Facies analysis and diagenetic evolution of the Dinantian carbonates in the Dutch subsurface: data and analyses well S02-02

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Facies analysis and diagenetic evolution of the Dinantian carbonates in the Dutch subsurface: data and analyses well S02-02

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12. S02-02

12.1 Introduction

The S02-02 well was drilled in the offshore of the south west Netherlands in 1983 to a depth of 2878 m TD (Figure 12-1 and Table 12-1). The well, drilled for hydrocarbon exploration, was dry. The target of the well was the Lower Carboniferous Zeeland Formation.
The location of the drilling has been interpreted as a carbonate anomaly as a reef close to a palaeoshelf edge on the north side of the London-Brabant Massif. The anomaly was thought to have been caused by a carbonate bank of unknown origin (Figure 12-2).

Figure 12-1: Map showing all the wells penetrating the Dinantian carbonates. Location of the S02-02 well is indicated by a dashed red circle.

Table 12-1: Table summarising the coordinates of the S02-02 well (from www.nlog.nl).

Co-ordinates (x, y in utm31, ed50 format)	541942, 5745321
Lat/Long (°)	51º51’21.743N / 03º36’32.27E
Supplied co-ordinates	
Depth in meters referred to :	Rotary Table
Water depth m	21.9
Total depth (m, along hole) :	2878
Vertical position of Rotary Table :	36 meter relative to sea level
Trajectory shape :	Vertical, max inclination 3.9º
Deviation in X-direction :	
Deviation in Y-direction :	
True vertical depth (TVD) in m :	2878

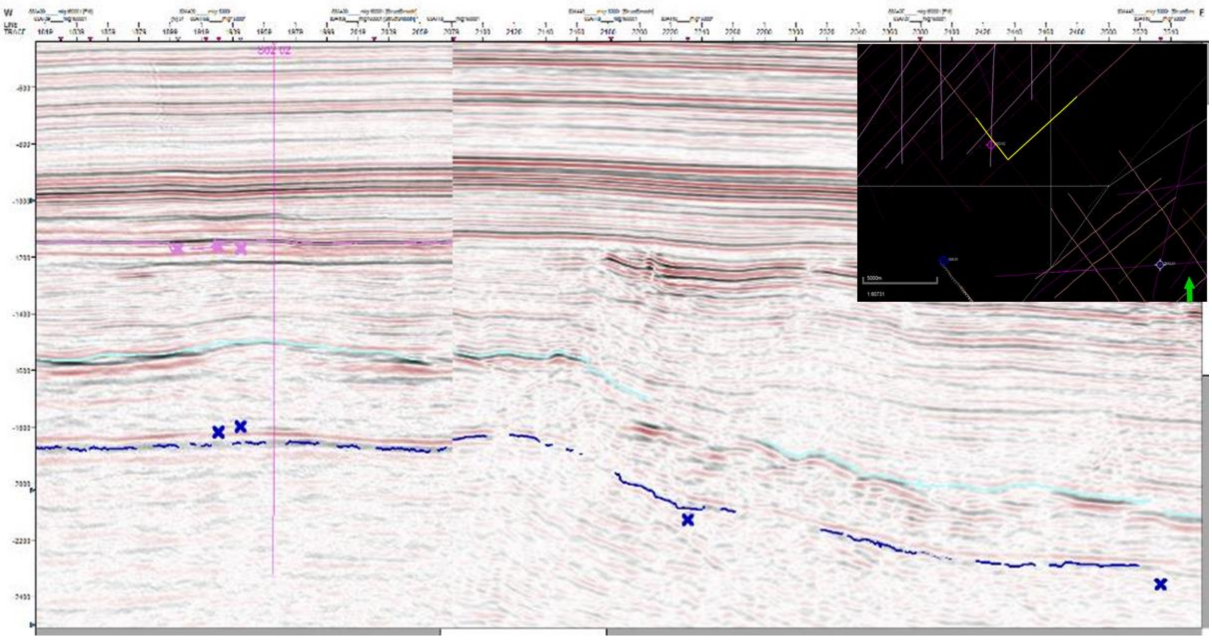

Figure 12-2: Composite seismic line crossing the S02-2 well.

12.2 Available dataset

Most of the available data and reports on the S02-2 well are available on “www.nlog.nl” within the following link:

https://www.nlog.nl/nlog/requestData/nlogp/allBor/metaData.jsp?tableName=BorLocation&id=106526656

The most relevant publications discussing and presenting the data obtained from S02-02 well are as following:

Bamborough, D. W. (1983). Mobil Producing Netherlands Inc. End Of Well Report Well: S/2-2, Offshore Netherlands. Hughes. AH Velsen Noord.

Carlson, T. (2019). Petrophysical Report of the Dinantian Carbonates in the Dutch Subsurface. SCAN Report, April 2019, 26 p. Report downloadable from www.nlog.nl/scan.

Dronkers, A. J., Graves, W., and Standing, D. W. (1984). S/2-2 Final Geological Report. Mobil Producing Netherlands Inc.

Edelman, D. W. (1984). Visual kerogen analysis vitrinite reflectance and hydrocarbon source-bed evaluation mobil block S/2-2 Netherlands North Sea. Mobil Report. Houston.

Graves, W. (1984). Mobil producing netherlands, inc., photomicrograph report well MOBIL S/2-2. Mallorca.

Pickard, N. A. H., and Gutteridge, P. (1997). Dinantian depositional systems and exploration potential: offshore and onshore, The Netherlands. Sedimentological study.

Reijmer, J. J. G., Ten Veen, J. H., Jaarsma, B., and Boots, R. (2017). Seismic stratigraphy of Dinantian carbonates in the southern Netherlands and northern Belgium. Geologie En Mijnbouw/Netherlands Journal of Geosciences, 96(4), 353-379. https://doi.org/10.1017/njg.2017.33

Somerville, I. D., and Strogen, P. (1992) Ramp sedimentation in the Dinantian limestones of the Shannon Trough, Co. Limerick, Ireland. Sedimentary Geology, 79, p. 59-75.

TNO (2003). Toelichting bij kaartbladen Xl en Xll Middelburg-Breskens en Roosendaal-Terneuzen. Geologische Atlas van de Diepe Ondergrond van Nederland.

12.2.1 Logs

This well has a complete suite of logs (Figure 12-3) and has been petrophysically evaluated within the scope of the SCAN project (Carlson, 2019).

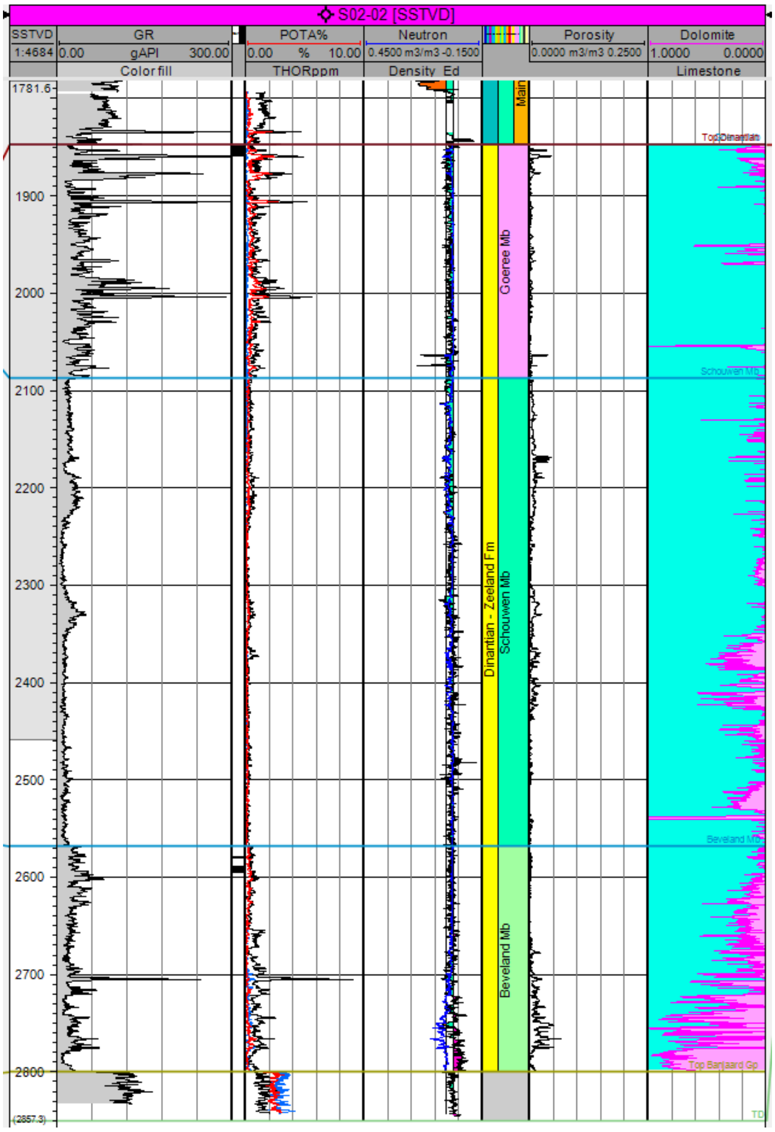

Figure 12-3: Gamma ray, neutron/density, porosity and mineralogical logs in the S02-02 well.

12.2.2 Cores, sidewall cores and cuttings

Cores 1 and 2: These two cores consist of thickly bedded mainly clast-supported limestone breccio-conglomerate with pebble to cobble-sized sub-rounded clasts; an interval of matrix-supported breccia with sub-angular to angular clasts is also present. Clasts include stromatolitic boundstone and wackestone with fenestrate bryozoans and stromatactoid cavities lined by marine fibrous cement and sub-angular granule- to pebble-sized clasts of friable green and brown siliciclastic mudstone are present in the matrix-supported breccia. The matrix of the breccia consists of bioclastic grainstone, dark mudstone and pale carbonate mudstone in the matrix-supported breccia.

Some clasts contain cavities lined by vadose cement and layered interval sediment suggesting that the clasts have undergone karstic dissolution during exposure; the attitude of the sediment infill and the direction of vadose pending suggests that some have been subsequently rotated. The breccio-conglomerate is interpreted as a combination of cave infill and collapse. The clasts suite and the matrix suggests that the original facies included carbonate mud mounds and bioclastic grainstone deposited in a shelf margin setting. The matrix includes contemporaneous marine sediment and dark siliciclastic mudstone. This is interpreted as a karst infill or collapse (Figures 12-4 and 12-5).

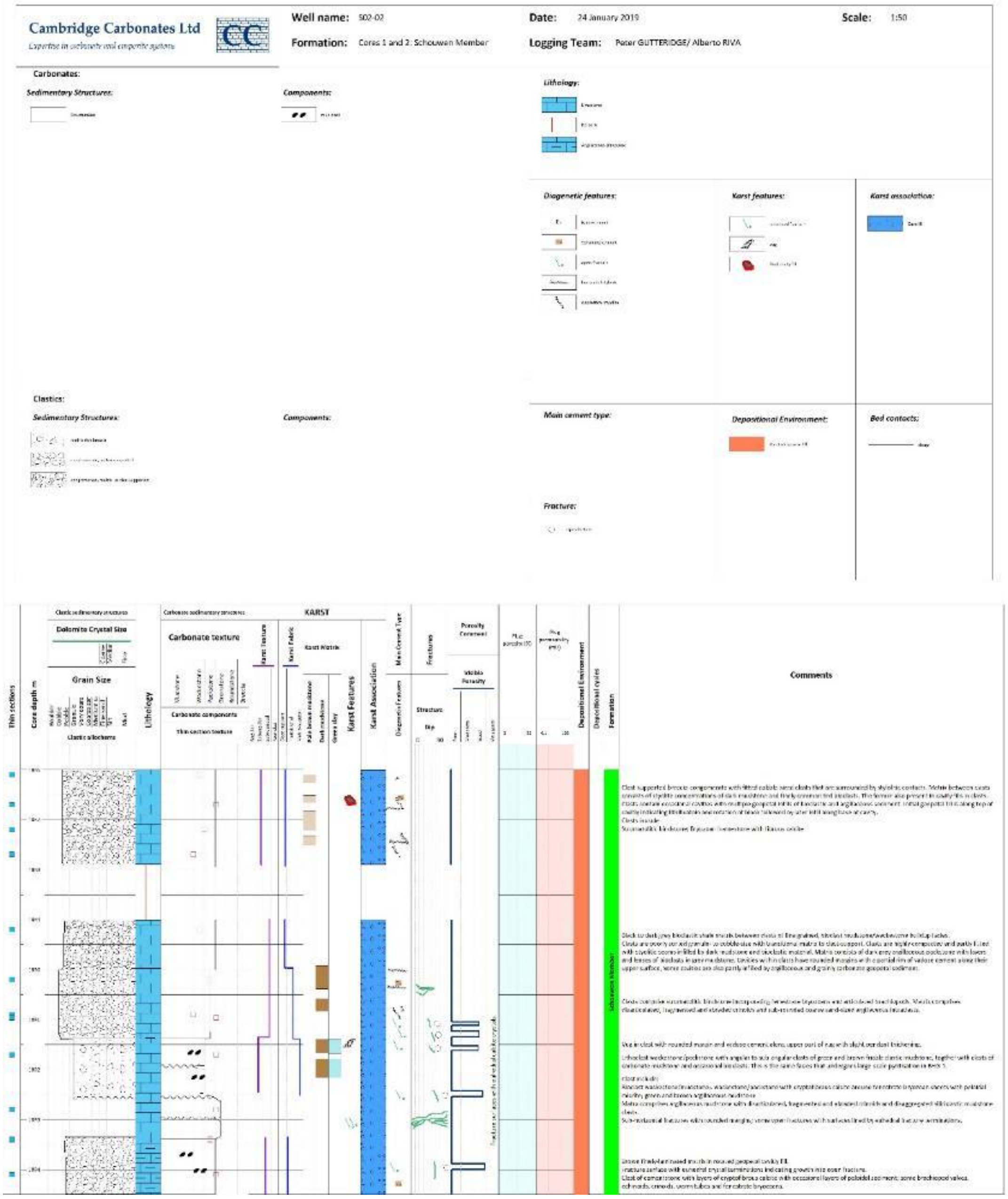

Figure 12-4: Overview of the sedimentological log constructed for Cores 1 and 2, well S02-02 (an image of higher resolution is available in Appendix B as a supplementary document).

Figure 12-5: Left) Matrix-supported breccia with clasts of reefal carbonate in argillaceous matrix (1891.2 m). Right) Matrix-supported breccia with clasts of friable brown and green mudstone (1891.6 m).

Cores 3 and 4: These cores consist of shallowing-upwards cycles of bioturbated bioclast oncoid wackestone /packstone deposited in a shallow subtidal setting close to normal wave base. Cycle tops comprise fenestral peritidal carbonate mudstone and wackestone with hard grounds that are sometimes overhanging and may represent intertidal microkarst. Some cycle tops show pedogenic features. The basal part of the overlying subtidal cycle consists of intraclasts of reworked hardgrounds. This core represents the HST of the 1c (orange) depositional cycle (Figure 12-6).

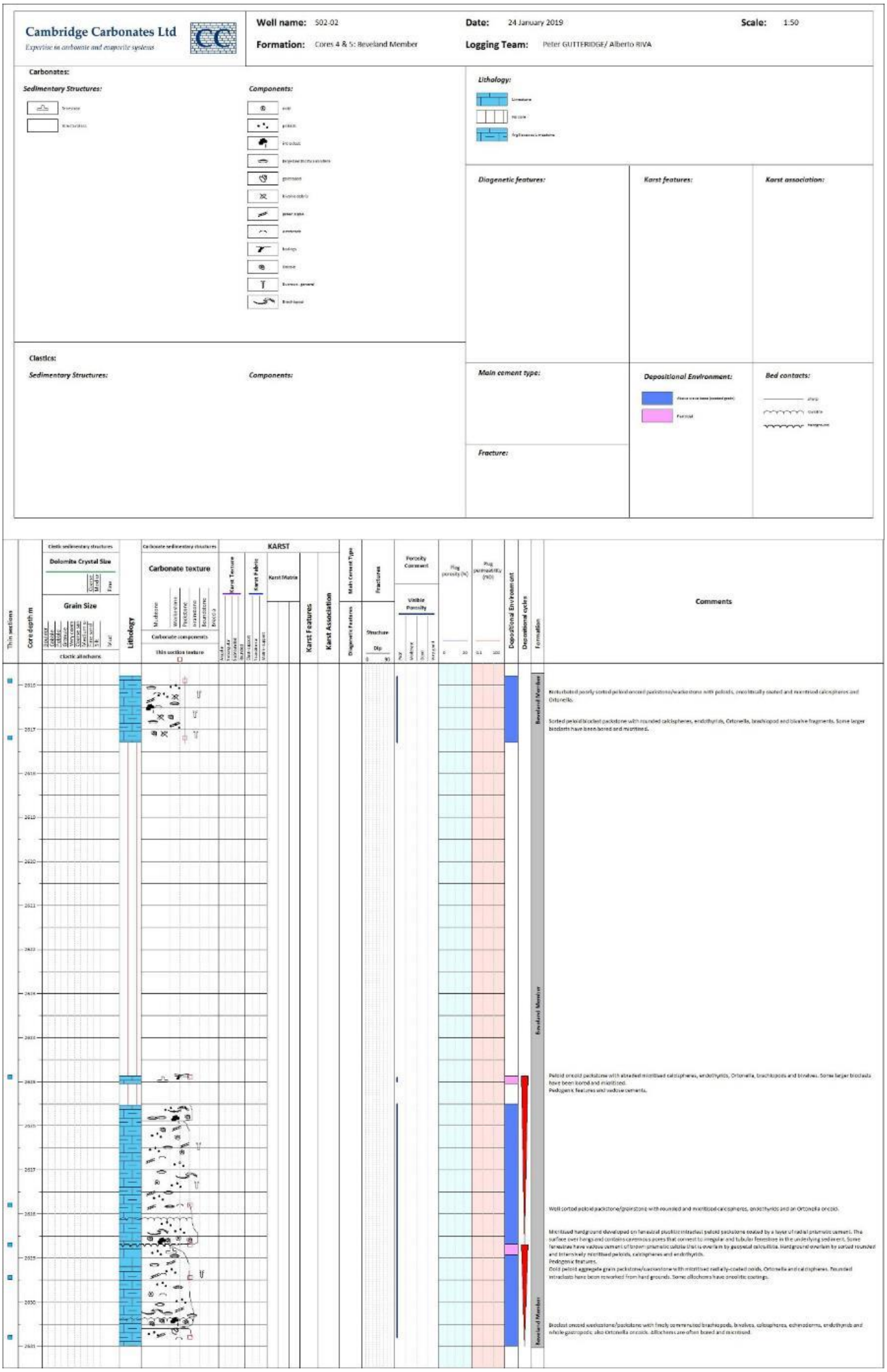

Figure 12-6: Overview of the sedimentological log constructed for Cores 3 and 4, well S02-02 (an image of higher resolution is available in Appendix B as a supplementary document).

12.2.3 Petrography and additional analyses

Although photomicrographs of selected thin sections were available in Pickard and Gutteridge (1997) report, the thin sections not available for further evaluation in this study. Therefore no additional petrographic or diagenetic work has been undertaken. The Vitrinite reflectance measurements are given from TNO reports (Table 12-2).

Table 12-2: Vitrinite reflectance measurements for S02-02.

Depth (MD)	Type of Measurement	%R	Source
1375	Vitrinite reflectance (random, mean) - %Rr	0.71	TNO-NITG
1515	Vitrinite reflectance (random, mean) - %Rr	1.04	TNO-NITG
1810	Vitrinite reflectance (random, mean) - %Rr	1.68	TNO-NITG
1850	Vitrinite reflectance (random, mean) - %Rr	2.04	TNO-NITG
2735	Vitrinite reflectance (random, mean) - %Rr	1.96	TNO-NITG
480	Vitrinite reflectance - %Ro	0.78	
880	Vitrinite reflectance - %Ro	0.77	
980	Vitrinite reflectance - %Ro	0.78	
1180	Vitrinite reflectance - %Ro	0.90	
1280	Vitrinite reflectance - %Ro	0.89	
1380	Vitrinite reflectance - %Ro	0.79	
1480	Vitrinite reflectance - %Ro	0.90	
1580	Vitrinite reflectance - %Ro	0.93	
1600	Vitrinite reflectance - %Ro	1.05	
1780	Vitrinite reflectance - %Ro	1.19	
2180	Vitrinite reflectance - %Ro	1.59	
2380	Vitrinite reflectance - %Ro	1.62	
2580	Vitrinite reflectance - %Ro	1.67	
2615	Vitrinite reflectance - %Ro	2.07	
2624	Vitrinite reflectance - %Ro	2.09	
2627	Vitrinite reflectance - %Ro	1.90	
2680	Vitrinite reflectance - %Ro	1.92	

12.3 Stratigraphy

The succession of the S02-02 well spans from Quaternary to the Devonian (Table 12-3), encountering the Cretaceous unconformity at depth of 1336 m MD, over the Namurian and the Dinantian at depth of 1883 m MD.

Table 12-3: Stratigraphy of the S02-02 well (from www.nlog.nl).

Stratigraphic unit	Top interval	Base interval
Upper North Sea Gp.	0	257
Rupel Clay Mb.	257	358
Vessem Mb.	358	409
Asse Mb.	409	518
Brussels Sand Mb.	518	560
Ieper Mb.	560	842
Basal Dongen Sand Mb.	842	874
Landen Clay Mb.	874	932
Ommelanden Fm.	932	1336
Ruurlo Fm.	1336	1510
Baarlo Fm.	1510	1609
Ubachsberg Mb.	1609	1717
Epen Fm.	1717	1883
Schouwen Mb.	1883	2604
Beveland Mb.	2604	2835
Bollen claystone Fm.	2835	2878

12.3.1 Dinantian interval

Figure 12-7 shows the original interpretation of the lithostratigraphy using the terminology of Van Adrichem Boogaert and Kouwe (1994) with the Zeeland Formation made up of the Beveland, Schouwen and Goeree Members. However, in this study, the Beveland and Schouwen members have been replaced by sequence stratigraphic units described below and the Goeree Member is re-interpreted as an interval of karst collapse.

12.4 Biostratigraphy

Cores 1 and 2: Foraminiferal assemblages at depth of 1894.1 m indicate a V_3c, late Warnantian (Brigantian). Build-up facies at depth of 1887.7 m indicated a $V_3b\gamma$, Warnantian (latest Asbian-Brigantian), stromatolites with encrusting bryozoans resemble the buildups found in the North Dublin Basin of Viséan age.

Well sorted peloid intraclast bioclast grainstone at depth of 1886.1 m well sorted V_3c, late Warnantian (Brigantian).

All three samples appear to be of late Warnantian (Brigantian) age and are buildup or peri-buildup facies. Fabrics are similar to stromatolitic bryozoan buildups in the North Dublin Basin of Visean age (Somerville et al., 1992). New data from Cores 1 and 2 yield a Cf6δ foraminifera assemblage (late Warnantian) which suggests that the buildups here, are younger than those encountered in O18-01.

Cores 3 and 4: No age diagnostic bioclasts may be late Tournaisian or early Visean age based on correlation with S05-01.

12.5 Sequence stratigraphy

Based on correlations with O18-01, BHG-01 and S05-01 wells, ten depositional cycles have been recognised in S02-02 (Figure 12-7).

Cycle 1a: This depositional cycle represents the initial flooding of the basin; the thin TST has a clean gamma ray signature above the thick high gamma ray fine Tournaisian clastics. This is interpreted as deposition of clean carbonates in shallow water, which followed by increasing gamma ray interpreted as deposition of more muddy carbonates in deeper water. The related HST has a moderate gamma ray signature suggesting that it consists of mid ramp carbonates.

Cycle 1b: This depositional cycle comprises a thin TST with a thick HST interpreted as cyclic shallow to mid-ramp ramp carbonates.

Cycle 1c: This depositional cycle comprises a thick TST with a HST interpreted as cyclic subtidal to peritidal shallow ramp carbonates, probably capped by peritidal facies. Here, a thick TST passing up into a HST that has a moderately high gamma ray signature. Core from the HST intervals in other wells suggests that this depositional cycle consists of cyclic shallow subtidal to peritidal shallow ramp carbonates with cycle tops marked by peritidal facies. The subtidal facies are dominated by oncoids, other coated and highly micritised grains suggesting deposition took place in a relatively restricted shallow carbonate ramp setting.

Cycle 1d: This depositional cycle comprises a low gamma ray TST increasing to moderate gamma ray maximum flooding intervals. The HST has a lower gamma signature suggesting deposition in an inner or mid- carbonate ramp setting.

Cycle 2a: This depositional cycle consists of uniform moderate gamma ray interval that may represent an aggradational inner- or mid carbonate ramp or shelf interior.

Cycle 2b: This depositional cycle consists of a thin TST with increasing-upward gamma ray towards a high gamma ray maximum flooding interval with an overlying decreasing-upwards gamma ray HST. This was deposited in a high energy setting above normal wave base, in an inner carbonate ramp or carbonate shelf interior.

Cycle 2c: This depositional cycle has a thin TST with high gamma ray towards a high gamma ray maximum flooding interval with a thickly bedded low gamma ray HST. The depositional cycle may have been deposited in a moderate to high energy setting above or near normal wave base on a carbonate shelf interior.

Cycle 2d: This depositional cycle has a relative low, uniform gamma ray character. Core data in other wells suggests that the this depositional cycles was deposited in a high energy, but slightly restricted environment in carbonate shelf interior.

Cycle 3a: This depositional cycle is a TST to maximum flooding interval interpreted as storm deposits on a distal carbonate ramp or slope. The HST is interpreted as a generally shallow water carbonate shelf or ramp setting.

Cycle 3b: This depositional cycle consists mainly of bioclastic wackestone/carbonate mudstone with whole fenestrate bryozoan sheets, articulated brachiopods, gastropods, bivalves and a goniatite. The micritic matrix generally has a micropeloidal texture. Common irregular cm- to dm-sized cavities lined by fibrous calcite cement that are also partly infilled by peloidal geopetal and bioclastic sediment. These cavities may represent stromatactoid cavities that formed as modified shelter cavities in a micrite matrix around fenestrate bryozoan sheets. The depositional setting is interpreted as carbonate mud mounds that were associated with a carbonate shelf margin.

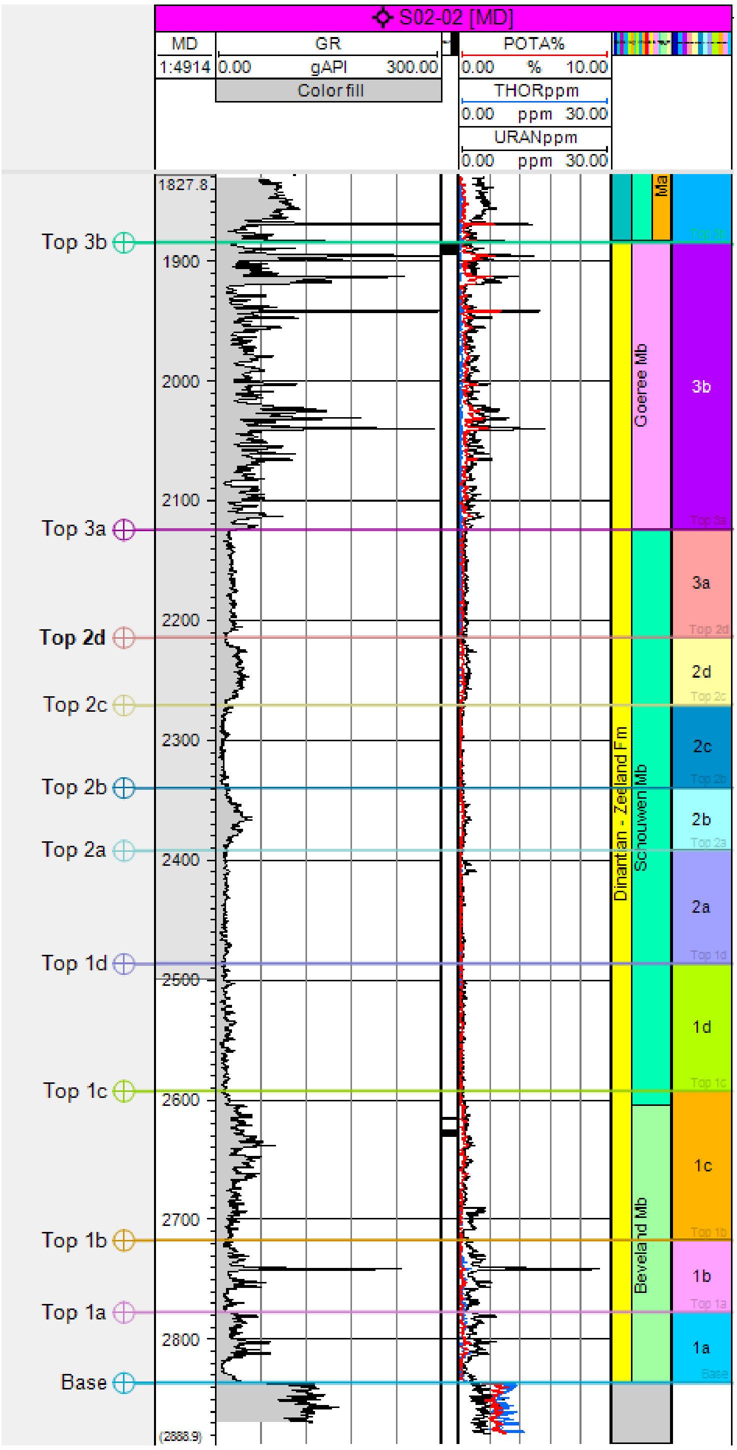

Figure 12-7: Depositional cycles recognised in well S02-2.

12.6 Diagenesis

No thin sections are available for S02-02. Thus, no further diagenesis studies were performed for this well. Thermal Alteration Index: (spore colouration) indicate 480-1880 m is thermally mature, and 1880-2800 m is over mature.

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