Report for ESF – Magellan program from the workshop

Workshop on Marine Research Drilling
Marine Impacts and Environmental Consequences

1. Summary

In September 2007 a workshop was organized in Longyearbyen, Svalbard (Norway) from September 10. to September 13, to discuss impact into marine targets and their environmental consequences and to prepare for the planned drilling of the 40-km in size Mjølnir impact structure in the Barents Sea (Figure 1). The workshop was attended by 32 scientists from 15 nations in addition to staff and students from UNIS (University Center in Svalbard).

The workshop focussed on two topics:
1) Mechanisms of marine impact cratering including ejecta formation and distribution, geothermal reactions and the formation of tsunami and
2) Environmental effects of marine impacts.

The goal was to relate and discuss such effects of the Mjølnir impact event to the geological evolution of the Arctic, as well as biological changes at the Boreal Jurassic/Cretaceous boundary. Presentations of the current knowledge of these topics formed the background for formulating concrete goals of a drilling project on the Mjølnir crater, and the establishment of a PI group and science teams. This information will form the core of a drilling proposal to be submitted jointly to IODP, ICDP and the Norwegian Research Council. The principal investigators (PI) are aiming at submitting the drilling proposals in the early spring 2009.

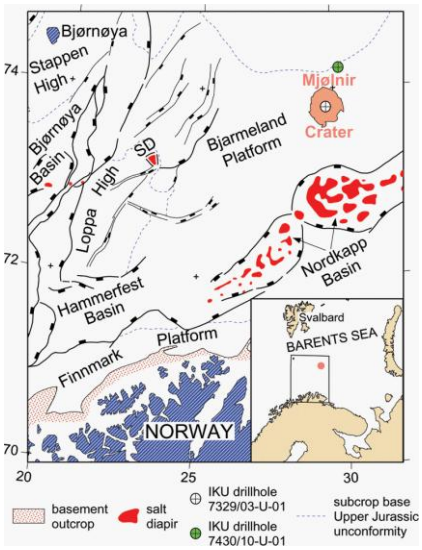

Figure 1. The Barents Sea with the location of the Mjølnir impact structure.

The principal investigators group has the following composition:

Henning Dypvik, University of Oslo, Norway
Philippe Claeys, Vrije Universiteit Brussel, Belgium
Alex Deutsch, University of Muenster, Germany
Frank T. Kyte, University of California, Los Angeles
Takafumi Matsui, University of Tokyo, Japan
Morten Smelror, Geological Survey of Norway, Trondheim.

The workshop was kindly supported by ICDP, ESF- The Magellan Program, Statoil, Norsk Hydro, UNIS (University Center in Svalbard), and the University of Oslo.

2. Event and discussion of scientific content

Scientific background

Asteroid and comet impacts are now recognized as important geological processes releasing vast amounts of energy and resulting in near instantaneous increase in temperature and pressure, structural deformation, and redistribution of target materials. Only within the last two decades it turned out that impacts, especially those in a marine environment, have a significant effect onto the geological evolution of the Earth. However, detailed knowledge of the geological and physical aspects and constraints of the marine impact process itself, as well as its environmental and biological consequences, is still limited. This is mainly due to the fact that only a few of the about 170 currently known terrestrial impact craters are well preserved. In addition, the number of identified ejecta layers is limited, and most ejecta deposits are in a rather incomplete state of preservation. Of the known Earth crater population, only 25 impact structures had a marine target, and very few of those are currently under water retaining chances of intact preservation. This is in great contrast to the very well preserved, still buried and not eroded, Mjølnir impact structure.

Hydrocarbon exploration has been going on in the Barents Sea for nearly 30 years. An extensive geophysical database exists and more than 60 wells have been drilled, particularly along basin margins and on structural highs. In addition, many shallow drill holes on sub-cropping sedimentary sequences have been drilled in the more central and remote areas of the Barents Sea. Based on this information the Mjølnir structure was discovered and its impact origin proven.

The Mjølnir structure is located on the Bjarmeland Platform in the central Barents Sea where water depth is approximately 350 m. The elevated parts of the structure (i.e., central peak) are covered by about 50 m of post-impact sediments. Due to this sedimentary cover, Mjølnir is considered to represent one of the best preserved impact craters on the Earth. The impact occurred about 142 mill. years ago into a sedimentary platform with 300-500 m paleo-water depth. At the time of impact, the platform comprised upper Paleozoic strata, mainly carbonates and evaporates, overlain by a 4-5 km thick succession of loose to gradually consolidated Mesozoic siliciclastic marine sediments. The time of impact event was close to the Boreal Jurassic-Cretaceous boundary (Volgian-Ryazanian boundary) and a thin, pristine ejecta layer has recently been found in a few localities (e.g. Janusfjellet mountain on Svalbard) around the structure.

The Mjølnir impact hit an anoxic to dysoxic sea-bottom, with a relatively thick succession of organic rich sediments covering larger parts of the shelf. Calculations have now show that organic matter equivalent to one years oil production of one Norwegian Shelf giant field burned during the 20 first minutes of the Mjølnir event!

Svalbard workshop
The workshop took place at the University Centre in Svalbard (UNIS), and focussed on the following topics:

(1) Review of the science behind the marine impact / Mjølnir project. The state of the art in geological and geophysical knowledge of the Arctic and at Mjølnir were presented by specialists of Arctic geology and members of the Mjølnir research group (Henning Dypvik, Roy Gabrielsen, Atle Mørk, Morten Smelror, Filippos Tsikalas).

(2) Review of petroleum exploration in the Barents Sea was given by representatives from the Norwegian Petroleum Directorate (NPD), Norsk Hydro and Statoil (Stein Erik Kristensen, Arild Ingebrigtsen, Robert Williams). Experts from ICDP/DOSECC/IODP presented their options for drilling the structure (Mike Coffin, Uli Harms, Dennis Nielson).

(3) Using this background information, scientific goals and drilling strategies were discussed in breakout groups (headed by Philippe Claeys, Roy H. Gabrielsen, Filippos Tsikalas). New information on available core material, geophysical characterization, models on ejecta generation and distribution will be collected for the final application. Based on the reports from the break-out groups, the final discussions concluded in defining scientific goals and the establishment of an international PI group.

(4) During an excursion to the site of Mjølnir ejecta at the mountain Janusfjellet in Isfjorden the workshop participants got an impression of the target rocks and the Mjølnir ejecta layer.

3. Results and future directions of the project

Drilling the Mjølnir structure is a project that fits the scientific goals of IODP, ICDP and the Norwegian Research Council (NFR). Deep wells in the Mjølnir impact structure would be of great interest for the international scientific community. However, due to large drilling costs in such harsh and difficult environments, and also considering the current pressure in the international drilling-market, it is presently regarded as unrealistic to raise the money needed for such large operations.

One of the great scientific advantages with the Mjølnir impact structure is the detailed correlation between the crater and the very well preserved ejecta found in shallow drillings of the Barents Sea and on land (the Arctic islands and Siberia). Because the crater and parts of the ejecta locations are buried and have remained under water since formation, those locations have been little affected by erosion. Moreover, the Barents Sea was dominated by gentle sea floor conditions, with restricted bottom-water circulation, during latest Jurassic time (i.e. a situation comparable to the present Black Sea). Hence, severe disturbances of those parts of the ejecta layer can be excluded. Because of this, Mjølnir is considered one of the few places on the Earth where the important crater – ejecta relation can be studied in detail. This is clearly of great importance for achieving a better understanding of the marine cratering

processes, and for studying environmental consequences of marine impacts. This kind of basic information of one of the fundamental processes on the Earth is still not known and can hardly be gained by studying other presently known marine craters of the Earth. Factors such as ejecta generation and distribution will be in focus, combined with investigations of the impact mechanisms and the event, and the consequences for the biotal evolution. Mjølnir's importance as a Boreal - Tethyan stratigraphic marker event will be discussed in order to aid correlations across the poorly understood Jurassic/Cretaceous boundary strata. The studies executed so far has also shown the importance of e.g. tsunami generation and formation, fires and soot distribution.

The development of the Mjølnir impact research and drilling program will be performed in close contact with the Norwegian authorities and the oil industry active in the Barents Sea. Already during the Svalbard workshop it turned out that the good relations with the oil industry is an invaluable asset for planning and conducting such an ambitious project in the rough waters of the Arctic. The majority of geophysical information, along with the available core and drilling material from the Barents Sea, has formed the base for the Mjølnir studies so far. This material was collected and put at our disposal by the active oil industry of the area. We expect this also to be the case in the future. In the drilling program we will need similar and updated information from the area and the active players in the field. It is in relation with the suggested drillings possible with some scientific, technical and financial support from the oil companies and the Norwegian Petroleum Directorate (NPD). The drilling program in the Barents Sea has to formally be approved by the NPD.

A two step drilling project was recommended, again to be performed in full cooperation with NPD, and the petroleum industry.

Step 1. Drilling of 5 to 6, up to 300 m deep core holes in 350 – 400 m water depth around the Mjølnir structure to map and understand ejecta formation and distribution, coupled with *in situ* disturbance of sediments due to seismic and shock waves, or erosion by displaced water near the crater. Analysis of the cored material will be accompanied by more sophisticated simulation models of the formation and deposition of ejecta in a marine environment.

Step 2. Drilling of one or two deep holes, riser demanding, within the central moat to understand the inner structure of a large crater. At this point, however, the cost of such a project appears exorbitant.

Figure 2. Most of the participants outside the UNIS building in Longyearbyen.

4. Final program and participants list

4a. Workshop program

Program "Marine Impacts and Environmental Consequences"

Monday September 10.
16:00 Meeting at UNIS
Henning Dypvik: Welcome. Introduction. 10 minutes.
Morten Smelror /Atle Mørk: Presentations of Svalbard and Barents Sea Geology. 30 minutes.
Henning Dypvik: The Mjølnir story. 20 minutes.
15 minute break.
Atle Mørk: Shallow drilling in the Barents Sea. 25 minutes.
Robert W. Williams/Bente Nyland: Norwegian petroleum activity in the Barents Sea, today and in
the future. 25 minutes.
Arild Johan Ingebrigtsen: Statoil activity in the Barents Sea, today and in the future. 25 minutes.
Stein-Erik Kristensen: Norsk Hydro activity in the Barents Sea, today and in the future. 25 minutes.
Posters at UNIS.

Tuesday September 11.:
09:00 Meeting at UNIS
Filippos Tsikalas: Mjølnir crater geophysics: impact-related structure and post-impact evolution. 30 minutes.
Natalia Artemieva: The Mjølnir impact mechanisms / modeling.20 minutes.
Atle Mørk/Morten Smelror: Impact target strata and the Jurassic / Cretaceous Boundary. 20 minutes.
15 minutes break.
Roy H. Gabrielsen: Post-impact structural history of the central peak of the Mjølnir structure.
15 minutes
Filippos Tsikalas: Previous proposed drill-sites and drilling objectives
10 minutes.
Stein-Erik Kristensen, Arild Johan Ingebrigtsen: Drilling for in the Barents Sea petroleum, technical considerations.
Dennis Nielson: DOSECC options.
Henning Dypvik, Uli Harms, Mike Coffin: How to organize the drilling program? 20 minutes.
12:00 – 13:00 Lunch .
13:10 – 14:10 Meeting at UNIS
Christian Koeberl: The Chesapeake Bay Drilling; project administration, drilling approach, and preliminary results. 20 minutes.
Frank Kyte: Impact deposits from the late Pliocene deep-ocean (5 km) asteroid impact. 20 min.
Jeff Plescia: Using Gravity Data to Define Impact Structures. 20 minutes.
14:10 **Break out group discussion**
1) Ejecta formation and distribution and drilling challenges

2) Crater structure, geophysics and impact mechanisms

15:30 15 minutes presentation by each breakout group leader; **Philippe Claeys, Roy H. Gabrielsen**

16:00 General discussion of potential drilling sites and themes for proposals.
Posters at UNIS.

Wednesday September 12.:

09:00 Meeting at UNIS.
Henning Dypvik, Philippe Claeys, Roy H. Gabrielsen
General discussion of potential drilling sites and themes for proposals, continue.

11:30 Fieldtrip with MS Langøysund to the Janusfjellet mountain.

Thursday September 13.:

09:00 Meeting at UNIS
Henning Dypvik
Selection of PIs and group leaders.
Closing remarks.

12:00 Lunch.

4b. Participants list

”Marine Impacts and Environmental Consequences“

Natalia Artemieva, Inst.Dynamics Geospheres, Russia
Penelope Jane Barton, Bullard Labs, Cambridge, UK
Alvar Braathen, UNIS, Norway
Philippe Claeys, Vrije Universiteit Brussel, Belgium
Mike Coffin, University of Tokyo, Japan
Alex Deutch, Westfaelische Wilhelms-Universitaet Muenster, Germany
David Anton Dinter, University of Utah, USA
Henning Dypvik, University of Oslo, Norway
Roy Gabrielsen, University of Oslo, Norway
Arild Johan Ingebrigtsen, Statoil ASA, Norway
Uli Harms, GeoForschungsZentrum, Potsdam, Germany
Lutz Hecht , Humboldt-Universität zu Berlin, Germany
J. Wright Horton Jr., U.S. Geological Survey, USA
Eckart Håkansson, Københavns Universitet, Denmark
Christian Koeberl, University of Vienna, Austria
Stein-Erik Kristensen, Norsk Hydro ASA, Norway
Frank T. Kyte, University of California, USA
Takafumi Matsui ,University of Tokyo, Japan
Mike Mazur, Norske Shell A/S, Norway
Suzanne McEnroe,Geological Survey of Norway, Norway
Atle Mørk, SINTEF Petroleum Research, Norway
Dennis L. Nielson, DOSECC, USA
Jens Ormø, Centro de Astrobiologia (INTA/CSIC), Spain
Lauri Pesonen, University of Helsinki, Finland
Jeff Plescia, Johns Hopkins University, USA
W. Uwe Reimold , Humboldt-Universität zu Berlin, Germany
Roman Skala, Czech Republic
Dechen Su, Chinese Academy of Geological Sciences, China
Filippos Tsikalas, University of Oslo / ENI Norge, Norway
Stephanie Werner, Geological Survey of Norway, Norway
Andrzej Wierzbowski , University of Warsaw, Poland
Robert W. Williams, Norwegian Petroleum Directorate, Norway

Report by Henning Dypvik
21/02/2008