and mid latitudes, with mean annual precipitation values of >1200 mm/yr as e.g. estimated for Axel Heiberg Island and Greenland (Greenwood et al., 2010; Eldrett et al., 2009). This resulted in high volumes of freshwater entering the Arctic Ocean and the Norwegian-Greenland Sea (Andreasson et al., 1996; Greenwood et al., 2010).

Apparently, Northern Hemisphere mid and high latitude conditions near the termination of a period known as the Early Eocene Climatic Optimum (EECO), were suitable for proliferation of two different *Azolla* species, one in the Arctic Ocean and one in the southern North Sea.

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Ocean drilling expedition to the Antarctic Margin: Reconstruct Antarctic Glaciation from Eocene-Oligocene inception to Holocene retreat.

Contribution by Peter K. Bijl

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Early this year the Integrated Ocean drilling program vessel JOIDES *Resolution* left the Wellington port and headed south. Destination: the Antarctic continental Margin. On board: ~60 personnel, ~30 ocean drillers and ~30 scientists. And I was fortunate to have been one of the latter.

The proposal to drill the Antarctic Margin was a classic example of “high risk-high gain”: drilling in a region that is completely ice-covered except for a month (plus or minus 2 weeks) in austral summer. This means that, from the start, the expedition’s success was completely tied to the weather conditions (Mother Nature was in charge). Because the drill-ship was not capable to operate in ice-conditions, the schedule was tightly bound to those few weeks of open water on the shelf. We sailed down south from Wellington with constant updates on the weather forecasts. On our journey down, we got a live flavour of how ‘roaring’ and ‘screaming’ the fourties and fifties really are. Near gale-force winds and 15 meters high waves made the journey quite bumpy.

What were we set out to do in such a harsh environment anyway? The entire expedition focussed on the history of Antarctic glaciation, from its inception somewhere around the boundary between the Eocene and Oligocene epochs (~35 million years ago) all the way up to the ice sheet's retreat during Holocene warmth. Little is known about the "history book" of the Antarctic glaciation. Particularly enigmatic still is the East Antarctic Ice sheet, which is supposed to have been a stable large block of ice, ignorant to the climate changes of the past 35 million years. This inference, however, is based on computer models simulating the ice sheet's behaviour, and is only poorly supported by field data. We sailed out for 2.5 months to drill sediments that have been eroded from the Antarctic continent and dumped along the Antarctic margin. These sediments contain a wealth of information, from surface water conditions fringing the Antarctic continent in microfossils, to weathering regimes and provenance of the ice rafted debris transported by icebergs. The results of the expedition ultimately may help improve our understanding of the dynamics of the East Antarctic ice sheet, whether it really was as invariable over the past 35 million years. Climate and ice sheet computer models may use the results from the expedition as boundary conditions to reconstruct past, and predict future climate change.

Figure 3.14: The Antarctic ice sheet, as seen from the drill ship, ~30 kilometres offshore

The drill ship was highly equipped for the task. Unfortunately however, she was not capable to withstand any large icebergs, so avoiding collision was crucial. However, with a kilometers long pipeline going down to the ocean floor, it is not possible to leave the spot directly when an iceberg approaches. Particularly during storms, a sea with many icebergs could be hazardous for the Resolution. Therefore, we had two men on board dedicated to safety related to ice and weather: one iceberg expert and one weather forecaster. Our "ice-man" monitored the icebergs visually, by radar and by satellite images. The weather forecaster updated us daily on the weather. When either iceberg coverage becomes too dense or a storm approaches, the drill string was pulled up and the ship moved to open sea. With these two experts we could very well adapt our schedule to the weather/ice conditions and they really were crucial in the success of the expedition.

Figure 3.15: Peter processing the samples on the ship: body protection was required with such hazardous chemicals.

And a success it was. Here's a fact sheet: the *Resolution* drilled 3,200 meters into the ocean floor, and recovered over 2,000 m of core (~60% recovery), divided over 7 sites. She drilled at great depth as well, 1,000 meters into the ocean floor at 4,000 meters water depth. She was also able to retrieve critical cores from close to the Antarctic continent, despite the small time widow to operate. Importantly, not only was the history of the Antarctic ice sheet drilled, deep drilling on one of the sites also revealed sediments from the Eocene Greenhouse world, when Antarctica was supposed to be largely ice-free.

My specific task on the ship was, as part of the micropaleontology team, to date the sediments that were retrieved from the ocean floor. You would wonder why this is necessary directly on the ship, and not back on shore. The reason is that during the expedition, the scientific coordinators (co-chiefs; in this case Carlota Escutia and Henk Brinkhuis) constantly evaluate whether the objectives of the cruise, as described in the drilling proposal, are met. During most expeditions, critical time periods are specified as objective, hence, a constant monitor of the stratigraphic position is needed while drilling. Only when it is absolutely sure that the target age is present in the cores retrieved, the site is abandoned. Hence, our task was to get ages for the cores as soon as possible, and we did that by analyzing the microfossil content in the cores. In the micropaleontology team, all members had their own expertise in different microfossils. As palynologists, my colleague and palynological "guru" Joerg Pross and I were responsible for the organic microfossils preserved in the cores, mainly dinoflagellate remains. Other micropaleontologists include diatomists, a foraminifer and a radiolarian expert. As drilling continued 24/7, the palaeontology team was needed 24/7 as well.

Figure 3.16: Bow of the drillship JOIDES *Resolution* on a sunny day. Temperatures were around freezing on such sunny days.

Figure 3.17: Peter Bijl and Henk Brinkhuis, posing in front of the JOIDES *Resolution* in the Wellington port, a few days prior to sailing south.

Figure 3.18: The JOIDES *Resolution* in the Wellington port, New Zealand.

Therefore, all scientists worked in 12 hour shifts. The days were really intense. Before a palynologist can analyze the organic microfossils, all inorganic content (sediment, carbonate) needs to be digested. We use strong acids (HCl, HF) to remove silica and carbonate, and this requires processing the samples in the laboratory. Working with hazardous chemicals on a moving ship for long days 7 days a week is a real challenge, but it is really exciting to be a part of a team and see a story evolving from retrieving cores on deck. Also, the teamwork at such an expedition, with everybody working 12 hours a day for 7 days a week really bonds, makes new friends and provides a base line for future collaborations.

When the ship sailed into the Hobart port mid-March I could not believe I had been on the ship for 2.5 months. With such hard work and such good fun time goes by so fast. After some well needed down time, we reconvened June this year in College Station, Texas to sample the cores that we retrieved during our expedition. All scientists have the obligation to work with the material retrieved (like someone would not want to work on such unique sediments!) for at least one year post-cruise. Everyone was really excited to work on the sediments, and produce results from these unique cores. My focus will be on the Eocene part of the succession, when Antarctica was largely ice-free, and climates were much warmer than today, globally. In a multi-disciplinary project, we will combine palynology (dinocysts, but also pollen and spores) and organic geochemical tools to reconstruct Eocene paleoclimate on the Antarctic Margin in high resolution. This project combines expertise from Glasgow University, Frankfurt University, Bremen University, Utrecht and the Royal NIOZ. Results are expected mid 2011.

Figure 3.19: Some of the micro-paleontologists looking at an interesting core, freshly retrieved from the Southern Ocean

Figure 3.20: The Captain and the first mate checking sea ice conditions...

For more information about the expedition:
iodp.tamu.edu/scienceops/expeditions/wilkes_land
Professional film clips made during the expedition:
www.youtube.com/oceanleadership
Peter Bijl blogged during his expedition to the Antarctic Margin: ***www.pooljaar.nl*** (in Dutch)
Henk Brinkhuis blogged and twittered during the expedition: ***www.kennislink.nl***