PRELIMINARY CURRICULUM – GEOV272 – AUTUMN 2014

(1) Lectures
(2) Exercises
(3) E-learning modules (see" Knowledge resources" below)

Knowledge resources for the seismic Interpretation course GEO272

The course uses the pedagogic principle of problem-based learning (PBL). This means that the students are themselves responsible for acquiring the necessary knowledge to fulfill the requirements set forward in the learning goals for the course and each case. Although the course supervisor will recommend reading to the students, the students must make sure that they have acquired the necessary knowledge. If in doubt, they should discuss this with the course supervisor.

E-LEARNING MODULES

The following e-learning modules give access to most of (but not all) the knowledge required in the course. Not everything in each module is relevant for the course and the students should avoid trying to go through everything in detail as this is far too extensive. Instead, they should focus on relevant parts necessary to fulfill the requirements set forward in the learning goals. Modules of specific interest are highlighted with bold title. Some of the modules have been updated and published in learningGEOSCIENCE (www.learninggeoscience.net). If this is the case, the students should use the modules from this site. These modules require only Flash plugin and can be viewed from any computer with a broadband connection to the Internet. There is also a requirement that each student evaluates the relevant modules published in learningGEOSCIENCE. The other modules are available from the course administration software. These require PowerPoint in order to view them properly.

1. **[IPT-SIG4024-M] Seismic Key Examples (Required) - Found separately**

Author(s): Egil Tjåland
Producer(s): Camilla Hagelund
Abstract: The module presents the basic geophysical needed to understand acquisition of marine multichannel seismic data.
The module provides key 2D seismic lines from different structural and stratigraphic settings around the world.
Key words: Seismic data, seismic interpretation, tectonics, structural geology

2. **[UiB-GFJ210-L3-M] Geophysical Principles (Required – overview) – Found on www.learninggeoscience.net**

Author(s): Rolf Mjelde
Producer(s): Ståle Solbakken, Sølve M. Skogland
Abstract: The module presents the basic geophysical needed to understand acquisition of marine multichannel seismic data.
Key words: Seismic acquisition, multichannel data, reflection seismic data

3. **[UiB-GFJ210-L3-M] Seismic Equipment (Required – overview) – Found on www.learninggeoscience.net**

Author(s): Rolf Mjelde
Producer(s): Ståle Solbakken, Sølve M. Skogland
Abstract: Describe how the most important equipment used in marine multichannel seismic data acquisition work.
Key words: Seismic equipment, acquistion

4. **[UiB-GFJ210-L3-M] Seismic Recording (Required – overview)– Found on www.learninggeoscience.net**

Author(s): Rolf Mjelde
Producer(s): Ståle Solbakken, Sølve M. Skogland
Abstract: The module describes the most important aspects in recording of marine multichannel seismic data acquisition.
Key words: seismic, recording, acquisition

5. **[UiB-GFJ210-L3-M] Processing (Required – overview) – Found on www.learninggeoscience.net**

Author(s): Rolf Mjelde
Producer(s): Ståle Solbakken, Sølve M. Skogland
Abstract: The module describes the most important aspects in processing of marine multichannel seismic data.
Key words: seismic, processing, multichannel data

6. **[IPT-SIG4024-M] Seismic Stratigraphy (Required) - Found separately**

Author(s): Egil Tjåland
Producer(s): Camilla Hagelund
Abstract: Recognition, mapping and interpretation of unconformities, seismic sequences and depositional sequences.
Key words: Seismic sequences, depositional sequence, unconformities, seismic facies

7. [IPT-Svalex-M] Seismic Modelling (Optional) – **Found on www.learninggeoscience.net**

Author(s): Ståle Johansen
Producer(s): Tone Berit Ørnskar and Camilla Hagelund
Abstract: The purpose of the module is to show how Synthetic Seismics can be used to improve Seismic Modelling. Also included in the learning objectives: To understant the principles and differences in Traditional Finite and Difference Finite Synthetic Seismics. To see how these different Synthetic Seismics are compareble to real seismics
Key words: Seismic modelling, synthetic seismic data

8. **[UiB-GFJ213-L3-M] Gullfaks (Required – brief overview)**

Author(s): Jonny Hesthammer
Producer(s): Petter S. Nielsen and Richard Kluge
Abstract: Gives a basic introduction to the Gullfaks Field (stratigraphy, production and structural geology).
Key words: Gullfaks, structural geology, stratigraphy

9. [UiB-GFJ213-L3-M] Closing the Gap (Optional) – **Found on www.learninggeoscience.net**

Author(s): Jonny Hesthammer
Producer(s): Petter S. Nielsen and Richard Kluge
Abstract: The ability to map small-scale faults from seismic surveys depends upon resolution, noise content and acquisition/processing procedure. In addition, the geoscientist must possess a sound understanding of plausible geometries consistent with analyses of well data. The comparison of two seismic datasets from the Gullveig structure, northern North Sea, demonstrates that the lateral resolution of the data is strongly dependent on the signal-to-noise ratio. By combining a theoretical approach with statistics from well analyses, exemplified by data from the Gullfaks Field, it is possible to enhance our understanding of the limits of fault resolution on 3D seismic data.
Key words: seismic resolution, theoretical and practical resolution, Gullfaks and Gullveig

10. [UiB-GFJ213-L3-M] Seismic Attribute Analysis (Optional) **– Found on www.learninggeoscience.net**
Author(s): Jonny Hesthammer
Producer(s): Richard Kluge and Petter S. Nielsen
Abstract: Seismic attribute maps provide a useful tool in interpreting faults particularly those close to or below seismic resolution. Dip, relief, azimuth, and amplitude maps are most useful. One of the challenges is to distinguish between anomalies related to real geological features and to seismic noise: -both of which may occur as linear or curvi-linear, continous features on the attribute maps. This challenge is solved by use of independent data as core data, dipmeter data, stratigraphic log correlation and forward modelling.
Key words: timedip map, azimuth map, amplitude map, relief map, Gullfaks

11. [UiB-GFJ213-M] Seismic data vs bore hole data (Optional) **– Found on www.learninggeoscience.net**
Author(s): Jonny Hesthammer
Producer(s): Katherine K. Gausland
Abstract: Seismic data can be integrated with well data (core data, dipmeter data) to provide an integrated analysis of the structural geology of an area. Such intergration should be carried out whenever possible.
Key words: Gullfaks, integration, well data, seismic data

12. **[UiB-GFJ213-L3-M] Use & Abuse of seismic data (Required – overview) – Found on www.learninggeoscience.net**
Author(s): Jonny Hesthammer
Producer(s): Richard Kluge and Petter S. Nielsen
Abstract: The article shows with examples from the Gullveig and Gullfaks Field how seismic data can be misinterpreted due to the presence of noise and how well data can provide information needed to distinguish real features from noise.
Key words: Seismic data, noise, Gullfaks

13. [UiB-GFJ213-L3-M] Improving Seismic Data (Optional) **– Found on www.learninggeoscience.net**
Author(s): Jonny Hesthammer
Producer(s): Richard Kluge and Petter S. Nielsen
Abstract: Seismic data can be improved after final processing by applying simple techniques. One method is to combine several seismic surveys. In addition, the data set can commonly be further improved by applying dip filters and frequency filters. This requires a thorough understanding of the geology of the area. By combining and filtering seismic surveys from the Gullfaks Field, northern North Sea, an enhanced seismic interpretation could be carried out.
Key words: Gullfaks, combining, filtering, improving

14. [UiB-GFJ213-M] Combining Seismic Data (Optional) **– Found on www.learninggeoscience.net**
Author(s): Jonny Hesthammer
Producer(s): Katherine K. Gausland
Abstract: The learning experience discusses how it is possible to enhance seismic data quality (increase the signal to noise ratio) for structural interpretation by combining several seismic surveys. Such surveys are commonly available due to the focus on 4D seismic.
Key words: Gullfaks, combining seismic data, seismic surveys

15. [UiB-GFJ213-L3-M] Evaluation of the Timedip, Correlation and Coherence maps (Optional) **– Found on www.learninggeoscience.net**

Author(s): Jonny Hesthammer
Producer(s): Petter S. Nielsen and Richard Kluge
Abstract: Investigation of the timedip, correlation and coherence attribute maps from the Gullfaks Field demonstrates that in areas of poor data quality, the timedip map is best for structural interpretation. Although the coherence map can be developed without having any seismic interpretation, the method will reveal numerous (curvi-)linear features that may be misinterpreted as faults unless quality controlled against well data. Control against well data shows that it is very easy to overinterpret the seismic data based on surface and volume attributes.
Key words: seismic attribute maps, Gullfaks, timedip

TEXT BOOKS

There is no need to buy any books for the students. Relevant reading material will be made available during the course. The following text books give access to the knowledge required in the course. However, the students should avoid trying to read everything as this is far too extensive. Instead, they should focus on relevant parts necessary to fulfill the requirements set forward in the learning goals. The books are listed in recommended order.

1. **Hart, B., 2000: 3-D Seismic interpretation: A primer for geologists. SEPM Short Course No. 48., Tulsa.** This excellent short and concise (thus highly recommended) book contains the basics needed in order to understand the concepts of seismic interpretation. The students will be able to fulfill most requirements set forward in the learning goals by reading this book. However, for further reading, the students are encouraged to indulge in the books listed below. The book can be ordered from www.sepm.org. The book is available in digital format from one of the computers in the PBL-room.

2. **Brown, A.R., 1999: Interpretation of three-dimensional seismic data. AAPG Mem. 42, Oklahoma.** The book contains some very good chapters relevant for the seismic interpreter and it is recommended that the students scan the content for relevant knowledge. The book is available in digital format from one of the computers in the PBL-room and the students can click on the link and from the index choose the chapters they want to read. Relevant chapters are:
   Ch. 1: The whole chapter, p. 1-26
   Ch. 2: Assessment of zero-phaseness
   Ch. 3: Look trough the whole chapter. Required reading is Interpretation procedures and Advantages and disadvantages of different displays.
   Ch. 8: Classification of attributes
   Ch. 10: The whole chapter on Depth conversion (not depth imaging), p. 421-434
   Appendix A: The whole chapter, p. 489-494

3. **Sheriff, R.E., and Geldart, L.P., 1999: Exploration Seismology. Cambridge University Press, Cambridge.** This book is a must for the geophysicist. But the book also contain much relevant information for the general seismic interpreter. However, the book is very extensive and only minor parts need to be read for this course (and is only recommended, but strongly so for those with little background in geophysics). Relevant chapters are:

Ch. 2.4.1: P-waves and S-waves, p. 44-46
Ch. 2.7: Effects of the medium on wave propagation, p. 57-63
Ch. 3.2: Partitioning at normal incident, p. 76-77
Ch. 3.3: Partitioning at non-normal incident, p. 77-78
Ch. 5.1: Model of a sedimentary rock, p. 107-113
Ch. 5.2: Experimental data on velocity, 113-122
Ch. 5.3.4: Abnormal-pressure detection, 126-128
Ch. 5.3.5: Gas-hydrate effects, p. 128
Ch. 5.4.1: Velocity terminology, p. 128-130
Ch. 6.2: Reflections, p. 146-159
Ch. 6.3.2: Multiples, p. 161-169
Ch. 6.4: Resolution, p. 172-177
Ch. 6.7: Noise, p. 183-185
Ch. 9.12.1: Procesesses to repository data – introduction, p. 326-327
Ch. 9.12.2: Kirchoff migration, p. 327-329
Ch. 9.14, Processing, p. 341
Ch. 10.2: Interpretation procedures, p. 353-364
Ch. 10.4.4: Synthetic seismograms, p. 392
Ch. 10.8: Hydrocarbon indicators, p. 415-418
Ch. 13.7.2: Sonic waveform logging, p. 500

4. **Weimer, P., and Davis, T.L., 1999: Applications of 3-D Seismic Data to Exploration and Production. AAPG Studies in Geology, No. 42. SEG Geophysical Developments Series, No. 5.** The book may be of interest to flip through but it is not necessary for the student to know the content in order to take the course. The book is available in digital format from one of the computers in the PBL-room.

ARTICLES

Articles are considered only as recommended reading and the students should be careful about what they read from each article. Many of the articles have a corresponding e-learning module that the student should go through instead of the more complicated article. Several of the articles are available in digital format from the course administration software. Use articles if there is a need for very specific knowledge not found elsewhere.

Fossen, H. and Hesthammer, J.
1998: "Structural geology of the Gullfaks Field, northern North Sea"; in Coward, M.P., Johnson, H. and Daltaban, T.S. (eds.) "Structural geology in reservoir characterization". Geological. Society of London, Special Publications, **127**, 231-261.
The article gives an introduction to the Gullfaks area which also contains Gullveig, the field that is used in the three cases in the course.

Gabrielsen, R.H.
1986: "Structural elements in graben systems and their influence on hydrocarbon trap types"; in Spencer, A.M. et al. (eds.) "Habitat of hydrocarbons on the Norwegian Continental Shelf". Norwegian Petroleum Society, Graham and Trotman, London, 55-60.
The article explains the main structural style of the Viking Graben, including the Tampen area which is the focus of the three cases in the course.

Gabrielsen, R.H., Færseth, R.B., Steel, R.J., Idil, S., and Kløvjan, O.S.
1990: "Architectural styles of basin fill in the northern Viking Graben"; in Blundell, D.J. and Gibbs, A.D. (eds.) "Tectonic evolution of the North Sea rifts". Oxford, Clarendon Press, 158-179.
The article gives an overview of the architecture of the area relevant for the three cases in the course.

Hesthammer, J.
1998; "Evaluation of the timedip, correlation and coherence maps for structural interpretation of seismic data"; *First Break, **16**, 151-167.*
Seismic attribute maps have gained much focus over the last few years. As a result, the number of attribute maps that can be generated is increasing rapidly. However, not all attribute maps provide new information. The important thing is to realize that attribute maps can not reveal what is not in the data prior to attribute processing, but new artifacts may appear!

Hesthammer, J.
1999; "Improving seismic data for detailed structural interpretation"; *The Leading Edge, **18**, 226-247.*
This article explains how simple combination and filtering techniques carried out on the work station can improve seismic quality for structural interpretation.

Hesthammer, J., and Fossen, H.
1997: "Seismic attribute analysis in structural interpretation of the Gullfaks Field, northern North Sea"; *Petroleum Geoscience **3**, 13-26.*
The article introduces the reader to the most useful seismic attribute maps for structural interpretation on a reservoir scale. The focus is on the timedip, relief, azimuth and amplitude maps.

Hesthammer, J., and Fossen, H.
1997: "The influence of noise in structural interpretation of seismic data"; *First Break **15**, 209-215.*
All seismic data contain abundant noise. The noise interferes with real data and the interpreter is faced with the challenge of separating real features from noise.

Hesthammer, J., and Løkkebø, S.M.
1997: "Combining seismic surveys to improve data quality"; *First Break **15**, 103-115.*
This article provides an in-depth explanation to some basic techniques for combining data from different seismic surveys.

Hesthammer, J., and Fossen, H.
in print: "From seismic to core data; an integrated approach to enhance reservoir characterisation"; *in Ameen, M. (ed.) Fracture & In-Situ Stress Characterization of Hydrocarbon Reservoirs, Geol. Soc. Spec. Publ.*
In this article, the authors show how different types of data can be integrated in order to obtain a fuller understanding of the characteristics of an area. Seismic data should always be quality controlled against well data whenever possible.

Hesthammer, J., Landrø, M., and Fossen, H.
2001: "Use and abuse of seismic data"; *Marine and Petroleum Geology.*

Seismic data are commonly misused and misinterpreted. There are many potential traps to be aware of. This is the focus of the present article.

Hesthammer, J., and Henden, J.O.
2000: "Closing the gap between theory and practice in seismic interpretation of small-scale faults"; *Petroleum Geoscience*, **6**, 107-111.
There are many misconceptions regarding seismic resolution. It is also important to be aware of the differences between theoretical and practical seismic resolution.

Simm, R., and White, R.
2002: "Phase, polarity and the interpreter's wavelet"; *First Break*, **20**, 277-281.
Every interpreter should know about phase and polarity of seismic data. However, this is not necessarily an easy task. This article gives an introduction to the concept and uncertainties related to the topic and is necessary reading for all seismic interpreters.

Tollefsen, S., Graue, E., and Svinddal, S.
1994: "Gullfaks development provides challenges"; *World Oil*, **94**, 45-54.
The article gives an introduction to the field development plans for the Gullfaks Field.

Vollset, J., and Doré, A.G.
1984: "A revised Triassic and Jurassic lithostragraphic nomenclature for the Norwegian North Sea"; in Norwegian Petroleum Directorate, 53.
This article provides the basics for understanding the stratigraphy of the North Sea. However, the students will also find much of this information in some of the other articles listed above.

WEB LINKS

The following web-links give access to information that can be relevant for the course. Use the links to obtain knowledge about specific problems. Do not try to go through everything found on the web pages. Some web-sites may be outdated.

1. **Introduction to Gullfaks**

   (This link is from the Gullfaks PBL project at the University of Trondheim and gives a brief introduction to the Gullfaks Field. For more information, the students are encouraged to look at some of the learning modules and articles.)

2. **The Tampen area**

   (This link is from one of Norsk Hydro's web pages and gives a brief introduction to the Tampen area.)

3. **The Gulf of Mexico**

   (Understanding seismic interpretation demands more than knowledge about seismic data from the North Sea. The following link gives an introduction to seismic data from the Gulf of Mexico.)

4. **How to tie wells to seismic – 1**

(Tying wells are crucial in order to understand the seismic data and what phase and polarity to interpret. The link provides crucial information related to this aspect.)

5. **How to tie wells to seismic – 2**

(The link provides information similar to the link "How to tie wells to seismic – 1". I.e.: Tying wells are crucial in order to understand the seismic data and what phase and polarity to interpret. The link provides crucial information related to this aspect.)

6. **About GeoGraphix**

(GeoGraphix is Landmark's software for seismic interpretation – and many other things – on a PC. The link provides information on the software. This course may use GeoGraphix for work tasks such as seismic attribute analysis.)

7. **About Acoustic Impedance**

(In order to interpret seismic data, it is crucial to know what signal to interpret and what the signal represents with respect to real geology. This is closely related to acoustic impedance – a topic all seismic interpreters must be familiar with.)

8. **Overview of seismic interpretation**

(Performing seismic interpretation can be very complex and the students should be familiar with basic work processes such as those provided in this link.)

9. **Geophysical glossary**

(Geologists are commonly unfamiliar with geophysical terms. This link provides explanation related to geophysical terms.)

10. **Seismic interpretation with Kingdom Suite**

(Similar to GeoGraphix, Kingdom Suite is a PC-based seismic interpretation software and the students can find information about the software on the following link.)

11. **Seismic wave theory**

(Nobody should try to interpret seismic data without being familiar with the most basic aspects of seismic wave theory.)

12. **Seismic stratigraphy and synthetic seismics**

(Seismic stratigraphy and synthetic seismic are two important aspects of seismic interpretation. The first is familiar among exploration geoscientists, whereas most geologists are unfamiliar with the second aspect. That is a pity!)

13. **Teaching seismic interpretation**

(This link may be more important for the teacher – but here the students can evaluate the quality of the course provided....)

14. **Synthetic seismograms**

(Although not commonly focused on, seismic interpreters MUST be familiar with the basics of synthetic seismograms. Information is provided in the following link.)