

## AG-209

### The Tectonic and Sedimentary History of Svalbard

#### **Objective:**

To offer a thorough understanding of the geological evolution of Svalbard and the Barents Sea from the Precambrian to the Cenozoic, and to use sedimentary, structural and stratigraphic relationships to understand important geological principles.

#### **Content:**

In the Svalbard Archipelago there is a well developed and well exposed stratigraphic record that comprises Precambrian, Late Palaeozoic, Mesozoic, and Cenozoic strata. Based on the extensive research that has been carried out in the area, the course will offer students an understanding of the tectonic and sedimentary evolution of Svalbard and the Barents Sea from the Precambrian to the Cenozoic. Importance is attached to the understanding of the tectonic development and changes in the sedimentary environment over time. The geological evolution of Svalbard will be used to illustrate important geological subjects such as the formation of sedimentary basins, fold and thrust belts, hydrocarbon formation and sequence stratigraphy. The course will also give insight into coal mining, the mineral resources of Svalbard, and the hydrocarbon potential of the Barents Sea area. Fieldwork (mostly carried out from a ship) is an important part of the course, during which students will study examples of a large part of Svalbard's history and receive training in sedimentological, stratigraphic and structural field techniques. Data collected in the field will form the basis of an independent synthesis project to be completed during the semester. A literature project presented as a seminar will emphasize aspects of the sedimentology and stratigraphy of Svalbard.



**Course details:**

**Credits:** 15 ETCS

**Duration:** one semester (autumn 2008)

**Teaching:** 30 hrs lectures, 30 hrs practicals, 9-10 days cruise in conjunction with AG-210 (obligatory)

**Evaluation:** Written 3 hr exam (60 %), project work (40%)

**Responsible for the course:** Maria Jensen, UNIS ([maria.jensen@unis.no](mailto:maria.jensen@unis.no))

**Teachers:**

Maria Jensen  
Alvar Braathen  
Arvid Nøttvedt  
Jenő Nagy  
Roy Gabrielsen



**Course schedule autumn 2008:**

**WEEK 32: Introduction**

MON-TUES 4.& 5. AUG: Safety course

WED 6. AUG: 13-15: General introduction to AG-209, AG-210 and cruise (AH & MJ)

THU 7. AUG: 13-15: Introduction to “The tectonic and sedimentary history of Svalbard (MJ)

FRI 8. AUG: 9-10: Safety briefing AG-209/AG-210 (Logistics)

FRI 8. AUG: 13-15: Field methods (MJ)

SUN 10. AUG: 9-12: Overview of the stratigraphy of Svalbard (AN)

SUN 10. AUG: Departure for field excursion (12pm)

**WEEK 33: Field excursion**

**WEEK 34: Field excursion**



**WEEK 35: Field report**

**WEEK 36: Field report**

**WEEK 37: From coal to CO<sub>2</sub> storage (geology in the Longyearbyen area)**

WED 10. SEPT. 9-12: Presentations of field reports

WED 10. SEPT. 13-15: Exercise (MJ)

THU 11. SEPT. 13-15: Exercise (MJ)

FRI 12. SEPT. 8-17: Excursion (Carolinefjellet & Firkanten Fm)

**WEEK 38: From coal to CO<sub>2</sub> storage (geology in the Longyearbyen area)**

MON 15. SEPT. 13-15: Exercise (MJ)

TUE 16. SEPT. 13-15: Exercise (MJ)

WED 17. SEPT 13-15: Exercise (MJ)

**WEEK 39: Term project**

**WEEK 40: The stratigraphy of Svalbard (JN)**

TUE 30. SEPT. 13-15: Introduction to sequence stratigraphy: Accommodation space, parasequences, systems tracts, sequence types (JN)

WED 1. OCT 13-15: Biostratigraphy of transgressive/regressive sequences demonstrated by microfossil samples – Exercise (JN)

THU. 2. OCT. 13-15: Devonian: Alluvial fan to fluvial sedimentation, typical features of the three river systems (JN)

FRI 3. OCT. 13-15: Thin sections and hand specimens characterizing depositional conditions of Devonian and Carboniferous formations. Interpreting facies of Carboniferous parasequences – Exercise (JN)

### **WEEK 41: The stratigraphy of Svalbard (JN)**

TUE 7. OCT. 13-15: Carboniferous: Climatic and tectonic influence on alluvial, fluvial to evaporite sedimentation; Lateral facies changes in a rift basin (alluvial fans, evaporites, carbonates) (JN)

WED 8. OCT. 13-15: Thin sections and hand specimens characterizing depositional conditions of Permian formations. Interpreting sequences and parasequences of Carboniferous rift facies – Exercise (JN)

THU 9. OCT. 13-15: Permian: Shallow marine carbonate to deep marine silica-rich (chert) sedimentation; Triassic: Siliciclastic marine shelf to deltaic sedimentation, transgressive-regressive developments. (JN)

FRI 10. OCT. 13-15: Thin sections and hand specimens characterizing depositional conditions Triassic and Jurassic formations. Interpreting sequences and parasequences from Mesozoic shelf and deltaic facies – Exercise (JN)

### **WEEK 42: The stratigraphy of Svalbard (JN)**

MON 13. OCT. 13-15: Jurassic: Hypoxic (organic-rich) marine shelf to prodelta, sedimentation; Cretaceous: fluviodeltaic sedimentation with transgressive/regressive developments.

TUE 14. OCT. 13-15: Organic facies analysis of Jurassic and Cretaceous hypoxic (organic-rich) to prodelta shals based on kerogen preparations - Exercise

WED 15. OCT. 13-15: Tertiary: Basin development and sedimentation showing in marine shelf to delta environments; Response of sedimentation to strike/slip movements during opening of the North Atlantic

THU 16. OCT. 13-15: Repetition of curriculum: Main features of Devonian to Tertiary basin Developments in Svalbard.

### **WEEK 43: Term project**

### **WEEK 44: Regional tectonic history (AB)**

MON 27. OCT 13-15: Lecture (AB)

TUE 28. OCT 13-15: Lecture (AB)

WED 29. OCT 13-15: Lecture (AB)

THU 30 OCT 13-15: Exercise (AB)

**WEEK 45: The Barents Sea shelf and petroleum system (RG)**

MON 3. NOV. 13-15: Lecture (RG)

TUE 4. NOV 13-15: Lecture (RG)

WED 5. NOV. 13-15: Lecture (RG)

THU 6. NOV. 13-15: Exercise (RG)

**WEEK 46: Written presentation of term projects**

MON 10. NOV: Deliver written report

**WEEK 47: Oral presentation of term projects**

TUE 18. NOV. 8-17: Seminar (oral presentation of term projects)

WED 19. NOV. 8-17: Seminar (oral presentation of term projects)

**WEEK 50: Exam**

MON. 8. DEC: 3 hours written exam



## **Reading list**

All lecture-related handouts are relevant for the course, so are handouts from Seminars and Exercises.

The reading for the course is divided into literature that is regarded as required reading, and papers that are recommended. There is also a list of papers and books of relevance to the course.

### **Required reading:**

Bergh, S.G., Braathen, A. & Andresen, A., 1997, Interaction of basement-involved and thin-skinned tectonism in the Tertiary fold-and-thrust belt, central Spitsbergen, Svalbard: American Association of Petroleum Geologist Bulletin 81 (4), p. 637-661.

Dypvik, H., Nagy, J., Eikeland, T.A., Backer-Owe, K., & Johansen, H. 1991. Depositional conditions of the Bathonian to Hauterivian Janusfjellet Subgroup, Spitsbergen. *Sedimentary Geology* 72, 55-78.

Gabrielsen, R.H., Færseth, R.B., Jensen, L.N., Kalheim, J.E. & Riis, F., 1990: Structural elements of the Norwegian Continental Shelf. Part I: The Barents Sea Region. Norwegian Petroleum Directorate, Bulletin, 6, 33pp.

Gabrielsen, R.H., Grunnaleite, I. & Rasmussen, E., 1997: Cretaceous and Tertiary inversion in the Bjørnøyrenna Fault Complex, south-western Barents Sea. *Marine and Petroleum Geology*, 14(2), 165-178.

Gabrielsen, R.H., Steel, R.J. & Nøttvedt, A., 1995: Subtle traps in extensional terranes: A model with reference to the North Sea. *Petroleum Geoscience*, 1, 223-235.

Gjelberg J. & Steel R.J. 1981. An outline of Lower-Middle Carboniferous sedimentation on Svalbard. Effects of tectonic, climatic and sea level changes in rift basin sequences. In Kerr J.W. (ed.): *Geology of the North Atlantic Borderlands*, 543-561. Canadian Society of Petroleum Geologists Memoir 7.

Gjelberg J. & Steel R.J. 1995. Helvetiafjellet Formation (Barremian - Aptian), Spitsbergen: characteristics of a transgressive succession. In Steel et al. (eds.). *Sequence stratigraphy on the Northwest European Margin*, NPF Special Publication 5, 571- 593, Elsevier, Amsterdam.

Helland-Hansen, W., 1990, Sedimentation in a Paleogene foreland basin, Spitsbergen. *Bull. Am Assoc. Pet. Geol.*, 74 (3), p. 260-272.

Johannessen, E.P. & Steel, R.J. 1992: Mid-Carboniferous extension and rift-sequence in the Billefjorden Trough, Svalbard. *Norsk Geologisk Tidsskrift* 72, 35-48.

Kjærnet, T., 2006. Svalbard's mineral resources. Unpublished compendium, UNIS.

- Lønne, I., 2001. Devonian in Svalbard. Unpublished compendium, UNIS.
- Lønne, I., and Stenvold, J., 2001. Coal-bearing strata and coal exploration in Svalbard. Unpublished compendium, UNIS.
- McCann, A.J. & Dallmann, W.K., 1995, Reactivation history of the long-lived Billefjorden Fault Zone in north central Spitsbergen, Svalbard: *Geological Magazine* 133, p. 63-84.
- Plink-Bjorklund, P, Mellere D, Steel R.J., 2001. Turbidite variability and architecture of sand-prone, deep-water slopes: Eocene clinofolds in the Central Basin, Spitsbergen. *JOURNAL OF SEDIMENTARY RESEARCH* 71 (6): 895-912.
- Maher, H.D., Craddock, C., and Maher, K., 1986, Kinematics of Tertiary structures in upper Paleozoic and Mesozoic strata on Midterhuken, west Spitsbergen. *Geological Society of America Bulletin*, v. 97, p. 1411-1421.
- Mørk A., Knarud R. & Worsley D. 1982. Depositional and diagenetic environments of the Triassic and Lower Jurassic succession of Svalbard. In Embry A.F. & Balkwill H.R. (eds.): *Arctic Geology and Geophysics*. Canadian Society of Petroleum Geologists Memoir 5, 371-398.
- Nøttvedt, A., Cecci, M., and Gjelberg, et al., 1992. Svalbard-Barents Sea correlation – a short review. *NPF special Publications* 2, Elsevier, 363-375.
- Steel, R.J. & Worsley, D. 1984. Svalbards post-Caledonian strata - an atlas of sedimentological patterns and paleogeographic evolution. In Spencer A.M. (ed.): *Petroleum geology of the North European Margin*, 109-135. Norwegian Petroleum Society, Graham and Trotman.
- Steel R.J., Gjelberg J., Helland-Hansen W., Kleinspehn K., Nottvedt A. & Rye-Larsen M. 1985. The Tertiary strike-slip basins and orogenic belt of Spitsbergen. In Biddle K.T. & Christie-Blick N. (eds.): *Strike-Slip Deformation Basin Formation and Sedimentation*, 339-359. Society of Economic Paleontologists and Mineralogists Special Publication 37, Tulsa.
- University of Georgia Stratigraphy Lab. 2005. An online guide to sequence stratigraphy. <http://www.ugo.edu/~strata/sequence/seqStrat.html>. 24 p.

**Additional recommended reading:**

- Braathen, A., Bergh, S.G. & Maher, H.D. 1995, Structural outline of a Tertiary basement-cored uplift/inversion structure in western Spitsbergen, Svalbard: *Kinematics and controlling factors: Tectonics*, 14, p. 95-119.
- Gabrielsen, R.H., Færseth, R.B., Jensen, L.N., Kalheim, J.E., & Riis, F., 1990. Structural elements of the Norwegian continental shelf: Part I – The Barents Sea Region. *NPD Bulletin* 6, 33 pp + plates.

- Gabrielsen, R.H. & Møller-Holst, J., 1997: The influence of present and future development in information technology on the Exploration and Production phase model. *Petroleum Geoscience*, 3(3), 193-202.
- Haremo, P., Andresen, A., & Dypvik, H. 1993. Mesozoic extension versus Tertiary compression along the Billefjorden Fault Zone south of Isfjorden, central Spitsbergen. *Geological Magazine* 130, 783-795.
- Lamar, D.I., Reed, W.E., and Douglass, D.N., 1986, Billefjorden fault Zone, Spitsbergen: Is it part of a major Late Devonian transform? *Geological Society of America Bulletin*, v. 97, p. 1083-1088.
- Maher, H.D. and Welbon, A.I., 1992. Influence of a Carboniferous basin margin on Tertiary tectonism at St. Jonsfjorden and Bellsund, Western Svalbard, Nor. *Geol. Tidsskr.*, 72, 67-75.
- Mellere D, Plink-Bjorklund P, Steel R., 2002. Anatomy of shelf deltas at the edge of a prograding Eocene shelf margin, Spitsbergen. *SEDIMENTOLOGY* 49 (6): 1181-1206.
- Nøttvedt, A., Livbjerg, F., Midbø, P.S. & Rasmussen, E., 1992, Hydrocarbon potential of the Central Spitsbergen Basin: Norwegian Petroleum Society Special Publication, 2, p. 333-361.
- Muller, R.D., and Spielhagen, R.F., 1990. Evolution of the Central Tertiary Basin of Spitsbergen: towards a synthesis of sediment and plate tectonic history. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 80, 153-172.
- Nagy, J., 2005. Delta-influenced foraminifera facies and sequence stratigraphy of Paleocene deposits on Spitsbergen. *Palaeogeography, Palaeoclimatology, Palaeoceanography* 222, 161-179.
- Nemec, W., 1992. Depositional control on plant growth and peat accumulation in a braidplain delta environment: Helvetiafjell Formation (Barremian-Aptian), Svalbard. *Geological Society of America Special Paper* 267, 209-226.
- Plink-Bjorklund P, Steel R., 2002. Sea-level fall below the shelf edge, without basin-floor fans. *GEOLOGY* 30 (2): 115-118.
- Plink-Bjorklund P., 2005. Stacked fluvial and tide-dominated estuarine deposits in high-frequency (fourth-order) sequences of the Eocene Central Basin, Spitsbergen. *SEDIMENTOLOGY* 52 (2): 391-428.
- Steel, R.J., Gjelberg, J. & Haarr, G. 1978. Helvetiafjellet Formation (Barremian) at Festningen, Spitsbergen - a field guide. *Norsk Polarinstitutt Årbok* 1997, 111-128.
- Wennberg, O.P., A. Andresen, S. Hansen, and S.G. Bergh, 1994, Structural evolution of a frontal ramp section of the West Spitsbergen Tertiary fold-and-thrust belt, north of Isfjorden, Spitsbergen, *Geol. Mag.* 131, 67-80.

## Useful papers and books:

- Braathen, A. & Bergh, S.G. 1995, Kinematics of Tertiary deformation in the basement-involved fold-thrust belt, western Nordenskiöld Land, Svalbard; Tectonic implications based on fault slip data analysis: *Tectonophysics*, 249, p. 1-29.
- Dallmann, W.K., A.Andresen, S.G.Bergh, H.D.Maher & Y.Ohta, 1993, Tertiary fold-and-thrust belt of Spitsbergen, Svalbard: *Meddelelse 128*, 46 pp., Norsk Polarinstitut, Oslo.
- Dallmann, W.K.,1989, The nature of the Precambrian-Tertiary boundary at Renardodden, bellsund, Svalbard: *Polar Research* 7, p. 139-145.
- Dallmann, W.K. 1999. Lithostratigraphic Lexicon of Svalbard. Upper Palaeozoic to Quaternary bedrock. Review and recommendations for nomenclature use. Norsk Polarinstitut, Tromsø, Norway.
- Harland, W.B. 1997. The Geology of Svalbard. Geological Society Memoir 17, The Geological Society, London.
- Haremo, P., Andresen, A., Dypvik, H., Nagy, J., Elverhøi, A., Eikeland, T.A., and Johansen, H., 1990, Structural development along the Billefjorden Fault Zone in the area between Kjellstrømdalen and Adventdalen/ Sassendalen, central Spitsbergen. *Polar Research*, v. 8, p. 195-216.
- Haremo, P., and A. Andresen, Tertiary decollement thrusting and inversion structures along Billefjorden and Lomfjorden Fault Zones, East Central Spitsbergen, in *Structural and Tectonic Modelling and Its Application to Petroleum Geology*, edited by R.M. Larsen, H. Brekke, B.T. Larsen and E. Talleraas, Spec. Publ., 1, pp. 481-491, Nor. Pet. Soc., Oslo, 1992.
- Maher, H.D.Jr., Bergh, S.G., Braathen, A. & Ohta, Y., 1997, Svartfjell, Eidembukta, and Daumannsodden Lineament - Decoupled orogen-parallel motion in the crystallin hinterland of Spitsbergen's fold-thrust belt: *Tectonics* 16, p. 88-106.
- Maher, H.D.Jr., Braathen, A., Bergh, S.G., Dallmann, W., & Harland, W.B. 1995, Tertiary or Cretaceous age for Spitsbergen's fold-thrust belt on the Barents Shelf: *Tectonics*, 14, 1321-1326.
- Orvin, A.K., 1940, Outline of the geological history of Spitsbergen, *Skrifter Svalbard Ishavet*, v. 78, p. 1-57.
- Welbon, A.I. and H.D. Maher, 1992, Tertiary tectonism and basin inversion of the St. Jonsfjorden region, Svalbard, *J. Struct. Geol.*, 14, 41-55.
- Worsley, D. & Aga, O.J. 1986. The Geological History of Svalbard. Statoil, Harstad.