænesø Formation will be an important part of our research in the coming months.

The Morænesø Formation fills a series of ancient valleys cut into the underlying Independence Fjord group (Fig. 6). The Morænesø formation is made of river and aeolian sediments and its base has proximal rock fall deposits. More widespread conglomerates overlie valley-floor fluvial sands and contain evidence for ice-push. These conglomerates, unlike the rock fall deposits (Fig. 7A), contain fartravelled clasts, many of which are granitic. Some clasts have striated surfaces suggesting a phase of glacial transport prior to final emplacement (Fig. 7B). The granitic clasts will help define the older basement of the region, which is presently covered by the Greenland ice cap. Further evidence of peri-glacial process operating at the time of deposition includes fossil polygonal ground and dropstones (pebbles deposited from floating ice). Towards the top of the sequence, carbonate rocks are preserved as spectacular stromatolite domes (Fig. 7C). Such sequences in locations around the world have been interpreted to reflect deglaciation and associated flooding of continental shelves while ice sheets melted. The lack of an erosion surface between the conglomerates and the dolomite indicates a



+

Figure 6
Simplified geology of North Greenland with base camps indicated by numbered boxes. Left inset shows simplified geology of study area (after Ineson et al. 2005). Right inset shows simplified stratigraphy of southern Peary Land (after Ineson and Peel 1997).

relatively rapid transition between siliciclastic and carbonate deposition. However in order to understand Neoproterozoic climatic processes we need *absolute* time constraints.

The study area is essentially undeformed and stratigraphic relationships show that the oldest unit in the region is the Independence Fjord group, a sequence of sedimentary rocks over 2 km thick. This group comprises deltaic cross bedded, arkosic and abundantly ripple-marked sandstones (Fig. 7D). It is interpreted to overlie 'crystalline basement' which, however, is not exposed in the region. Age constraints on the Independence Fjord group are sparse, with only a lower age limit provided by the approx. 1 380 Ma intrusive Zig-Zag Dal basalt suite (Kalsbeek and Jepsen 1984). Studies of detrital minerals in this group will provide further age constraints and also test the hypothesis that the Morænesø Formation was locally derived.

The youngest unit investigated was the Portfjeld Formation consisting of 500–700 m of dominantly carbonate rocks. Sitting unconformably above the Portfjeld is the Early Cambrian Buen formation (Fig. 6). We sampled sandstone intervals within the Portfjeld formation, as well as a possible ash bed which may provide an absolute time marker for the sequence. The Portfjeld formation was considered to be Early Cambrian in age and correlated to the Ella Bay Formation of Ellesmere Island (Peel and Christie 1982). The Ella Bay formation is one of the oldest stratigraphic units exposed in the Franklinian margin sedimentary sequence in the Canadian Arctic Islands, but is now considered to have a probable late Neoproterozoic age (Dewing et al. 2004). Constraint from detrital zircon crystals will help clarify the depositional timing of the Portfjeld and its correlative formations.

Concluding remarks

Circum-Arctic projects cover a very large region and because we generally target a single location per year, it will take many years to visit each important location necessary to understand the growth and development of the Arctic Ocean. The International Polar Year 2007–2008 (IPY) is designed to increase awareness of the importance of the Earth's polar regions (the Arctic and Antarctica), which are significant not only for societal resources (petroleum, fishing, shipping lanes, etc.), but also for the planet's biodiversity, environmental monitoring, etc. The circum-Arctic region will continue to be a focus of our research during the IPY, when we hope to visit Axel Heiberg Island, as well as the Franz Josef Land Islands of the Russian Arctic.

Acknowledgments

This research has been made possible by logistic/financial support from the Swedish Polar Research Secretariat, the Swedish Research Council, the National Science Foundation, and the Russian Foundation of Basic Research. We also wish to thank all our friends at the Wrangel Island Nature Reserve. Thanks also to J. Mansfeld for help with the Swedish translation.

Figure 7
Field photographs. A) Angular, proximal clast derived from the Independence Fjord Formation in the Morænesø Formation. B) Striated sandstone clast within the Morænesø Formation. C) Large stromatolite domes immediately above glacial diamictite in the Morænesø Formation. D) Wave rippled bedding surface in sandstones of the Independence Fjord Formation. Photo: Chris Kirkland.

References

Collinson, J.D., Bevins, R.E. and Clemmensen, L.B. 1989. Post-glacial mass flow and associated deposits preserved in palaeovalleys: the Late Precambrian Morænesø Formation, North Greenland. *Meddelelser om Grønland Geoscience* 21, 27.

Dewing, K., Harrison, J.C., Pratt, B.R. and Mayr, U. 2004. A probable late Neoproterozoic age for the Kennedy Channel and Ella Bay formations, northeastern Ellesmere Island and its implications for passive margin history of the Canadian Arctic. *Canadian Journal of Earth Sciences* 41(9), 1013–1025.

Hoffman, P.F., Kaufman, A.J., Halverson, G.P. and Schrag, D.P. 1998. A Neoproterozoic Snowball Earth. *Science* 281, 1342–1346.

Ineson, J.R., Jepsen, H.F., Mikkelsen, N., Piasecki, S., von Platen-Hallermund, F., Thomassen, B., Schjøth, F. and Weng, W.L. 2005. Thematic maps and data of North and Northeast Greenland: geology, mineral occurrences and hydrocarbons. *Danmarks og Grønlands Geologiske Undersøgelse Rapport* 28.

Ineson, J.R. and Peel, J.S. 1997. Cambrian shelf stratigraphy of North Greenland. *Bulletin of the Geology of Greenland Survey* 173, 1–120.

Jackson, R. and Gunnarsson, K. 1990. Reconstructions of the Arctic: Mesozoic to Present. *Tectonophysics* 172, 303–322.

Kalsbeek, F. and Jepsen, H.F. 1984. The late Proterozoic Zig-Zag Dal Basalt Formation of eastern North Greenland. *Journal of Petrology* 25(3), 644–664.

Kosko, M., Cecile, M., Harison, J., Ganelin, V., Khandoshko, N. and Lopatin, B. 1993. Geology of Wrangel Island, between Chukchi and East Siberian Seas, Northeastern Russia. *Geological Survey of Canada Bulletin* 461, 101.

Lawver, L.A., Grantz, A. and Gahagan, L.M. 2002. Plate kinematic evolution of the present Arctic region since the Ordovician. In: Miller, E.L., Grantz, A. and Klemperer, S.L. (eds.) *Tectonic Evolution of the Bering Shelf-Chukchi Sea-Arctic Margin and Adjacent Landmasses*. Special Paper. Geological Society of America, Boulder, CO, 333–358.

Miller, E.L., Toro, J., Gehrels, G., Amato, J., Prokopiev, A., Tuchkova, M., Akinin, V., Dumitru, T., Moore, T. and Cecile, M. 2006. New insights into Arctic paleogeography and tectonics from U-Pb detrital zircon geochronology. *Tectonics* 25, TC3013, doi:10.1029/2005TC001830.

Pease, V. 2006. The Amerasian Basin Puzzel. In: Rickberg, S. (ed.) *Polarforskningssekretariatets årsbok 2005*. 170–174. Stockholm: Polarforskningssekretariatet.

Peel, J.S. and Christie, R.L. 1982. Cambrian–Ordovician platform stratigraphy: correlations around Kane Basin. In: Dawes, P.R. and Kerr, J.W. (eds.) Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddelelser om Grønland Geoscience,* vol. 8., 117–135.

Utvecklingen av Arktiska oceanen

Kunskapen om den arktiska paleogeografin har avgörande betydelse för världens ekonomiska resurser. I shelfområdena finns betydande påvisade och antagna reservoarbergarter för olja och gas, och de kallvattenströmmar som går från de arktiska och antarktiska havsområdena driver jordens havsvattencirkulation. Dagens moderna Arktiska ocean började först bildas för 130 miljoner år sedan. Vår internationella expedition till Wrangelön syftade till att pröva hypotesen att den Arktiska oceanen bildades då plattspridningen skilde norra Ryssland från norra Kanada vid denna tidpunkt. Om detta kan bevisas låg Wrangelön bredvid Ellesmere Island en gång i tiden! Sedimenten på norra Grönland är kontinuerliga och i sin orginala lagerföljd. Vår forskning på norra Grönland ingår i vår strävan att att göra en referensdatabas som andra områden på Arktis kan jämföras med.

Properties of aerosol particles in polar regions and trends in background CO_2 levels: Long-term monitoring and aircraft measurements

Project leader

Johan Ström
Department of Applied Environmental Science
Stockholm University

Project participants

Birgitta Noone
Juri Waher
Department of Applied Environmental Science
Stockholm University

Ann-Christine Engvall
Radovan Krejci
Department of Meteorology
Stockholm University

Project aim

The energy budget on Earth is largely determined by the so-called greenhouse gases, which occur naturally in the atmosphere: mainly water vapor, carbon dioxide, methane, ozone and nitrous oxide. These gases block the Earth's heat radiation, preventing it from escaping into space. Without this natural greenhouse effect the Earth would be a very cold place. Since the introduction of industrialism man has increased the amount of greenhouse gases in the atmosphere. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as well as chlorofluorocarbons (CFC's) show large increases over the past century due to human activity. The effect of this increase is forcing the climate towards a warmer atmosphere.

Whereas the greenhouse gases warm the Earth, particles in the atmosphere generally, but not always, have a cooling effect on the climate. When sunlight hits the particles in the atmosphere some of the light is scattered back from the Earth. This means that less of the sun's radiation reaches the ground. Particles also cool the planet by modifying the droplet size distribution of clouds. Shifting the cloud droplet distribution to smaller sizes makes the cloud brighter, in other words it scatters more radiation back to space. Black particles such as soot tend to warm the atmosphere. Contrary to greenhouse gases, which stay in the atmosphere for a long time and are almost equally distributed over the world, the particle concentration is highly variable.

Our research aims at a better understanding of these atmospheric constituents and their roles in the climate system. We seek knowledge about their sources and sinks, transport and transformation processes and their interactions with clouds and climate. We do this through long-term measurements, currently at three locations (the Zeppelin station in Svalbard, Aspvreten in Sweden, and Pico Espejo in Venezuela), and by detailed spatial observations using aircraft platforms deployed from locations from pole to pole.

Figure 1
Ann-Christine Engvall and Andreas Minikin (DLR) making sure the equipment is in good order before the test flights that took place outside Bremerhaven, Germany in September 2006.
Photo: Johan Ström.

+

Figure 2
Picture was taken from the Zeppelin station 26 April 2006 just prior to the pollution event. Photo: Ann-Christine Engvall.

Research platforms

Aircraft measurements

The aircraft measurements are mainly conducted in collaboration with the German Alfred Wegener Institute (AWI), the Japanese National Institute of Polar Research and the German Aerospace Center. The antarctic campaign ANTSYO was performed towards the end of 2006, and will be reported upon in next years yearbook together with reports on the Arctic campaign ASTAR2007. Although the actual measurement flights were conducted at the very end of 2006 and beginning of 2007, preparations such as sea and ice survival training, high altitude and pressure chamber tests and instrument aircraft-certification, including test flights, took place in the summer of 2006 (Fig. 1). During ANTSYO the aircraft is based at the German station Neumayer and the Japanese station Syowa. The aircraft experiments are mainly funded by the Swedish Research Council (VR) with support from the Swedish Polar Research Secretariat.

Observations at the Zeppelin station

The Zeppelin station is located in Ny-Ålesund on the west coast of Svalbard (78°54'N, 11°53'E). The research station is an excellent platform for atmospheric studies, as its elevation of about 475 m a.s.l. on the Zeppelin mountain ridge minimizes influences from local sources. The station is owned by the Norwegian Polar Institute (NPI), but the two main users are Stockholm University and the Norwegian Institute for Air Research (NILU). The station was officially opened in 1990, but in 2000 the original building was replaced with a new and more user-friendly one. The activities at the Zeppelin station are mainly supported by the Swedish Environmental Protection Agency with support from the Swedish Polar Research Secretariat.

Measurements

Long-term measurements imply continuous or semi-continuous measurements that run throughout the year and from year to year. Despite this continuous operation many parameters are observed at a rate as high as one data point every minute. Such long-term, high frequency measurements are the only viable way to determine trends and to place campaign-like observations such as measurements from aircraft or ships into context.

Carbon dioxide

The air around us consists almost entirely of nitrogen (ca 78%) and oxygen (ca 21%). The remaining one percent is mainly argon, but also contains trace amounts of very important gases. One of the better known of these trace gases is carbon dioxide (CO_2). Because CO_2 absorbs thermal radiation emitted by the Earth, it functions like a blanket or greenhouse. The more CO_2 present in the atmosphere, the warmer the climate. The use of fossil fuel emits large amounts of CO_2 and as a result the carbon dioxide concentration in the atmosphere has increased quickly since the beginning of industrialization. When trees and other plants grow, they consume CO_2 from the atmosphere, which cause an annual cycle in the CO_2 concentration. Making measurements away from the direct sources and sinks provides a clearer signal in the data in order to monitor possible trends in trace gas concentrations.

Carbon dioxide is measured using a Non-dispersive Infrared Radiometer (NDIR), Li-COR model 7000. For more details on the measurement approach please visit www.itm.su.se/zeppelin/measure_gases.html. Figure 4 shows data from the Zeppelin station, which is actually the only long-term CO_2 monitoring operated by Sweden. The data series show not only the marked annual variation in CO_2 but also the very large increase in the baseline concentrations. The increase is currently between 2 and 3 ppmv (parts per million per volume) per year. Since the measurements started in the late 1980's the CO_2 level has increased by almost 10%.

Never before in any historical record, such as ice core data, has the magnitude of the concentration (in some years about 400 ppm) or the rate of increase been larger. It is truly unprecedented. On a global scale the polar regions present the largest increase. The reason for this is not clear, but changes in ocean temperature and altered thawing cycle are possible mechanisms to enhance the CO_2 level in the atmosphere. In addition to the real-time observations of CO_2, flask samples are taken weekly and analysed for CO_2, CH_4, CO, and $^{13}CO_2$, H_2, N_2O, SF^6 and ^{18}O in CO_2 by NOAA/CMDL, Boulder, Colorado, USA (Thomas J. Conway). These data can be seen by visiting www.cmdl.noaa.gov/ccgg/iadv/ and selecting Ny-Ålesund.

Particle measurements

Particles mixed with air are called aerosols. Aerosol particles are very small and in the atmosphere they are typically smaller than one micrometre (0.000001 m) in diameter. Despite their small size they are an important component of our environment in several aspects. In the atmosphere particles are an integral part of the energy budget of the Earth, in other words our climate. Particles scatter and absorb light from the sun that gives rise to many, often beautiful, optical phenomena. The fact that all cloud and rain drops began their life as small aerosol particles is of course of great interest to meteorologists. The source of particles may be natural, e.g. from the forests or oceans, or they may be anthropogenic, arising through human activities such as industry or traffic. By studying aerosols at different locations and over longer times we can better understand how aerosol particles affect our environment and us.

At the Zeppelin stations aerosols are characterized based on their number concentration, size distribution, light scattering and light absorbing properties, as well as their chemical compositions (inorganic chemistry analysis are performed by NILU). As aerosol particle's properties range over a wide scale, an array of particle counters and instruments are needed to cover all relevant aspects. For more details on particle measurements please visit www.itm.su.se/zeppelin/measure_particles.html.

Activities in 2006

Five visits were made to the station: 1) at the end of January and beginning of February, 2) at the end of April and beginning of May, 3) at the end of July 4) in October, and finally 5) in December. Personnel from NPI perform daily supervision of the instruments but there is always room for maintenance and improvements. Each visit is typically between one and two weeks. Most of the year there are two flights per week to Ny-Ålesund from Longyearbyen. However the element of weather sometimes makes travelling difficult to plan in detail. Hence visits may sometimes be longer than anticipated.

During the visit in spring we experienced the most severe pollution event ever recorded in Ny-Ålesund. The photographs in Figure 2 and 3 illustrate the visual impression of this. Figure 2 was taken on 26 April 2006, the day prior to the first main plume of pollutants reaching Svalbard. The picture is taken from our laboratory room at the Zeppelin station, viewing due north towards Ny-Ålesund. The village can be seen by the waterfront. Figure 3 is taken on 2 May 2006 a few hours before the maximum values were observed. A webcam view from our laboratory room at the Zeppelin station is published at www.nilu.no/onlinebilder/zeppelin. Click on "Current view" to see the latest picture.

The difference in visibility between the two days is striking and was caused by farmers in Eastern Europe who burned their fields before the start of the new growing season. Springtime agricultural burning in Eastern Europe appears to be a yearly event, so what caused it to make such impact in 2006? Two factors seem to be key players. Firstly, the fires were lit later in 2006 than previous

Figure 3
Picture was taken on 2 May 2006 during the pollution event.
Photo: Ann-Christine Engvall.

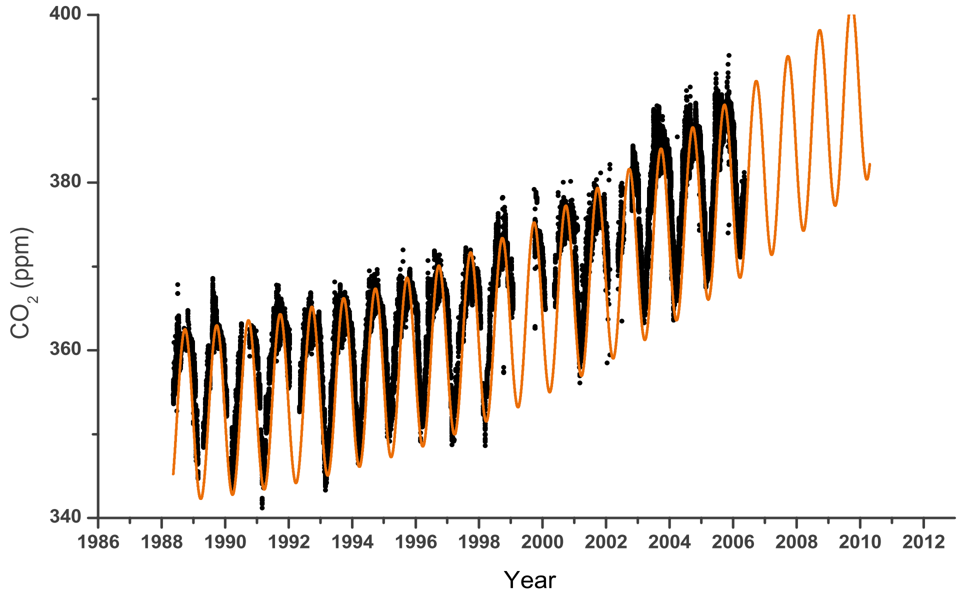


Figure 4
Carbon dioxide concentration observed at the Zeppelin station. The red line is a simple harmonic fit to data with a non-linear increasing trend.

years due to late melting of the snow in the area. Secondly, the European sector of the Arctic was very warm, as a matter of fact more than 10 degrees above average temperatures, which caused a reduced temperature contrast between the source region and the Arctic. These factors together pave the way for air from lower latitudes to quickly be transported into the Arctic.

With the warming of the Arctic it is possible that events such as this may be more frequent in the future. To emphasise the magnitude of the pollution, the estimated particle mass concentration for the day with the maximum concentrations during this event exceeded regulated values for urban environments. The fact that the impact of the pollution is visible, as in Figure 3, implies that it has a large climate impact regionally. The plume contained a large amount of soot (black particles) that results in a so-called heating rate of almost half a degree per day. This means that in this case the particles in the atmosphere are driving the temperature to increase just as the greenhouse gases do.

Egenskaper hos aerosolpartiklar i polarområdena och trender i koldioxidhalter: Långtidsövervakning och luftburna mätningar

Temperaturökningen går dubbelt så snabbt i Arktis jämfört med resten av världen. Resultatet är högst påtagligt i bl.a. minskad utbredning av glaciärer och ändrade is- och markförhållanden. Det kan finnas flera orsaker till en förändring i temperaturen, men sedan industrialismens början har mänskliga aktiviteter förändrat atmosfärens sammansättning genom utsläpp av partiklar och gaser, vilket i sin tur förskjutit Jordens energibalans mot en högre medeltemperatur. Målet med vår forskning är att studera dessa klimatpåverkande ämnen som genom direkta eller indirekta processer påverkar Jordens energibalans och därmed atmosfärens temperatur. Vi gör detta genom att studera långa tidsserier från Zeppelinstationen i Ny-Ålesund på Svalbard, samt genom att göra detaljerade rumsliga observationer från flygplan. Förutom att de långa tidsserierna är det enda sättet att studera nutida trender så skapar det ett ramverk för att sätta in kortare mätkampanjer i ett större sammanhang.

2006 var ett aktivt år inom projektet. Det var mycket förberedelser för dom flygburna mätningarna, med en integrations- och testflygkampanj i Bremerhaven i september och mätflygningar över Antarktis i december. Resultat från mätflygningarna, som utgick från baserna Neumayer och Syowa i Dronning Maud Land, rapporteras i årsboken för 2007. Vi gjorde fem besök under året till Zeppelinstationen på Svalbard. Återigen blev det rekordhöga halter av koldioxid som för närvarande ökar med mellan 2 och 3 ppm per år. Rekordhöga halter av i stort sett alla atmosfäriska ämnen som observeras uppmättes under våren då gaser och partiklar från bränder i östra Europa nådde Svalbard. Bränderna är en del av ett slags svedjebruk där bönder bränner gammal växtlighet inför den nya växtsäsongen. Episoden av föroreningar i slutet av april och början av maj var upphovet till mycket vetenskaplig aktivitet. En första vetenskaplig rapport om denna s.k. plym av föroreningar finns redan publicerad (www.copernicus.org/EGU/acp/acpd/6/9655/acpd-6-9655.htm). Fler rapporter är på gång och väntas bli klara i början av 2007.

Polarforskningssekretariatet är en statlig myndighet med uppgift att främja och samordna svensk polarforskning. Det innebär bl.a. att följa och planera forskning och utvecklingsarbete samt organisera och genomföra forskningsexpeditioner i Arktis och Antarktis.

Polarforskningssekretariatet är förvaltningsmyndighet för lagen (2006:924) om Antarktis och prövar frågor om tillstånd för vistelse eller verksamhet i enlighet med lagen.

The task of the Swedish Polar Research Secretariat is to promote and co-ordinate Swedish polar research. This means e.g. to follow and plan research and development and to organise and lead research expeditions to the Arctic and Antarctic regions.

The Swedish Polar Research Secretariat is the administrative authority for the Act on Antarctica (2006:924) and handles permit issues for visits or activities in accordance with the Act.

ISSN 1402-2613
ISBN 978-91-973879-6-5