DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2008/62

Conventional Core Analysis Data from 10 Danish Onshore Wells

Wells Børglum-1, Fjerritslev-2, Frederikshavn-2, Gassum-1, Haldager-1, Horsens-1, Mors-1, Rødby-1, Skagen-2, Vedsted-1

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Contents

1. Introduction

Cores from 10 Danish onshore wells were analysed by conventional core analysis methods at Geological Survey of Denmark (DGU) during the period 1979 to 1981, mainly as part of a project investigating the potential for geothermal energy. Some of the results were used as background data in Michelsen et al (1981). The analytical data were transferred to an electronic database, POPE, at GEUS in 1983, but were never published. Today (September 2008), the original electronic data are not accessible as the electronic database, POPE, does no longer exist. However, the original paper sheets with analytical data remains in the archive of GEUS Core Laboratory.

Some time ago DONG Energy A/S requested GEUS Core Laboratory to collect, review, and tabulate the original core analysis data from the 10 Danish onshore wells. Though the work was entirely financed by DONG Energy, they have recently released the data for publication, which takes place with the present report.

DONG Energy A/S is acknowledged for financing the work that made a significant amount of core analysis data available in electronic form, and for releasing the data for publication.

2. Scope of work

The following wells have been processed:
- Børglum-1 drilled 1951 by DAPCO
- Fjerritslev-2 drilled 1958 by DAPCO
- Frederikshavn-2 drilled 1952 by DAPCO
- Gassum-1 drilled 1948 to 1951 by DAPCO
- Haldager-1 drilled 1950 by DAPCO
- Horsens-1 drilled 1958 by DAPCO
- Mors-1 drilled 1966-1967 by DUC
- Rødby-1 drilled 1952 by DAPCO
- Skagen-2 drilled 1951 by DAPCO
- Vedsted-1 drilled 1958 by DAPCO

The original core analysis work on the wells comprised:
- Gas permeability
- Porosity
- Determination of grain size, sorting and consolidation
- Lithological description

In connection with the recent data processing several tasks were performed:
- Reformatting the original core analysis data produced at the former DGU during the period 1979-1983.
- Compiling the data in Excel files.
- Control of data against the original analytical paper sheets.
- Quality control from available information, including replicate analyses.
- Description of analytical methods as far as possible.
- Evaluation of analytical uncertainty as far as possible.

In connection with the present work all the analytical data sheets on paper from the period 1979 to 1981 have been reviewed. Some of the electronic data resides now in GEUS's WinPOPE database that is the successor of POPE. However, WinPOPE cannot perform the processing necessary to convert the analytical data to permeability and porosity values. Therefore, all the electronic data have been transferred to Excel files where the necessary processing has been done. Additionally, a few analyses that were never entered in the electronic database have been added to the Excel files. The data transfer from paper sheets to the POPE database that took place in 1983 has been verified. An attempt has been made to assess the quality of the measurements, mainly by reviewing all replicate analyses. The replicate analyses are used to determine the reproducibility of the porosity and permeability determinations. However, no analyses of standards with known permeability and porosity are available, so the accuracy of the determinations is unknown.

New core analyses have not been performed as part of the present work.

The result of the work is 10 Excel files, one for each well, with tabulated analytical data. The Excel files and a file with the present report are included on the attached CD.

3. Instrumentation and Analytical Methods

This section describes the methods used in the core analysis work performed on the relevant wells during the period 1979 to 1981.

Most of the core analysis work was performed on plug samples with a diameter of 18 to 19 mm and a length of 15 to 30 mm. The samples used at GEUS today are significantly larger, with diameter either 25 mm or 38 mm, and length from 30 to 75 mm. The last batch of analyses to be performed in 1981 on the Gassum-1 well, i.e. the "Gassum-1 C measurements" were, however, performed on samples with a diameter of 25 mm and a length of approximately 25 mm.

The plug samples were cleaned and dried before measurement, but the cleaning method and temperature of drying is not documented.

Most of the gas permeability analyses were performed on a Ruska Gas Permeameter, probably Ruska model 1011-801. The instrument does not exist at GEUS any more. The instrument measured the flow with three ball flowmeters covering three different flow ranges. The total permeability range was from approximately 2 mD to 6000 mD. A sample was placed in a thick sleeve of soft rubber and placed in a sample cup. Confining pressure on the sample was produced by a handwheel pressing the sample and sleeve into the slightly conical sample cup. An upstream pressure between 0.25 and 1.0 atmosphere was applied, while the back pressure on the sample was the ambient atmospheric pressure. The reading of the flowmeter that best matched the flow was recorded. The flowmeter reading was a flow in arbitrary units that was originally converted to flow rate by a calibration chart. The three calibration charts for the flowmeters are no longer available and the present work therefore relies on the flow conversion performed during the original analytical work. Fortunately, for most measurements both a manual conversion and an electronic conversion performed by POPE are available, which increases the confidence in the flow conversion. Graphs of flow versus flowmeter reading have been made for all wells, which confirm the existence of a strict relationship between flow and flowmeter reading.

A few gas permeability analyses on Gassum-1 plugs (some of the "C measurements") with very high permeability were performed with a soap film flowmeter. In this analysis the gas flow from the core holder is passed through a calibrated burette and the movement of a soap film is determined with a stop watch. This method is superior to the Ruska permeameter for measuring high flow rates. The relevant measurements are flagged "Soap film flowmeter" in the Gassum-1 Excel file.

Børglum-1, Gassum-1, Haldager-1, and Vedsted-1 all contain samples with reported gas permeability values above 4000 mD. These high-permeability samples were very fragile and the accuracy of the results may have deteriorated. In the case of the soap film flowmeter measurements of Gassum-1 with permeabilities up to 4754 mD, the results are considered relatively accurate. In the case of Gassum-1 "A measurements" and measurements from Børglum-1, Haldager-1 and Vedsted-1, permeability values above 4000 mD are probably connected with increased uncertainty. In particular some permeability results in Børglum-1 ranging up to 12400 mD are dubious. Because these

samples undoubtedly had very high permeability they have been included in the listing, but are marked "Poor perm accuracy".

All porosity determinations were performed with a Ruska mercury porosimeter, probably Ruska model 1053, using the Kobe method (Beeson, 1950). Sample bulk volume was determined by a mercury pycnometer. The instruments do not exist at GEUS any more. In general this technique for porosity determination is quite accurate.

Grain size and grain sorting were determined by visual comparison with standard charts. Consolidation was estimated using a four level scale. Lithology was described by a geologist with standard geological terms. Grain size, grain sorting, consolidation and lithology were not characterized for all plugs.

4. Results

For each well the Excel file presents:

1. A sheet using the well name as identification giving the main results, i.e. plug id., depth, plug orientation, gas permeability, porosity, grain size, grain sorting, consolidation and lithology.
2. A sheet with a graph showing gas permeability, porosity grain size, sorting and consolidation versus depth.
3. A sheet with a graph showing gas permeability versus porosity.
4. A sheet with a graph showing gas permeability versus grain size.
5. A sheet showing details of the gas permeability determinations, including replicate analyses.
6. A sheet showing details of the porosity determinations, including replicate analyses.

Table 4.1 gives a summary of the number of plugs and analyses for the 10 wells.

The permeability measurements covered by the present work are generally of a quality inferior to present day standard. The gas permeability was measured on plug samples that were smaller than present day standard at GEUS, cf. the Section Instrumentation and Analytical Methods, resulting in inferior precision and higher risk of leakage along the rubber sleeve. Also, the instrumentation, i.e. the Ruska Permeameter, is considered

Table 4.1 Summary of analytical statistics.

		Permeability analyses			Porosity analyses		
	No. of samples	No. of samples	No. of replicate analyses	Average std.dev. for repl. analyses (%)	No. of samples	No. of replicate analyses	Average std.dev. for repl. analyses (por.units)
Børglum-1	74	65	21	12	72	13	1.02
Fjerritslev-2	6	5	2	18	5	2	0.03
Frederikshavn-2	29	18	5	14	29	2	0.29
Gassum-1 "A"	81	81	39	24	0	0	n.a.
Gassum-1 "B"	194	160	70	6.9	172	16	0.50
Gassum-1 "C"	70	51	40	4.5	57	0	n.a.
Haldager-1	70	55	29	12	65	6	0.75
Horsens-1	7	7	3	51	7	4	0.40
Mors-1	86	86	5	48	86	5	0.23
Rødby-1	38	28	6	31	28	3	0.35
Skagen-2	11	11	3	4.7	9	2	0.30
Vedsted-1	45	44	11	11	45	9	0.42
Total sample no.	711	611	234		575	62	
Average for 10 wells				20			0.43

inferior to present day standard. One measure of the quality of the permeability determinations is the reproducibility of replicate analyses, which is given in Table 4.1 as the average relative standard deviation for replicate analyses. It is seen that the reproducibility varies from 5 % to 50 % with most wells in the range 10 to 30 %. The values cover a spread with many replicate analyses better than 10 % and a few samples with spread above 40 %. However, please notice that the wells with many analyses in general have good reproducibility compared to the wells with few analyses. The mean reproducibility for all 10 wells is 20 %.

The porosity measurements are generally also of relatively poor quality but quite variable, cf. Table 4.1. The Ruska porosimeter is capable of measuring with good precision. It is estimated that a considerable part of the uncertainty associated with the porosity determinations is caused by samples loosing material between the porosity determination and the associated bulk volume determination. The mean reproducibility for all 10 wells is 0.43 porosity units.

Part of the relatively poor reproducibility for both permeability and porosity is due the replicate measurements being made on separate parts of a plug sample. The stated reproducibility therefore includes an amount of lithological variation.

The core analysis work on Gassum-1 was conducted during a period of more than 2 years, and the analytical methods were slightly improved during this period. Therefore, the Gassum-1 measurements are organize in three categories named "A measurements", "B measurements" and "C measurements" with "A measurements" being the first and "C measurements" being the last to be performed. The "A measurements" were some of the first petrophysical measurements to be performed in GEUS Core Laboratory. The three categories reflects 1) larger sample size for the "C measurements", 2) better documentation for the "B measurements" and "C measurements" and therefore better quality control in the present work, and 3) probably an improvement in general analytical quality from "A measurements" to "C measurements". The categories are reflected in the sample identification by subscripts "A", "B" and "C", and separate listings for each category are found in the Excel file Gassum-1 as well as a listing with all three categories.

5. References

Beeson, C.M. 1950. The Kobe Porosimeter and the Oilwell Research Porosimeter. *Petroleum Transactions of AIME, vol. **189**, p. 313-318.*

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