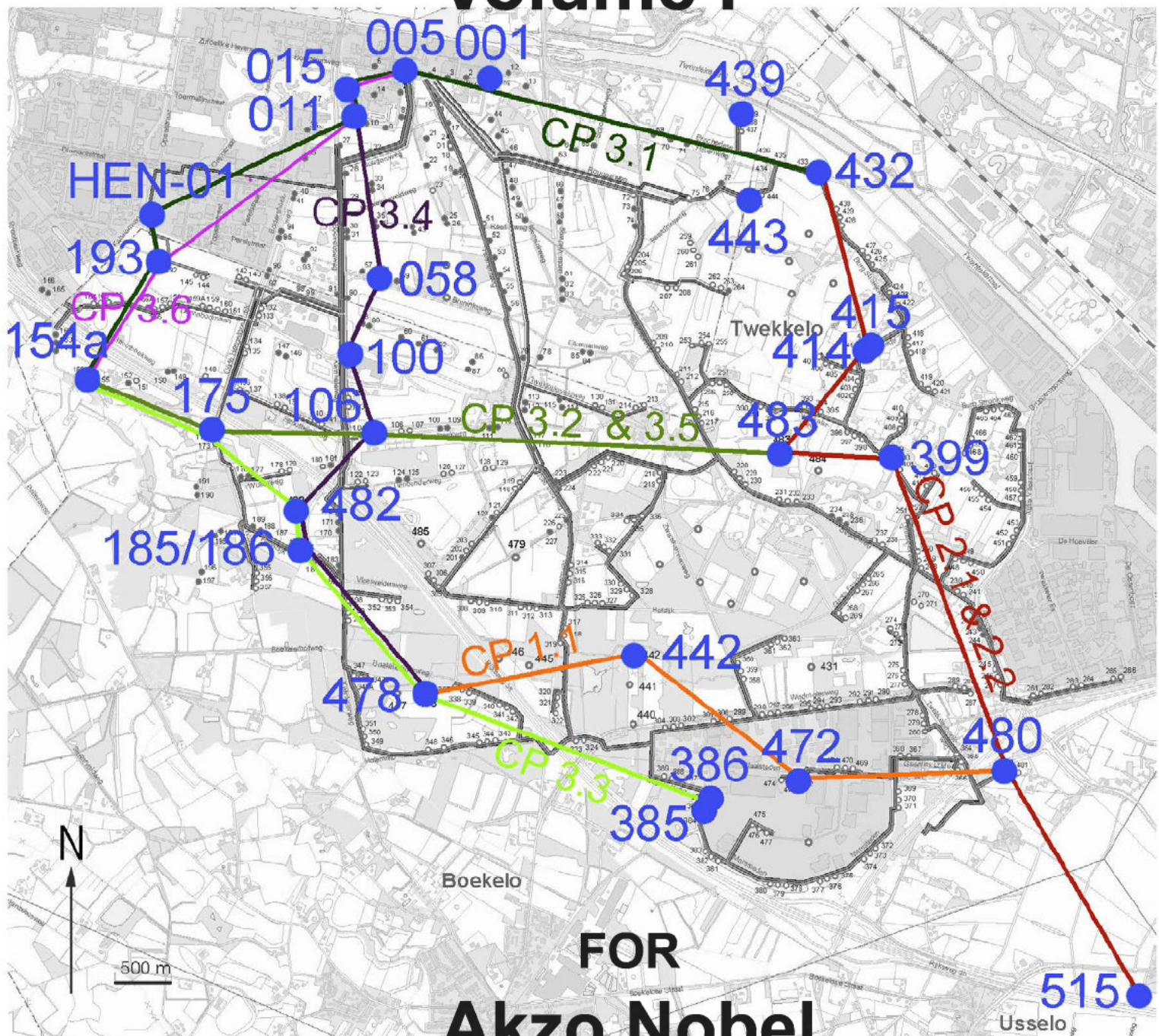


Geological Framework TWR Area Compilation Report Volume I



FOR
Akzo Nobel
Base Chemicals bv

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ATTACHMENTS

Volume II

Final Well logs

Correlation Panels line-up NAP
1.1; 2.1; 3.1, 3.2; 3.2; 3.3; 3.4

Correlation Panels line-up base Muschelkalk Fm.:
2.2, 3.5, 3.6

CD

Report in PDF format

All logs and Panels in DWF format

DWF viewer

Database in Excel format: Database April 2008 final

1. Introduction

This reports forms the compilation of a number of studies executed in the last two years on the geology of the TWR licence area.

In 2006, well B480 which was sampled at a 1m interval was described in detail. Based on microscopical study of the cuttings samples 56 lithological units and sub-units were defined, which were related to the wireline logs (report GL06.0406 & GL06.0601). In the winter of 2006/2007, well B478, which was also sampled at a 1m interval, was studied in a similar way. The previously defined units could also be recognised in B478 and a roughly West – East correlation panel was constructed from B478 to B480, including B442 and B472 (report GL07.101). The samples of the latter two wells had been previously studied for courses given in 1999 and spring 2006. Both wells had been sampled with a 10m spacing.

In 2007 Akzo Nobel Base Chemicals b.v. asked for a proposal for a field wide lateral variation project. Objective of the project was to characterize the lateral variation in the salt and overburden of the Hengelo brine field.

It was proposed by GL to define a phased study to develop a coherent geological framework for the area based on the same method as had been used in the study of B478 and B480, with emphasis on the overburden sections. In this approach the cuttings samples of a number of wells are studied in detail under the microscope, and described in relation to the Gamma Ray log and/or other available logs. Subsequently, the samples are grouped into informal lithological units. Though these informal lithological units and sub-units are not mutually exclusive as the regional stratigraphy is, they should at least have local continuity. The units are defined in such a way that they can be correlated on Gamma Ray logs. By correlating these units across the area, lateral variations and tectonic detail can be identified. The study is based on the stratigraphical and structural sub-regional framework as described in the 'Geological Atlas of the Subsurface of the Netherlands. Sheet X: Almelo – Winterwijk, TNO-NITG, 1998.

The results of the study of B478 and B480 defined the southern part of the area. In autumn 2007, B483 was studied in a similar manner (GL07.1001), bringing the number of reference wells to three. An eastern panel (CP2.1) was constructed running from B515 in the south, via B480, B399, B483, and B414 to B432 in the north. Of B515 samples were available for lithological study every ten meters. Of the north-eastern part of the area no samples were available and the wells have been tied-in on the basis of the Gamma Ray logs only. By using a number of logs of neighbouring wells it proved possible to recognize all informal units on Gamma Ray log only.

In spring 2008 the western and north-western part of the area was added to the framework study (GL08.501). Especially in the north-western part of the area not much information was available. Samples of a number of wells were studied (B001, B011, B106, B154a, B175, B186/B185, B482 and HEN-01). Wells B058, B100 and, B193 were added with the Gamma Ray logs only.

In the current report the combined results of the above studies are presented, stating the current ideas on the geological framework. In this framework the vertical succession (stratigraphy) is described in reference to a number of reference sections; the horizontal / lateral variation (facies) is described with reference to a number of correlation panels

and comparison of the stratigraphic differences between wells. Thirdly, the tectonically induced variations are described with reference to the correlation panels. For this report several new correlation panels have been constructed (CP 3.1 to CP 3.5) linking the western part to the southern and eastern part of the area. (See figure 1.1 for the wells included in this study).

The results are presented in a GIS-compatible Excell format spreadsheet/database. Per well the permanent data are given and the boundaries and thicknesses of all formal and informal units relative to NAP and Conductor Flange (CF).

It should be realized that the presented framework is based on a relatively small number of wells, compared to the total number of wells drilled in the area. A further refinement of the model, especially with respect to the exact location of fault systems will be obtained by adding more wells.

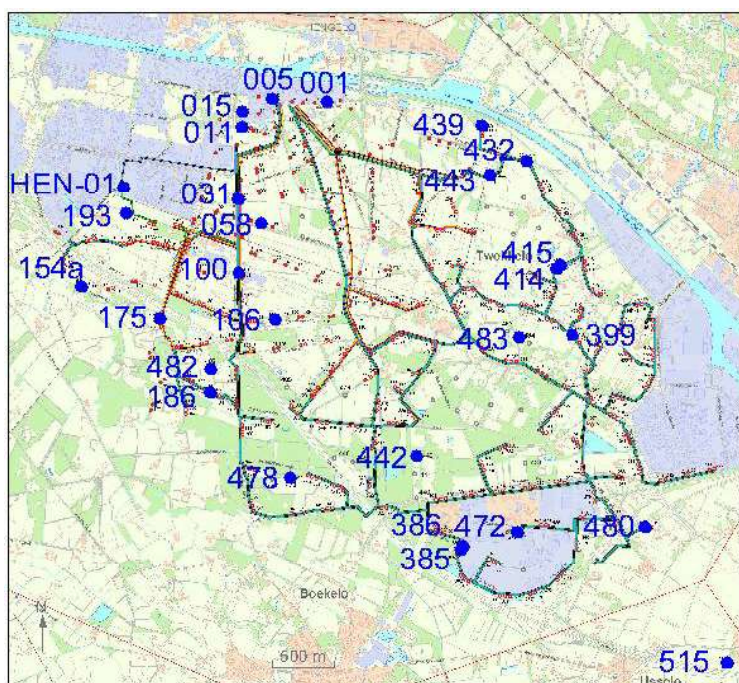


fig. 1.1; wells included in the correlation project

All studies were performed by

5.1.2.e

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2. Main Conclusions and Recommendations

A on the geological framework and lateral variation

1. Lithological units and sub-units identified in B480 can, whenever present, be recognised in all wells studied in the area.
2. In the section from base RNRO1-E to the uppermost part of the Muschelkalk Fm. no significant lithological lateral variations are present. The thickness distribution of RNROU and RNROM suggests slightly thinner sections in the south-western part of the area, possibly caused by minor syn-sedimentary tectonic movements or by larger scale tilting.
3. All significant lateral variation recognised in the overburden section in the studied wells is tectonically induced. Four to five phases of partly differential tectonics have been recognised. All these phases are post Muschelkalk deposition.

For example, the Muschelkalk Formation thins significantly in a northeasterly direction. In the southern part of the area two major units A and B, with 18 lithological sub-units can be distinguished (B478). These units and sub-units can be correlated throughout the TWR area. In the middle of the TWR-area, in B483, only the lower unit A and B-1 are present; a little further north in B414 only the lower half of unit A is present and in the northernmost part (e.g. B432) the Muschelkalk Formation has not been preserved at all. It can therefore be concluded that the progressive thinning of the Muschelkalk Fm. is due to erosion after differential tectonic uplift and not to lateral stratigraphic variation.

4. A number of fault lines have been tentatively identified from the correlation panels.
 - A. Faults have been identified between the wells
HEN-01 – B011 (CP 3.1)
B175 – B106 (CP 3.2)
B482 – B106 (CP 3.4)
B478 – B442 (CP 1.1)
B478 – B386 (CP 3.3)

This may represent one major fault line running roughly NNW – SSE, or a composite system made up of several smaller scale faults.
 - B. A fault is present between B515 and B480 (CP 2.1), placing B515 in another fault block relative to the other TWR wells. More data is needed to determine the strike of this system.
 - C. A fault has been identified between the northerly wells B001 - B006 and the wells B009 – B010 (see also report GL08.501). This fault runs roughly East – West, and may be related to the fault identified between B005 and B432 (CP 3.1); and/or B432 and B414 (CP 2.1).

5. Further development of the framework is needed to identify the exact position and direction of the fault systems, the timing and orientation of the tectonic phases, and to quantify the differential effects. Whenever modern Gamma Ray logs are available, correlation based on Gamma Ray logs only is considered feasible. However especially in areas where lithological information is lacking, the sampling of future in-fill wells is advised (see also recommendation C1).

A fine grid of wells and a large amount of information is available for the TWR area, which allows for a detailed tectonic reconstruction. In order to identify the timing of the tectonic phases and the direction of the related fault systems, it is advised to firstly study the area where occurrences of Niedersachsen Group and Altena Group sediments are expected. The (south)-western part of the TWR area is a good candidate for such an approach.

5. Especially in the north-western part information is limited. If modern Gamma Ray logs would be available for all wells, this would enhance the results of a possible study into this part significantly. Additionally, the wells O-1 and O-2 could be incorporated into the study.
6. A detailed base North Sea Supergroup depth map based on all available wells will more accurately define Tertiary syn-sedimentary faulting.

B on mechanical strength and cavern migration

1. Substantial lithostratigraphic lateral variation, which may relate to cavern migration, has not been encountered in the overburden section in the TWR area.

For example, the thickness distribution of the Anhydrite section (RNRO1-E) shows slightly thinner sections in the southern and south-western part of the area. Furthermore, slight differences in anhydrite versus claystone amounts within this section were recognized and quantified by application of a Gamma Ray cut-off analysis (GL08.101). This may have an impact on mechanical strength differences of the anhydrite in the TWR area. However, it is questionable whether this is a significant impact.

2. The Muschelkalk B section is of a mechanically more competent nature compared to the Muschelkalk A section. The Muschelkalk B section is eroded after tectonic uplift in the northern part of the TWR area. This may have an impact on mechanical strength of the total overburden section.
3. The determining factor on cavern migration is most likely tectonical. Four to five phases of partly differential tectonics have been recognised. Areas with successive extensional and compressional differential tectonic movement will be more sensitive to cavern migration compared to areas without differential tectonic movement and related fracturing.

C on data gathering and administration

1. It is advised to identify each year a number of wells which will be sampled in more detail (2m or 3m interval). In this way a grid of wells with available lithological data is built.

2. For many older wells, a Gamma Ray log over the upper part of the RNRO1 section is regularly run but no (modern) logs for the entire well are available. It is advised to run the Gamma Ray log over the overburden sections as well.
3. Naming of Gamma Ray log-files should state whether the log is filtered or unfiltered.
4. In order to exclude confusion, the header of the log files should not only include the name of the well but also the co-ordinates.
5. It is advised to prepare final well logs for newly drilled wells, including Gamma Ray log, permanent data and unit boundaries. Also, consistency with neighbouring wells should be indicated. The information should be added to the database.

3. Geological Framework

In this chapter the geological framework is described as represented in the correlation panels (CP1.1, CP2.1, CP2.2, CP3.1, CP3.2, CP3.3, CP3.4, CP3.5, CP3.6). For more details on the stratigraphy see also the chapter on stratigraphy (CH4). See figure 3.1 at the end of this chapter for a summary of the regional geology.

3.1 *Triassic*

Sedimentation of the Solling and Röt Formations took place in a large scale arid coastal plain / coastal sebkha setting. Slight thickness differences between smaller units occur in nearly the entire section, suggesting a minor degree of syndepositional tectonic movement. The Röt evaporites were deposited in this basin mainly as halite lithologies which is common for Triassic evaporites. Only minor amounts of intercalated anhydrite, dolomite or claystone are found. As such, the evaporite sequences are incomplete compared to Zechstein evaporite sequences which begin with a thin clastic section, followed by limestone, anhydrite, sodium chlorides and finally the soluble magnesium and potassium salts. This leads to the suggestion that a single evaporite succession of the Röt salt did not precipitate from a substantial column of water, but instead from repeated smaller scale marine incursions. This is also illustrated by the relative high amounts of dispersed anhydrite often present within the halite. Core descriptions (BGR report 5145031243) mention meter scale polygonal structures which are probably related to repeated evaporation.

On a vertical scale, the succession becomes increasingly immature in an upward direction; at the base of the A Salt, which is the thickest salt sequence, an anhydrite bed is found, the B Salt section begins with a dolomite or anhydrite bed and the C Salt has a claystone at its base with some anhydrite. Locally, a thin D Salt is present which is underlain by a section of claystone of about equal thickness, and finally, the evaporite section terminates with an anhydrite section without any halite present.

Clastic sedimentation again begins with the deposition of the clays of the Intermediate Röt Mb., caused by a slight uplift of the hinterland, deposition was still in the same arid coastal plain setting.

The Upper Röt Evaporite Mb. is a thin bed of anhydrite which is the result of a sudden marine incursion and subsequent evaporation. Halites, which are deposited in more basinal sections, were not deposited in the TWR area. Clastic sedimentation resumes with the deposits of the Upper Röt Claystone Mb.

The entire Upper Röt Claystone section and the Muschelkalk Formation together form one large mega sequence which has a maximum flooding in the RNROU-C unit. The subsequent highstand / progradational section continues upward and comprises the RNROU-D – I units and the Muschelkalk Fm. Following deposition of the C unit, clayey sediments first become more silty with siltstone intercalations which are upwardly gradually replaced by gypsum intercalations until sedimentation is taken over by the carbonates of the Muschelkalk Formation. Slight differences in thickness of individual units suggest minor syn-sedimentary tectonic influences or larger scale tilting.

The above mentioned mega sequence can be split up in a Röt sequence and a Muschelkalk sequence with the sequence boundary present within the basal Muschelkalk unit A1. For this reason, base Muschelkalk is an excellent marker which can be followed across the entire basin. Sedimentation in the coastal plain environment is of a very uniform nature and only subtle differences in amounts of gypsum and siltstone are found between wells. During sedimentation of the Muschelkalk Fm., supply of clastic material gradually decreased.

Early Kimmerian uplift caused non deposition and/or erosion of the regionally present Keuper Fm. and part of the Muschelkalk Fm. The Early Kimmerian phase can only be separated from later phases in localities where the Sleen Fm. is preserved. Correlation panel CP 3.3 illustrates Sleen Fm. unconformably overlying the locally youngest Muschelkalk unit B5. Only in well B480 Sleen Fm. is overlying RNMU-B4. This suggests that the Early Kimmerian phase had hardly any differential effects in the area. The hiatus spans the Carnian and Norian stages.

Sedimentation continued with the uppermost Triassic (Rhaetian) Sleen Fm. which is lithostratigraphically reckoned with the Altena Gp. In the TWR area, the Sleen Fm. is only locally preserved.

3.2 Jurassic

Sedimentation continued during Liassic and Dogger times with further deposition of the Altena Group sediments; which are not preserved in the TWR area.

Mid Kimmerian movements ended sedimentation in the TWR area which is situated on a NW – SE horst block south-west of the Gronau fault zone. In the latter area sedimentation continued. Further to the west and the south-west the 'TWR' horst block gradually steps down towards the Central Netherlands basin. Towards the North the area is fault bounded with the Friesland platform (see also fig 1.7, pg 24 of Explanation to map sheet X).

Mid Kimmerian uplift truncated Liassic and Dogger sections on the TWR horst block area until Late Kimmerian times. Up to 300m of Altena Group section was removed. Mid Kimmerian faulting and uplift can only be recognized and isolated in sections where Niedersachsen Group sediments are preserved. Effects of the Mid Kimmerian phase may have had a Late Kimmerian component as well; because of a lack of preserved sections, the two phases cannot be unambiguously separated.

Where Sleen Fm is preserved, presence and impact of differential Mid to Late Kimmerian faults in the area can be recognized; e.g. wells B478, B186 and B482 on panel CP 3.4 have Sleen Fm. preserved and differential tectonics between these wells can be excluded.

The main Mid Kimmerian fault recognized in the TWR area lies between B478 and B442 with a relative off set of approximately 55m (CP 1.1). Also between B478 and B386 a fault is present with an off-set of 50m (CP 3.3). Faults between B482 and B106 (CP 3.4) and between HEN- 01 and B011 (CP 3.1) and between B175 and B106 (CP 3.2) may belong to the same system but erosion of the sections in B106, and B011 cannot be separated from later phases because of absence of Niedersachsen Gp. sediments. Another rather large Mid Kimmerian fault is recognized between B480 and B515 with an offset of approximately 25m. More detail is needed to exactly outline the relationship and

directions of these systems. Smaller faults can also be recognized e.g. between B472 and B480 (CP. 1.1, off set approx 10m) and between B154a and B175 (CP 3.2 & 3.3, off set approx 5m).

Although Mid and Late Kimmerian faulting can only be recognized when Niedersachsen Gp. sediments are preserved, it cannot be excluded that other faults have Mid to Late Kimmerian components as well.

On a regional scale, the Late Kimmerian extensional phase created fault bounded basins and sub-basins in which Niedersachsen Gp. sediments accumulated. Niedersachsen Gp. sediments within the area comprise the upper part of the Weiteveen Fm. which is of an uppermost Jurassic age and the lower part of the Coevorden Fm. with a lowermost Cretaceous age. The boundary between these formations is not well recognized in the sections studied, and a lithological subdivision into 4 units is suggested which can be correlated both lithologically and on GR logs. Niedersachsen Gp. sediments were deposited in shallow water restricted basins without coarser clastics supplied. Only the bioclastic limestones in the upper unit D may point to higher energy levels. Indications for lateral facies variations are scarce; but especially the thinner sections which often have only one or two samples are difficult to correlate. A variation exists in the amount of gypsum nodules between well sections. High concentrations of gypsum are found in the sections of B175, B482, B186/185 and B478; these are the wells which also have Sleen Fm. preserved which may suggest a relationship between environment and syndimentary tectonics. Possible differential subsidence is suggested on the panels (e.g. CP 3.3, CP 3.4), but more research is needed to confirm lateral facies variations.

3.3 Cretaceous

Rijnland and Chalk Group sediments are not present in the TWR area. Rijnland Group sediments are preserved in the Enschede area south-west of the Gronau fault with thicknesses up to 350m. Also in the Almelo area towards the Friesland platform sections of Rijnland Group of up to 300m are present. Chalk Group sections are also absent in the TWR area, but up to 1150m of Chalk Group is preserved on the Friesland platform some 20 km north-west of Hengelo. Lateral variation is not documented in this area, and assuming continuous sedimentation in the TWR area too, at least some 1400m of Rijnland and Chalk section was removed after Sub-Hercynian and Laramide uplift (Upper Cretaceous – Paleocene). In the south-western part of the area, Niedersachsen Gp. sections are preserved and Sub-Hercynian to Laramide phases can be separated from older phases (e.g. CP 3.4). In the central and northern part of the area, erosion cuts as deep as the Röt Fm. and tectonic phases cannot be separately recognized.

3.4 Tertiary

Deposition again resumed in Lower Eocene times with shallow marine equivalents of the Dongen Fm. Deeper and more distal deposits in the western part of the area (HEN-01) are resembling the Dongen Fm. facies as it is known from more basinal settings. North Sea Supergroup sections are subdivided in a basal unit (N1) which does not show much variation in thickness (CP 1.1, CP 3.3) and an upper unit (N2) of which the thickness increases in a westward and north-westward direction. In the same direction the facies changes towards a more distal environment. Facies changes seem to have occurred approximately at the B186 to B482 locations, and further west and north-west at the HEN-01 well location. The thickness increase is controlled by differential subsidence related to early phases of the Pyrenean phase in Mid to Upper Eocene times. The strike of the faults that caused this thickening is N – S and NE – SW (see also Ch 4.1)

fig 3.1: Summary regional geology

Chronostratigraphy		Lithostratigraphy Mid - Eastern Netherlands				tectonic		
		regional codes		Formation/Member	facies	phase		
Quaternary Tertiary	Pleistocene	N		North Sea Supergp.	marine	Savian Pyrenean		
		NU						
	Pliocene		NUOT	Oosterhout Fm.				
	Miocene		NUBA	NUBAS			Upper Breda Sand Mb.	
				NUBAC			Lower Breda Clay Mb.	
	Oligocene	NM	NMRF	Rupel Fm.				
	Eocene	NL	NLFF	NLFFB			Asse Clay Mb.	
				NLFFM			Brussels Marl Mb.	
				NLFFS			Brussels Sand Mb.	
				NLFFY			Ieper Clay Mb.	
			NLFFT	Basal Dongen Tuff Mb.				
Cretaceous	Paleocene		NLLF	Landen Fm.	lagoonal	Laramide		
	Upper Cret.	CK	CKGR	Ommelanden Chalk Fm.		Sub-Hercynean		
				CKTX			Texel Chalk Fm.	
		KN	KNGL	KNGLU			Upper Holland Marl Mb.	
				KNGLM			Middle Holland Shale Mb.	
			KNGLL	Lower Holland Marl Mb.				
	Lower Cret.		KNNC	Vieland Claystone Fm.				
				KNNS		Vieland Sandstone Fm.		
		SK				Niedersachsen Gp.		
			SKCF			Coevorden Fm.		
Jurassic	Malm		SKWF	Weiteveen Fm.	lagoonal	Late Kimmerian		
		AT	ATBR	Brabant Fm.				
	Dogger		ATWD	Werkendam Fm.		Mid Kimmerian		
	Lias		ATPO	Posidonia Shale Fm.		Early Kimmerian		
Triassic	Keuper		ATAL	Aalburg Shale Fm.	lagoonal			
			ATRT	Sleen Shale Fm.				
		RN	RNKP	RNKPU		Keuper Fm.	Early Kimmerian	
				RNKPD		Dolomitic Keuper Mb.		
				RNKPR		Red Keuper Claystone Mb.		
				RNKPE		Red Keuper Evaporite Mb.		
				RNKPM		Mid Keuper Claystone Mb.		
				RNKPS		Main Keuper Evaporite Mb.		
	Muschelkalk		RNKPL	L. Keuper Claystone Mb.	coastal plain			
			RNMU	Muschelkalk Fm.				
				RNMUE			Muschelkalk Evaporite Mb.	
				RNMUL			Lower Muschelkalk Mb.	
	Buntsandst.		RNRO	RNROU	Upper Röt Claystone Mb.	coastal plain		
					RNRO2	Upper Röt Evaporite Mb.		coastal sebkha
					RNROM	Intermediate Röt Clayst. Mb.		coastal plain
					RNRO1	Main Röt Evaporite Mb.		coastal sebkha
			RNSO	RNSOU	U. Solling Claystone Mb.	coastal plain		
						hiatus		

4. Stratigraphy

In this chapter a summary of the stratigraphy of the TWR area is described, with lateral variation, thickness distribution and facies. Whenever relevant differences with the regional stratigraphy are described.

For each formation a description of the stratigraphy and facies is given, followed by microphotographs, reference sections, thickness and subcrop maps, and the abbreviated data as presented in the database.

See figure 3.1 for a summary of the regional geology.

4.1 North Sea Supergroup

regional code: N

Reference sections: B480
 B175

Sections of North Sea Supergroup sediments are found in all wells in the TWR area. The thickness of these Tertiary and Quaternary deposits varies from 67.5m (B515) in the south-east to 139m (B193) and 145m (HEN—01) in the north-western part of the study area. This means an increase in thickness of 77.5m within 6km. Sediments of the North Sea Supergroup are unconformably overlying the Röt Formation in the north-eastern part of the area, the Muschelkalk Formation in the central part, and Niedersachsen Group sediments in the southern and western part of the license area.

Biostratigraphical age dating of North Sea Supergroup sections in the area is very limited. Two samples of well B480 have been dated by TNO (report. NITG 05-074-C) as Lower to Middle Eocene based on sporomorphs, and a quick look survey was carried out by GL (report GL07.1001) on the foraminifera of B483 which suggested ages ranging from lowermost Eocene to Upper Eocene and possibly Oligocene for the section up to 33m. Because of remaining uncertainties in the exact age of the various well sections, and because of lithological dissimilarities with the regionally existing stratigraphy, an informal breakdown has been applied. Sections are subdivided into a lower part N1, and an upper part named N2. This subdivision is easily recognized on the Gamma Ray curves of all wells in the area.

Indications for the presence of the Paleocene Landen Formation have not been found in the area and sedimentation is thought to have started in lowermost Eocene times with the deposition of a thin basal sand which is a possible lateral equivalent of the regional Basal Dongen Sand Member. The thickness of this basal sand (N1a) ranges from 1-6m. Sands have an argillaceous matrix and are rich in glauconite. Grainsizes vary from very fine to fine and locally medium to coarse with a fining upward trend (pict 480-74-40c).

Overlying the basal sand is a predominantly clayey section (N1b) with a relative uniform thickness of 12 – 14.5m in the central and western part and a thickness of 8.5 – 10 m in the eastern and southern part (B483, B480, B515). In general the thinnest occurrences are found in the south-east and slightly thicker occurrences in the north-west.

Clays of the North Sea Supergroup sections have light brownish grey shades in general (pict B483-88-20) but locally in the western part of the area, also light greenish grey and slightly reddish brown colors occur. The slightly reddish brown shades are on a regional scale commonly found in the lower part of the Ieper Clay Member. Clays in the N1b section are silty to very fine sandy, and non calcareous. In the western part of the area (HEN- 01, B154a) clays of the N1 and N2 sections are of a more consolidated nature and they become gradational with claystones. Locally, thin intercalated glauconitic sand beds occur (pict B175-120-10). In well B482, the entire N1b section is of a very sandy nature as also indicated by the Gamma Ray curve. In the sample from this section much medium to coarse quartz grains are present, together with light brownish grey to light greenish grey clays and light brownish silts or sands. In the other wells studied, grainsizes do not exceed the very fine fraction in this interval, except for B175, which has very fine to fine and subordinate amounts of medium to coarse quartz grains.

The lithologies of the overlying N2 section are of a very uniform nature; they consist of a succession of light brown very fine glauconitic sands (pict B175-97.5-20) and light brownish grey silty to sandy clays (pict B480-53-10b). However, the vertical and lateral variation within these lithologies is considerable. Detailed correlation based on Gamma Ray logs only is difficult because of differences in clay and glauconite content. For instance, a sandy clay without glauconite may give lower Gamma Ray readings compared to a sand with much glauconite which is illustrated by the lower part of the N2 section in B175.

In the eastern part of the area, in B480, sedimentation of the N2 unit begins with a thin sand bed with relatively little argillaceous matrix which can be followed to B478 and B483 where it is 10m thick with associated medium to coarse quartz grains. Further towards the west and north-west, the basal part of N2 becomes of a more argillaceous nature and the cleaner sands with associated coarser grainsizes are overlying the basal N2 section.

Minor amounts of coarser grainsizes are commonly found in most well sections and locally much fine to coarse quartz grains are present in the samples. In B483 much medium to coarse fractions are present locally in the basal part of N2 and in the sample at 50m. In B186, increased amounts of fine to coarse quartz grains are found at the base of N2. In B482, much fine to coarse grainsizes are found in a number of samples of N2, but the section is insufficiently documented with a 10m sample interval. In B175, much fine to coarse quartz grains are present in the upper part of N2 down to the sample at 87.5m (pict B175-60-10) and still fair amounts are present in the samples down to 97.5m. The basal part of N2 however does not show increased amounts of coarser grainsizes. In the more westerly situated wells B154a and HEN- 01 coarse grainsizes are absent, and increased amounts of loose quartz grains do not have grainsizes exceeding the fine fraction and locally minor medium. The latter two wells are documented at a 10m sample interval.

The vertical and spatial distribution of concentrations of coarser quartz grains has to be interpreted with some caution because of the limited amount of data. As a working hypotheses it can be said that increased amounts of coarser fractions at the base of N2 occur in the eastern and central part of the area as far west as B186 and coarser intercalations in the upper parts of N2 continue in a westward direction until B175. Further west grainsizes diminish.

Compared to the B480 and B175 well sections, a different development is present in the HEN- 01 well. Unfortunately there are no logs across this section, and samples are at a 10m interval. Nearly the entire lower part of N2 consists of silty to very fine sandy clays to claystones with light brownish grey, pale reddish brown and light greenish grey shades (pict HEN-01-70-10). The upper part of N2 (samples 40 and 50m) is represented by very fine to fine sandstones with calcareous cement and quartz cement and much glauconite (pict HEN-01-50-20- & pict HEN-01-40-20). Lithologies of the claystones and of the sandstones resemble the regionally present Ieper Clay and Brussels Sand members. These lithologies have not been encountered in other wells in the study area. The increased thicknesses in the area together with more distal facies points to a more basinal position of this well location.

The depositional environment for North Sea Supergroup sediments is a linear clastic shoreline which rapidly deepens in a westward and north westward direction with a gradient of approximately 16m / km (Re: TNO map 15: depth of the base of the North

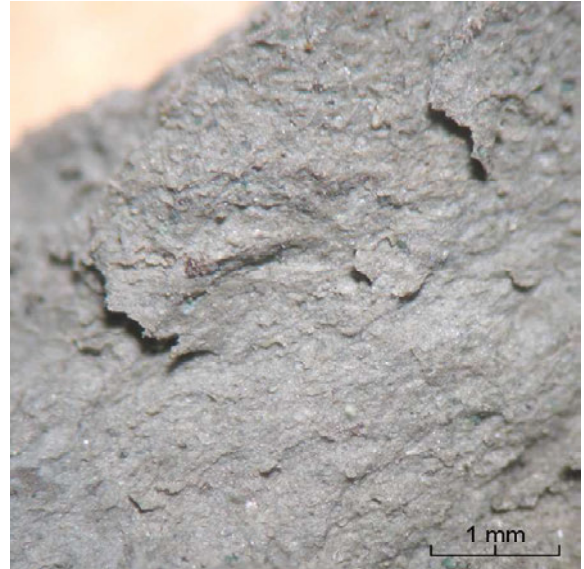
Sea Supergroup). The section starts with a transgressive sand (N1a), the clays of the N1b section are deposited in a slightly deeper environment. The N2 unit consist of a number of small scale sub-cycles, which represents an overall progradational basin fill.

Within the study area, the thickening is predominantly in the N2 section. The setting is probably induced by syndimentary tectonics in Middle Eocene to Early Oligocene times. The relatively thin and near shore deposits in the study area may be incomplete in parts due to (unidentified) erosional surfaces. The thickening of the N2 section goes together with the occurrence of more mature and consequently more distal sediments. Major changes may have happened in two steps; one is the disappearance of coarser grainsize fractions at the base of N2, this occurs approximately at the B186 – B482 locations. The second "sudden" change in facies is at the HEN- 01 location which shows recognizable Brussels Sand and Ieper Clay facies which are in line with the regional stratigraphy. To a lesser degree, a facies change is present in the B154a location which has calcareous lithologies in the upper part of the N2 section. NNE – SSW fault systems which should have been responsible for a stepwise sedimentary control as described above are not documented in recent publications (TNO, Geological Atlas). An older publication from Harsveldt (Harsveldt, H.M. (1978) Salt resources in the Netherlands as surveyed mainly by AKZO; Fifth International Symposium on Salt, Hamburg) suggests a number of N – S and NNE – SSW normal faults stepping down in a W and WNW direction approximately at the locations which are concluded in the above.

Microphotographs North Sea Supergroup



*pict. B480-74-40c: N-1a
light brown very fine to medium sand, with
argillaceous matrix, glauconite and dark
organic particles*



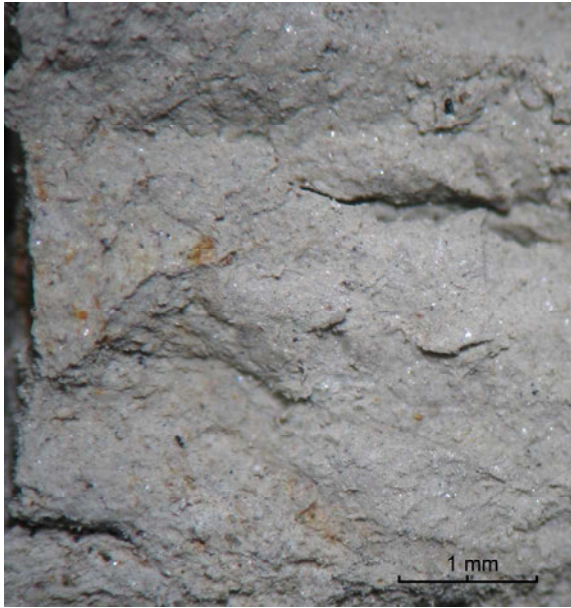
*pict. B483-88-20: N-1b
light grey to light brownish grey clay*



*pict. B175-120-10: N1b
light to medium brown to slightly reddish
brown very silty to very fine sandy clay,
grading argillaceous sand*



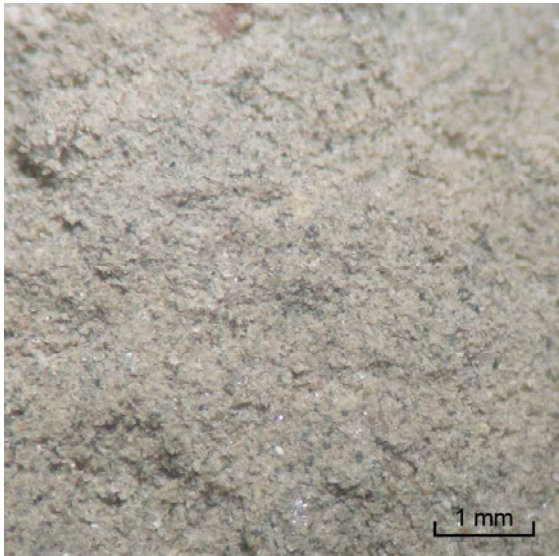
*pict. B175-175-97.5-20
relatively clean very fine sand with
glauconite*



pict. B480- 53-10b
silty to very fine sandy light brownish grey
clay



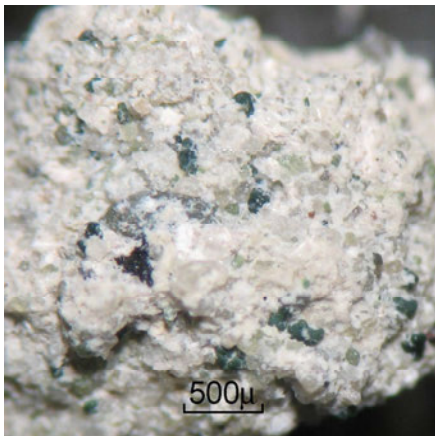
pict. B175-60-10 (washed sample)
fine to coarse quartz grains with
glauconite



pict. B483-70-10
silt to very fine grained slightly
argillaceous sand



*pict. HEN-01-70-10
non to slightly silty claystones resembling leper Clay Mb.
lithology*



*pict. HEN-01-40-20
very fine to fine sandstone with
calcareous cement and minor
quartz cement, resembling
Brussels Sand Mb.lithology*



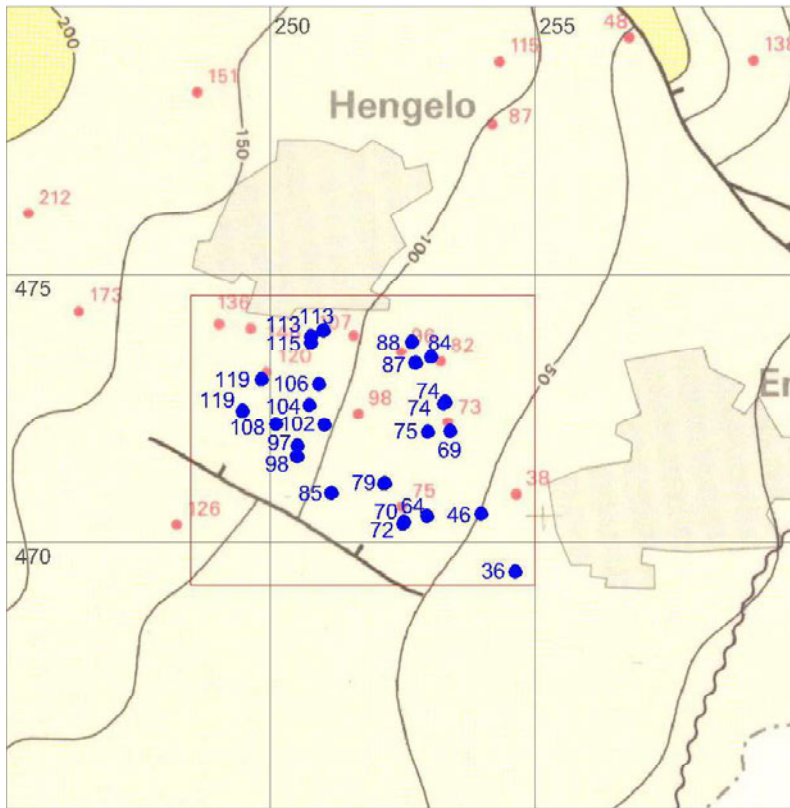
*pict. HEN-01-50-20
very fine to medium grained sandstone
with mainly quartz cement, resembling
Brussels Sand Mb.lithology*

Reference section North Sea Supergroup

The sections of B480 and B175 form the reference sections for the North Sea Supergroup in the area

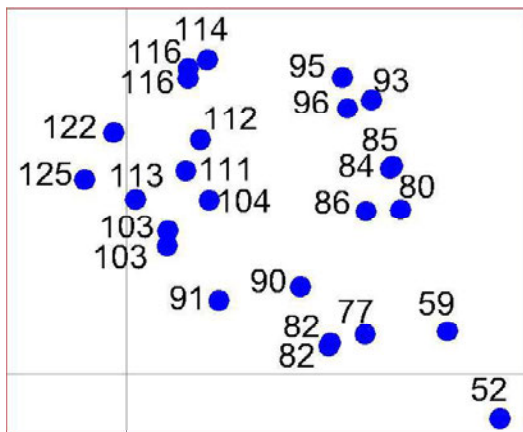
See attachments for log representation and unit descriptions.

Thickness of the North Sea Supergroup and units



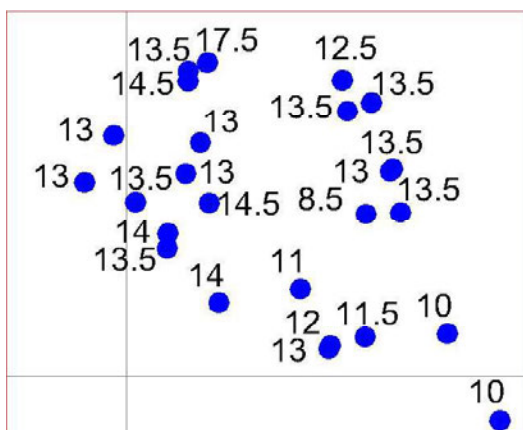
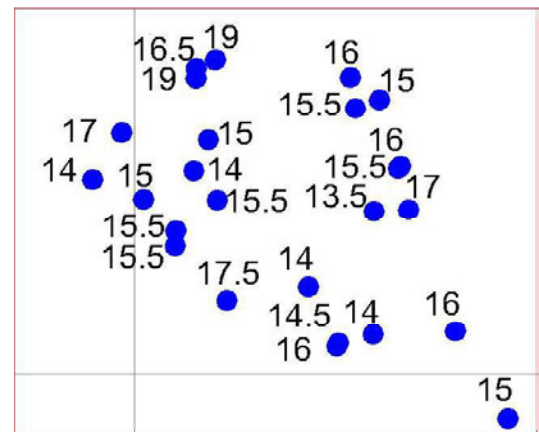
Depth N (NAP) in studied wells on background of the Geological Atlas of the Subsurface of The Netherlands Sheet X, Map 15: Depth of the base of the North Sea Supergroup (NAP)

Thicknesses are rounded to whole numbers.



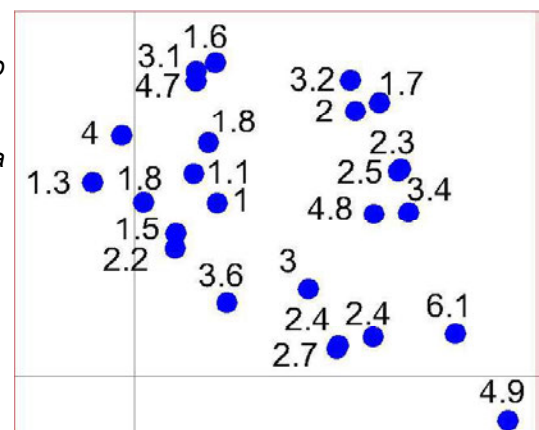
left:
Thickness N2

right:
Thickness N1



left:
Thickness N1b

right:
Thickness N1a



Database N

Below thicknesses and depths of units and sub-units with reference to CF and NAP as given in the database which forms part of the current study.

All values are rounded to one decimal place. Top N is taken at depth Conductor Flange.

<i>North Sea Supergroup</i>																
	<i>reference depth: m CF</i>					<i>reference depth: m NAP</i>						<i>thickness (m)</i>				
	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>top</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>base</i>	<i>N</i>	<i>N2</i>	<i>N1</i>	<i>N1b</i>	<i>N1a</i>
	<i>N</i>	<i>N2</i>	<i>N1</i>	<i>N1b</i>	<i>N1a</i>	<i>N</i>	<i>N</i>	<i>N2</i>	<i>N1</i>	<i>N1b</i>	<i>N1a</i>					
<i>B005</i>	133.1	114.1	133.1	131.5	133.1	-20.1	113.0	94.0	113.0	111.4	113.0	133.1	114.1	19.0	17.4	1.6
<i>B011</i>	134.6	115.6	134.6	129.9	134.6	-19.9	114.8	95.8	114.8	110.1	114.8	134.6	115.6	19.0	14.3	4.7
<i>B015</i>	132.4	116.0	132.4	129.3	132.4	-19.6	112.8	96.4	112.8	109.7	112.8	132.4	116.0	16.4	13.3	3.1
<i>B058</i>	126.6	111.8	126.6	124.8	126.6	-21.0	105.6	90.8	105.6	103.8	105.6	126.6	111.8	14.8	13.0	1.8
<i>B100</i>	124.7	110.5	124.7	123.6	124.7	-21.1	103.6	89.4	103.6	102.5	103.6	124.7	110.5	14.2	13.1	1.1
<i>B106</i>	119.1	103.6	119.1	118.1	119.1	-22.4	96.8	81.3	96.8	95.8	96.8	119.1	103.6	15.5	14.5	1.0
<i>B154a</i>	138.9	124.7	138.9	137.6	138.9	-20.2	118.7	104.5	118.7	117.4	118.7	138.9	124.7	14.2	12.9	1.3
<i>B175</i>	128.5	113.3	128.5	126.7	128.5	-20.9	107.6	92.4	107.6	105.8	107.6	128.5	113.3	15.2	13.4	1.8
<i>B186</i>	118.2	102.5	118.2	116.0	118.2	-20.7	97.5	81.8	97.5	95.3	97.5	118.2	102.5	15.7	13.5	2.2
<i>B193</i>	139.2	122.3	139.2	135.2	139.2	-20.2	119.0	102.1	119.0	115.0	119.0	139.2	122.3	16.9	12.9	4.0
<i>B385</i>	98.0	82.2	98.0	95.3	98.0	-25.9	72.1	56.3	72.1	69.4	72.1	98.0	82.2	15.8	13.1	2.7
<i>B386</i>	96.0	81.6	96.0	93.6	96.0	-25.6	70.4	56.0	70.4	68.0	70.4	96.0	81.6	14.4	12.0	2.4
<i>B399</i>	96.1	79.1	96.1	92.7	96.1	-26.7	69.4	52.4	69.4	66.0	69.4	96.1	79.1	17.0	13.6	3.4
<i>B414</i>	100.0	84.4	100.0	97.5	100.0	-26.2	73.8	58.2	73.8	71.3	73.8	100.0	84.4	15.6	13.1	2.5
<i>B415</i>	100.4	84.6	100.4	98.1	100.4	-26.4	74.0	58.2	74.0	71.7	74.0	100.4	84.6	15.8	13.5	2.3
<i>B432</i>	108.2	93.0	108.1	106.5	108.2	-23.8	84.4	69.2	84.3	82.7	84.4	108.2	93.0	15.1	13.5	1.7
<i>B439</i>	109.5	95.0	109.5	107.7	109.5	-23.3	86.3	71.8	86.3	84.5	86.3	109.5	95.0	14.5	12.7	1.8
<i>B442</i>	104.2	90.0	104.2	101.2	104.2	-25.0	79.2	65.0	79.2	76.2	79.2	104.2	90.0	14.2	11.2	3.0
<i>B443</i>	111.2	95.7	111.2	109.2	111.2	-23.9	87.0	71.8	87.3	85.3	87.3	111.2	95.7	15.5	13.5	2.0
<i>B472</i>	90.9	77.0	90.9	88.5	90.9	-26.9	64.0	50.1	64.0	61.6	64.0	90.9	77.0	13.9	11.5	2.4
<i>B478</i>	108.3	90.8	108.3	104.7	108.3	-23.5	84.8	67.3	84.8	81.2	84.8	108.3	90.8	17.5	13.9	3.6
<i>B480</i>	74.9	59.0	74.9	68.8	74.9	-28.6	46.3	30.4	46.3	40.2	46.3	74.9	59.0	15.9	9.8	6.1
<i>B482</i>	118.9	103.3	118.9	117.4	118.9	-22.1	96.8	81.2	96.8	95.3	96.8	118.9	103.3	15.6	14.1	1.5
<i>B483</i>	99.7	86.3	99.7	94.9	99.7	-25.1	74.6	61.2	74.6	69.8	74.6	99.7	86.3	13.4	8.6	4.8
<i>B515</i>	67.4	52.4	67.4	62.5	67.4	-31.9	35.5	20.5	35.5	30.6	35.5	67.4	52.4	15.0	10.1	4.9

4.2 *Niedersachsen Group*

regional code: SK

Reference sections: B478

Regionally, the Niedersachsen Gp. is subdivided in a lower Weiteveen Fm. and an upper Coevorden Fm. The Coevorden Fm. is correlated with the Wealden deposits in Germany and they have an Lower Cretaceous age (Ryazanian to Lower Valanginian). The upper part of the Weiteveen Fm. is correlated with the Serpulite of the German stratigraphy which has an Upper Jurassic age (Volgian).

Sediments of the Niedersachsen Gp. accumulated in differentially subsiding basins and sub-basins which formed during the Late Kimmerian tectonic phase. In the East Netherlands area, these basins are an extension of the larger basin in Germany. Because of this tectonic basin setting, considerable lateral variation between deposits at different localities can be expected.

Within the study area, thicknesses of Niedersachsen Gp. sections vary between 13m and 64.5m, but on a slightly larger scale, thickness variations are more impressive. Just west of the TWR area, up to 250m of Niedersachsen Gp. sediments are preserved in a small graben, and some 20 km North of the area up to 600m is preserved (TNO map sheet 10). It is not documented whether these differences are depositional or erosional.

In the southern and south-western part of the TWR area, sediments are unconformably overlying thin sections of Sleen Fm. or Muschelkalk Fm. (units B3 – B5). Niedersachsen Gp. sections are unconformably overlain by sediments of the North Sea Supergroup. Niedersachsen Gp. sediments probably have been present in the northern part as well, but they have been removed during later, Sub-Hercynian erosion. Relative truncation below the base Niedersachsen Gp. varies in the area. In wells in the south-western part of the area B154a – B478 Niedersachsen sections overlie Sleen Fm. or Muschelkalk unit B5 and the degree of erosion is more or less similar. South-east from this area there is a group of wells (B385, B386, B442 and B472) which show an approximately 15m deeper erosion. Again further SE at B515, the erosion is 38m deeper compared to the position of the unconformity in the B154a – B478 wells. An exception forms B480, which has a comparable erosion to B154a-B478. Erosion in B193 is 14m deeper than in B154a. Different erosional levels point to at least some differential tectonics in pre-Niedersachsen Group, Mid to Late Kimmerian phases.

In the TWR area, the most complete section is found in well B478. This section was studied in detail on the basis of cuttings samples at a single meter spacing (GL report GL07.101). Gamma Ray log correlation of this well section with other sections in the area is good (see also pg 28b) and the B478 Niedersachsen Gp. section is considered the Reference section for the area.

The section was subdivided into four lithological units designated A – D from base to top. Unit D is dominated by bioclastic limestones with much shell fragments and calcite present (pict B478-110-10, B478-121-20)). Unit C consists of interbedded claystones with common ostracods and micritic limestones with plant fragments (pict B478-127-20, pict B478-134-20). Unit B is more argillaceous and claystones are calcareous in general; micritic limestones present are rich in plant fragments; in the lower half of this unit much

gypsum nodules occur. (pict B478-156-20, B478-159-20, B478-160-10). The basal unit A consists of non to slightly calcareous claystones and micritic, locally sideritic limestones; much gypsum nodules are present (pict. B478-166-20, B478-170-20).

Lithological studies of Niedersachsen Gp. sections have furthermore been carried out on B480 (1 m sample spacing, report GL06.0406), B515 (10m sample spacing, report GL07.1001), B442 (1 sample, course 2006), B472 (2 samples, course 1999), and for report GL08.501 of the wells, B154a (1 sample), B175 (2.5m sample spacing), B185 (2.5m sample spacing), B482 (10m sample spacing), and HEN- 01 (2 samples).

Lithologies described from the B478 section could be recognized in all wells. Especially the amount of gypsum nodules varies between well sections. Gypsum nodules which are present in relatively large amounts in the A and B units of B478, B175 and B482, are near to absent in the B480, HEN- 01, B442, B472, B154a and B515 sections. In B185 substantial amounts of gypsum are present in the lower part of unit C and the uppermost part of unit B. The deeper parts of unit B and A are not covered by samples. The wells B478, B175, B482, and B185 form a cluster in the south-western part of the area and in these wells, Niedersachsen Gp. sediments are overlying Sleen Fm. This may be an indication for Late Kimmerian synsedimentary tectonics.

RGD report 545 on B386 mentions the presence of much gypsum in the sample from 130m which is in the basal section, but not from higher samples. Apart from B515, it are the thinner sections that have less gypsum nodules. Possibly, in the B515 section, gypsum concentrations have been missed because of the 10m sample interval.

Biostratigraphical work on ostracods was carried out on well B386 (RGD rept. 545) which concluded a Lower Ryazanian age for the samples at 105m and 110m and an Upper Volgian age for the samples at 120m and 125m. No samples are available for lithostratigraphic study, but based on Gamma Ray log correlation, all four samples are from the informal unit B. Palynological work on the section of B480 (TNO rept. NITG 05-074-C) gives an uppermost Jurassic to lowermost Cretaceous age for the sample at 80m and an uppermost Jurassic age for the sample at 100m. The sample at 80m originates approximately from the boundary between informal units B and C and the sample at 100m is from the boundary between the A and B units.

From the above, it can be concluded that unit B comprises the lowermost part of the Coevorden Fm. and the uppermost part of the Weiteveen Fm. Lithologically, and on Gamma Ray log character there are no features that justify a formation boundary in the study area. Only in well B175, a small sequence boundary can be recognized from the Gamma Ray log at 144.5m. The sample at 142.5m contains an intra? clastic limestone (pict B175-142.5-20) which may form the base of the Coevorden Fm. This small sequence boundary is situated 14m above the base of the Niedersachsen Gp. section. For reasons of convenience it is suggested to maintain the informal subdivision for the area which can be correlated on Gamma Ray curves.

The wells B515, B472, B442, B478, B193 and HEN-01 which have Niedersachsen Gp. sediments are located (just) outside the occurrences given on Map 10 – Sheet X, TNO-NITG. The wells B186 and B478 have thicknesses of over 60 meter but plot in the area below the 50m isopach. (see also CH 4.3 below on Altena Gp. for further discussion).

Microphotographs Niedersachsen Group



*pict. B478-110-10: SK-D
overview of sample of bioclastic limestone*



*pict. B478-121-20: SK-D
bioclastic limestone with pyrite*



*pict. B478-127-20: SK-C
light grey micritic limestone*



*pict B478-134-20: SK-C
claystone with much ostracods*



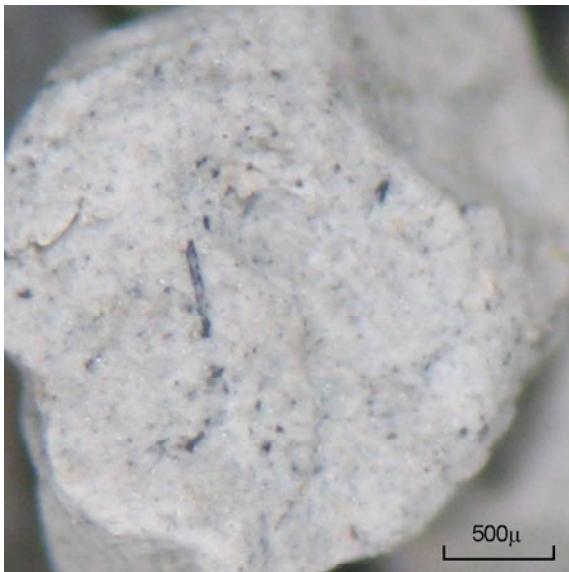
*pict. B478-156-20: SK-B
micritic argillaceous limestone with plant
fragments and traces mica*



*pict. B478-160-10: SK-B
sample of claystone with much gypsum*



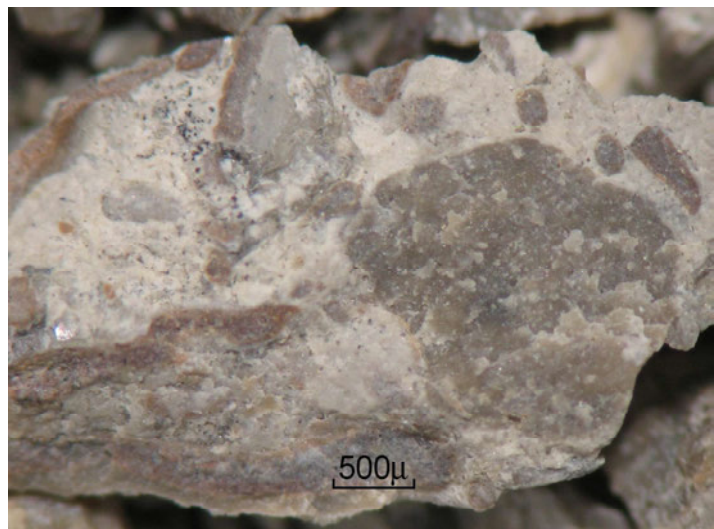
*pict. B478-159-20: SK-B
limestone with much plant fragments*



*above pict. B478-166-20: SK-A
very light grey argillaceous limestone
with plant fragments*



*pict. B478-170-20: SK-A
micritic argillaceous limestone with plant
fragments*



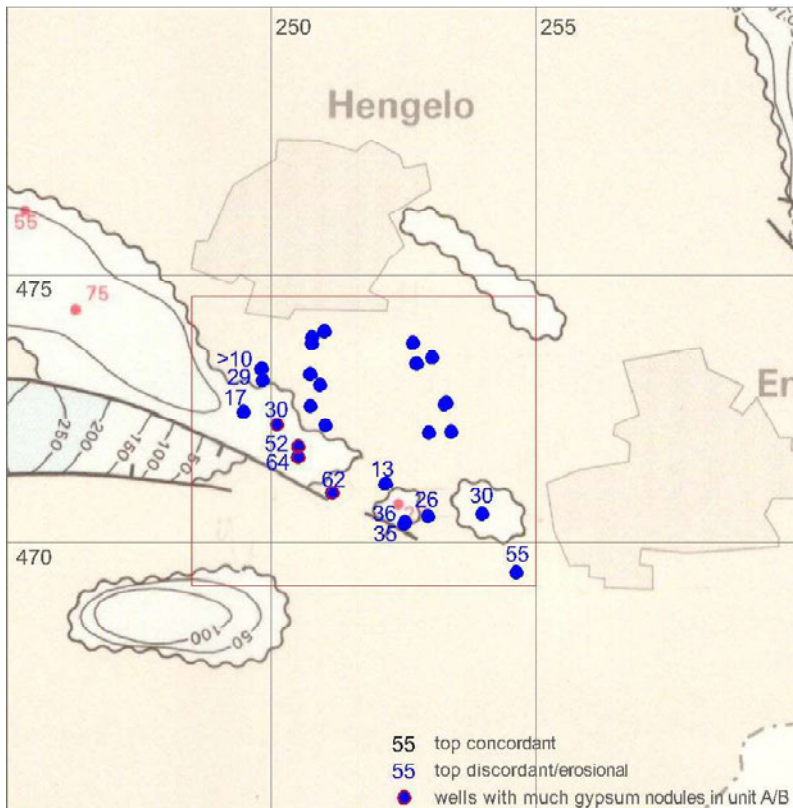
*pict. 175-142.5-20: SK-C
intra (?) clast limestone with
fragments in a micritic matrix*

Reference sections Niedersachsen Group

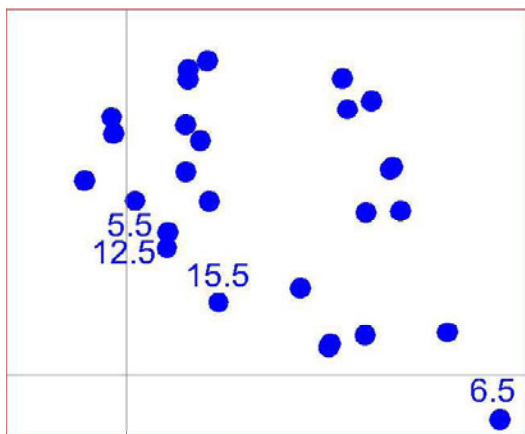
The sections of B478 is the reference section for the Niedersachsen Group in the area.

See attachments for log representation and unit descriptions and for a correlation panel with line-up at base SK.

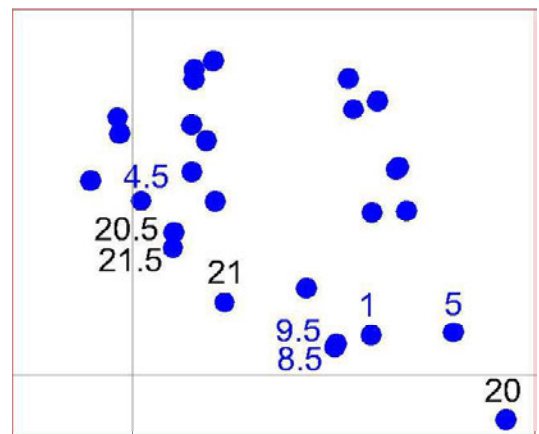
Thickness of the Niedersachsen Group and units



Thickness SK in studied wells
on background of the Geological
Atlas of the Subsurface of The
Netherlands
Sheet X, Map 10:
Thickness Niedersachsen Group

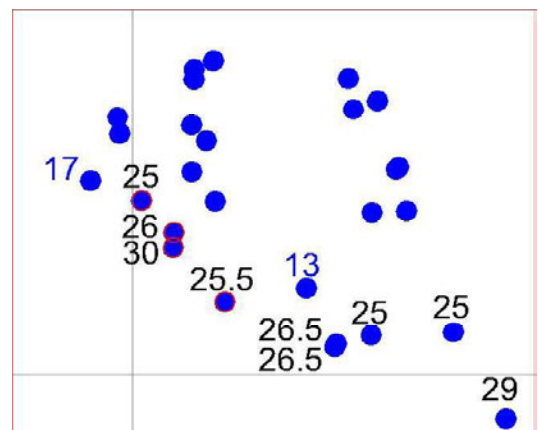


directly above: thickness SK-D

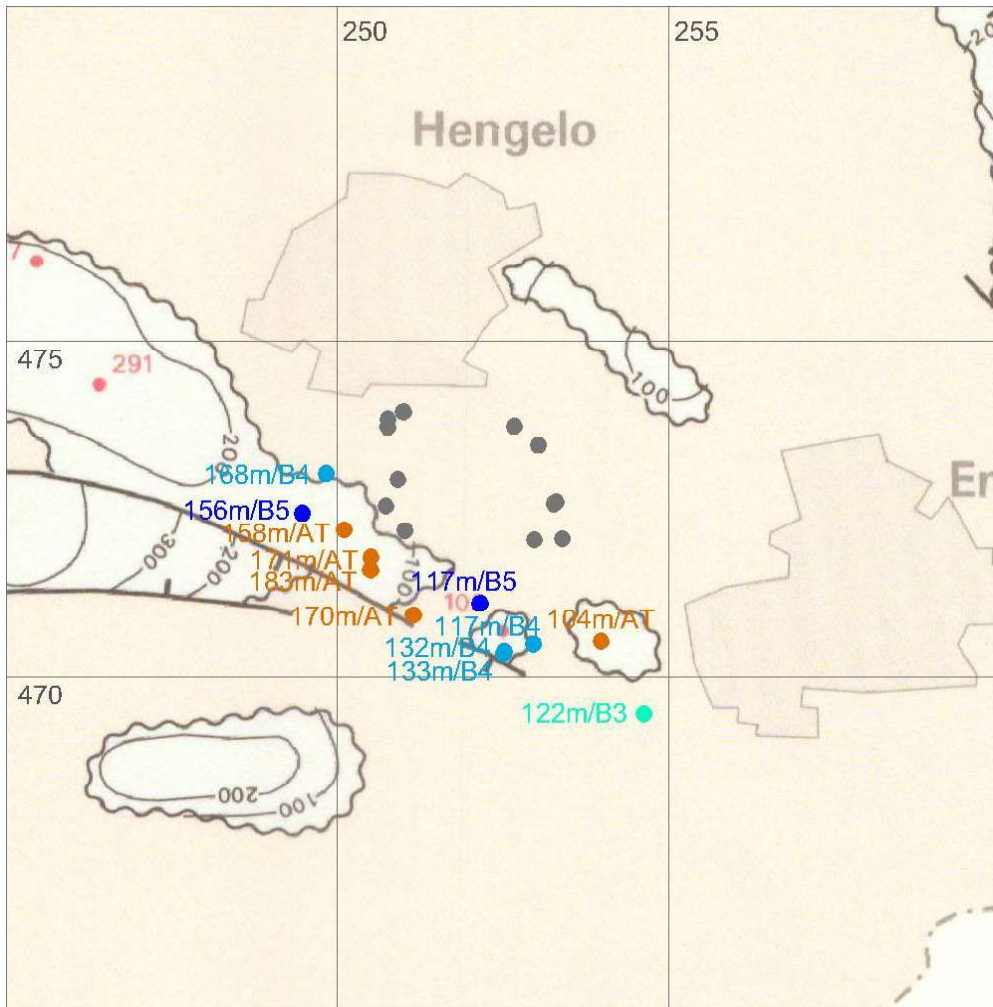


above right: thickness SK-C

right: thickness SK-AB



Depth and subcrop Niedersachsen Group



*Depth (NAP) of the base Niedersachsen Gp. found in the studied wells.
on background of the Geological Atlas of the Subsurface of The Netherlands
Sheet X, Map 9: Depth of the base of the Niedersachsen Group*

*per well the subcrop is given. (B3, B4, B5 refer to the informal units within the
Muschelkalk Formation)*

Database SK

Below thicknesses and depths of units and sub-units with reference to CF and NAP as given in the database which forms part of the current study.

All values are rounded to one decimal place.

<i>Niedersachsen Group</i>															
	<i>reference depth: m CF</i>							<i>reference depth: m NAP</i>							
	<i>Top SK</i>	<i>Base SK</i>	<i>Base D</i>	<i>Base C</i>	<i>Base A-B</i>	<i>Base B</i>	<i>Base A</i>	<i>Top SK</i>	<i>Base SK</i>	<i>Base D</i>	<i>Base C</i>	<i>Base A-B</i>	<i>Base B</i>	<i>Base A</i>	
B005															
B011															
B015															
B031															
B058															
B100															
B106															
B154a	138.9	156.3			156.3			118.7	136.1			136.1			
B175	128.5	158.3		133.2	158.3	152.6	158.3	107.6	137.4		112.3	137.4	131.7	137.4	
B186	118.2	182.6	130.9	152.6	182.6			97.52	161.9	110.2	131.9	161.7			
B193	139.2	167.9						119	147.7						
B385	98	133.2		106.6	133.2	131.4	133.2	72.13	107.3		80.73	112.3	105.5	107.3	
B386	96	132.1		105.5	132.1	129.8	132.1	70.44	106.5		79.94	111.2	104.2	106.5	
B399															
B414															
B415															
B432															
B439															
B442	104.2	117.4			117.4	111.2	117.4	79.2	92.4			92.4	86.2	92.4	
B443															
B472	90.9	117		91.9	117	112.4	117	64.0	90.1		65.0	90.1	85.5	90.1	
B478	108.3	170.4	123.9	144.9	170.4	163.8	170.4	84.8	146.9		118.0	143.5	136.9	143.5	
B480	74.9	104.4		79.7	104.4	99.3	104.4								
B482	118.9	171	124.5	145	171										
B483								46.3	75.8		51.1	75.8	70.7	75.8	
B515	67.4	122.4	73.7	93.5	122.4			96.8	148.9	102.4	122.9	148.9			

<i>Thickness Niedersachsen Group (m)</i>						
	<i>SK</i>	<i>D</i>	<i>C</i>	<i>A-B</i>	<i>B</i>	<i>A</i>
B154a	17.4			17.4		
B175	29.8		4.7	25.1	19.4	5.7
B186	64.4	12.7	21.7	30.0		
B193	28.7					
B385	35.2		8.6	26.6	24.8	1.8
B386	36.1		9.5	26.6	24.3	2.3
B442	13.2			13.0	5.8	6.2
B472	26.1		1.0	25.1	20.5	4.6
B478	62.1	15.6	21.0	25.5	18.9	6.6
B480	29.5		4.8	24.7	19.6	5.1
B482	52.1	5.6	20.5	26.0		
B515	55.0	6.3	19.8	28.9		

4.3 Altena Group – Sleen Formation

regional code: AT - ATRT

Reference section: B480

In the TWR area, locally erosional remainders of Altena Gp. sediments are found. In the B480 and B478 wells these sections are covered by samples with a 1m spacing and they were identified as Sleen Fm. In B480 and B478 the thickness of the section is 11m and 10m respectively. In both wells the Sleen Fm. is unconformably overlain by Niedersachsen Group sediments.

In a larger area, thick sections of Altena Group sediments are preserved, just south of the TWR area up to 200m is present, and north-west of the Gronau fault, some 10km north-west of the area, up to 500m of section occurs (TNO-NITG map 8). Thick occurrences of Altena Gp. sediments are nearly exclusively Aalburg Fm.; only from the Oldenzaal- 1 well also Posidonia Fm. and Werkendam Fm. is documented. In the TWR area, where Sleen Fm. is overlain by Niedersachsen Gp. deposits, truncation can be therefore dated as Mid - Late Kimmerian.

Biostratigraphical data is limited to one sample of B480 which gives a Rhaetian age based on sporomorphs (NITG report no. 05-074-C).

The lithology of the deposits in B480 and B478 is very similar; the sections can be subdivided into a lower part (A) and an upper part (B). Unit B consists of very light to light grey non silty and non calcareous claystones which are locally pyritic. Traces of clear and pale reddish gypsum nodules occur. In B480, the basal one meter of unit B has pale reddish brown shades (pict B480-109-20). The lower unit A consists of grey to brownish grey and locally slightly purple to reddish grey, non silty and non calcareous claystones which are slightly bituminous (pict B480-112-20). In B480, a siltstone is present at the base of unit A. In B478, a siltstone is present at the base of unit B.

In the wells B175, B186 and B482 thin occurrences of Sleen Fm. have been interpreted from the Gamma Ray log. In B482 no sample is available from this section but Sleen Formation lithologies have been encountered as caving in deeper samples.

In the south-eastern part of the study area occurrences of Altena Gp. sediments is indicated on the isopach map 8 – Sheet X of TNO-NITG. The plotted data point of 29m thickness probably corresponds with well B286 which is not included in the current study. B480, which plots on the 50m isopach has only 11m of section, but the total of Altena and Niedersachsen Gp. sections is 40m.

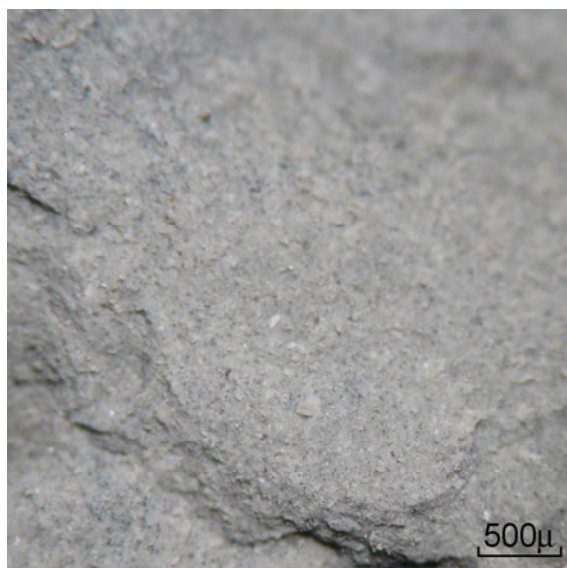
Well B515 plots in the thickest part of the indicated occurrence but no Altena Gp. sediments were found present here. The Niedersachsen Gp. section here has a thickness of 55m. It therefore has to be considered that the Altena Gp. occurrences in the south-eastern part of Map 8, are Niedersachsen Gp. and/or only Altena Gp. in part. Furthermore the Sleen Fm., recognized in the lithological studies in the wells B186, B482, B175 and B478, fall outside the occurrences of Altena Gp. sediments on the isopach map 8 – Sheet X. In the TNO database (TWR area, October 2002), both the Niedersachsen Gp. sediments and the Altena Gp. sediments are not recognized but included in the Tertiary North Sea Supergroup sediments.

Sleen Formation deposits unconformably overly the B5 sub-unit of the Muschelkalk Fm. Only in B480 they overlie the B4 sub-unit. This indicates slight differential tectonics during the Early Kimmerian phase, with the B480 well in a more easterly and slightly southerly position relative to the other wells (See also CH 3).

Microphotographs Altena Group / Sleen Formation



*pict. B480-108-10: ATRT-B
light grey to light greenish grey non silty
and non calcareous claystones*



*pict. B480-107-20: ATRT-B
detail of light grey non silty and non
calcareous claystone*



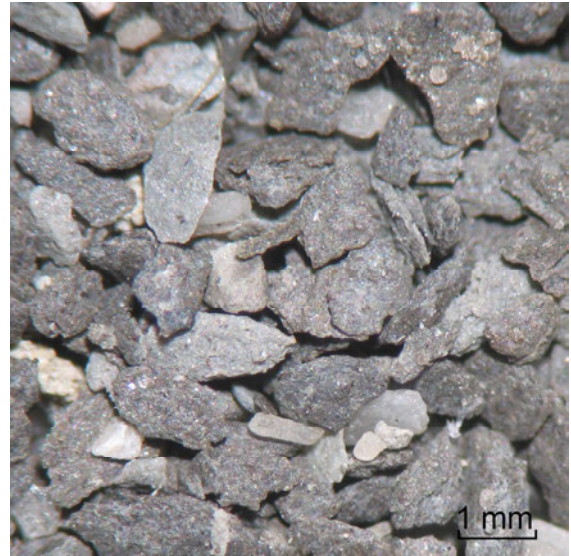
*pict. B480-109-20: ATRT-B
pale red brown non silty, non calcareous
claystone*



*pict. B175-160-10: ATRT
light reddish brown to yellowish
brown, non silty, non to very
slightly calcareous claystone*



*pict. B480-112-10: ATRT-A
brownish grey claystone, with very fine
organic matter/ plant fragments and
gypsum crystals*



*pict. B478-177-10: ATRT-A
brownish grey organic rich claystone*



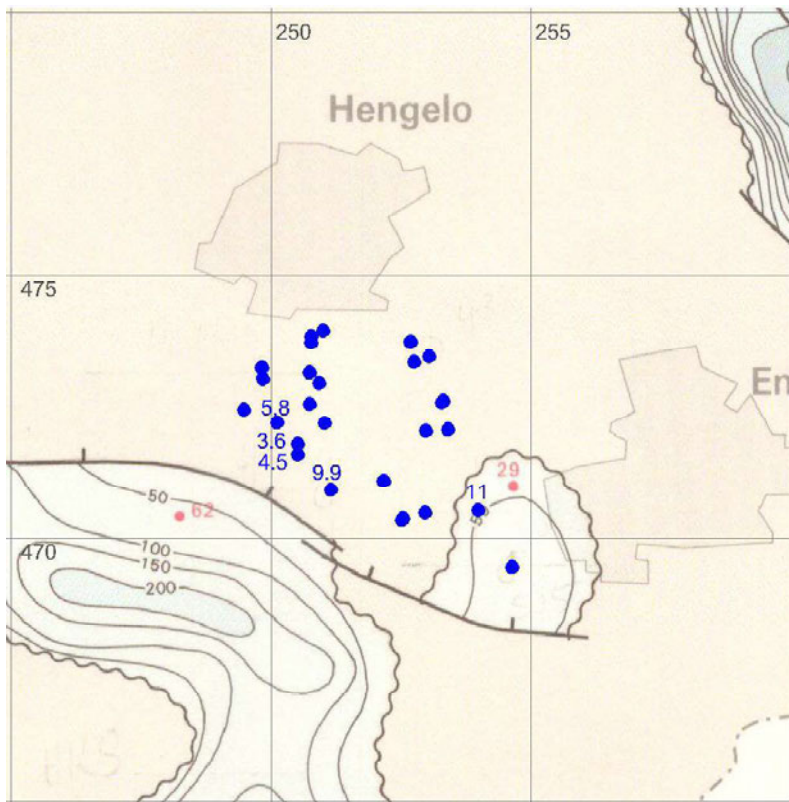
*pict. 482-180-20: ATRT
slightly bituminous fissile claystone with
very fine to fine plant fragments*

Reference sections Altena Group / Sleen Formation

The section of B480 is the reference section for the Altena Group / Sleen Formation in the area.

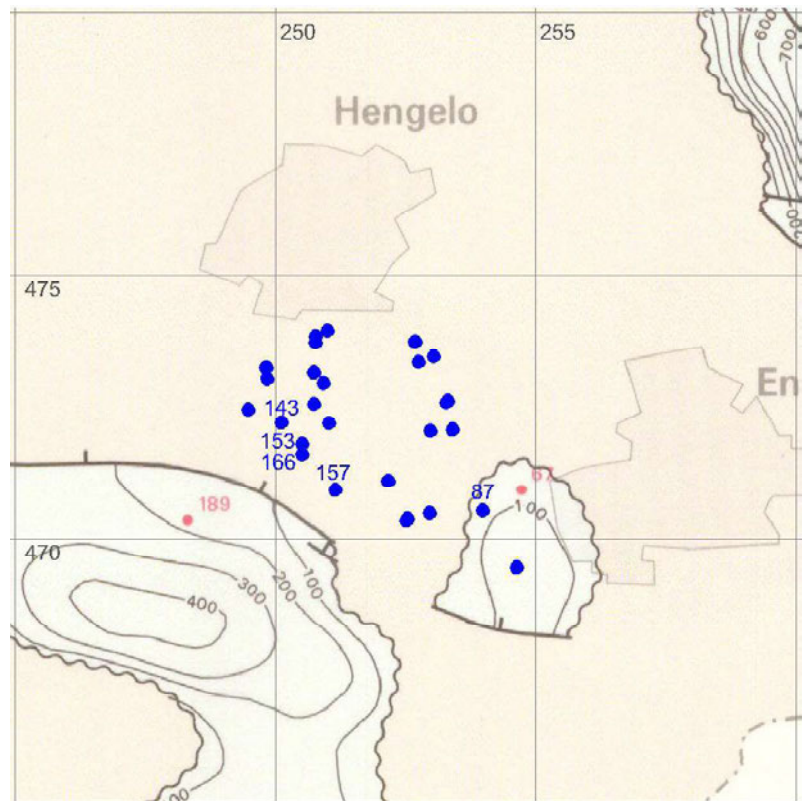
See attachments for log representation and unit descriptions.

Thickness and depth of the Altena Group – Sleen Formation



*Thickness ATRT in studied wells on background of the Geological Atlas of the Subsurface of The Netherlands Sheet X, Map 8:
Thickness of the Altena Group*

*Depth base ATRT (NAP) in studied wells on background of the Geological Atlas of the Subsurface of The Netherlands Sheet X, Map 7:
Depth of the base of the Altena Group*



Database ATRT

Below thicknesses and depths of units and sub-units with reference to CF and NAP as given in the database which forms part of the current study.

All values are rounded to one decimal place.

Altena Group / Sleen Formation	reference depth: m CF				reference depth: m NAP				thickness (m)	
	Top	Base	Top	Base	Top	Base	Top	Base	AT	ATRT
	AT	AT	ATRT	ATRT	AT	AT	ATRT	ATRT		
B005										
B011										
B015										
B031										
B058										
B100										
B106										
B154a										
B175	158.3	164.1	158.3	164.1	137.4	143.2	137.4	143.2	5.8	5.8
B186	182.6	187.1	182.6	187.1	161.9	166.4	161.9	166.4	4.5	4.5
B193										
B385										
B386										
B399										
B414										
B415										
B432										
B439										
B442										
B443										
B445										
B446										
B447										
B472										
B478	170.4	180.3	170.4	180.3	146.9	156.8	146.9	156.8	9.9	9.9
B479										
B480	104.4	115.4	104.4	115.4	75.8	86.8	75.8	86.8	11.0	11.0
B482	171.0	174.6	171.0	174.6	148.9	152.5	148.9	152.5	3.6	3.6
B483										
B515										

4.4 **Muschelkalk Formation**

regional code: RNMU

Reference sections

unit B:	B480
unit A:	B483

Except for the north-eastern part of the area, the Muschelkalk Fm. is found in the entire study area; the most complete sections are in the southern and south-western parts, in the central parts the Formation is partly eroded and in the north-eastern part the Formation is completely eroded. In the latter part of the area North Sea Supergroup sediments are found overlying the Röt Formation. The Muschelkalk Fm. conformably overlies the Röt Fm., and it is unconformably overlain by the Sleen Fm. or younger strata like Niedersachsen Gp. or North Sea Supergp. sediments. Thickness variations are erosional and caused by various tectonic phases. Wherever Muschelkalk is overlain by Sleen Formation sediments this points to a Early Kimmerian unconformity. Except for B480 where it overlies the B4 sub-unit, the Sleen Formation overlies the B5 sub-unit. Wherever Muschelkalk is directly overlain by Niedersachsen Gp. sediments the unconformity is Mid to Late Kimmerian. The Niedersachsen Group sediments overly the B5 sub-unit in well B154a and B442, the B4 sub-unit in B385, B386 and B472 and the B3 sub-unit in B515. Further to the north where the Muschelkalk Formation is directly overlain by the North Sea Supergroup sediments the unconformity is Mid Kimmerian to Sub-Hercynian. Biostratigraphical age dating has been performed by TNO – NITG (rept. 05-074-C) on palynomorphs of B480, which suggests a Ladinian or older age for the lower part of the Muschelkalk Fm. ((180) – (230m)) and a Ladinian to Carnian age for the upper part of the Formation ((120) – (160m)). Regionally, the Muschelkalk Fm. is of an Anisian to Ladinian age, which is in line with the NITG findings. Carnian ages are a bit young for Muschelkalk Fm., but the Ladinian to Carnian assessment can still mean a Ladinian age as long as not exclusively Carnian is stated.

The Formation is well documented in B480 of which samples were studied at a one-meter sample interval (report GL06.0406). The Muschelkalk Fm. of well B483 was studied at the same sample interval meter, but here most of the upper part of the section is truncated (report GL07.1001). Also of well B478 samples were studied in detail but good results were not obtained because of the amount of caving from the Niedersachsen Gp. section. Samples of the Muschelkalk sections of the wells B515, B154a, B482 and B185 were studied at a 10m interval which does not allow for much detail, but still good enough to determine the main lithologies (report GL08.501).

Muschelkalk occurrences in the area can be subdivided in a lower A section and an upper B section. The lower section can be further subdivided in 13 informal lithological units and sub-units; the upper B section is subdivided in 5 informal units. Units and sub-units can be correlated across the entire study area.

Although the name Muschelkalk suggests limestone with shells, the main lithology is dolomite which is locally calcareous to a certain degree. Non dolomitic limestones have not been encountered in the samples. Shells or shell fragments are near to absent, only occasionally a recrystallized shell fragment is found.

In the early days of drilling in the Netherlands, the German stratigraphy was followed and base Muschelkalk was laid at the occurrence of the first redbrown claystones in a downward direction. Following the current subdivision this is at the top of sub-unit A2c;

but thin intercalations of redbrown claystone also occur higher up (sub-units A4a and A4e). Later, when wireline logs became available, base Muschelkalk was re-defined to its current position which forms an excellent marker on the Gamma Ray log throughout the basin. When processing old well data without wireline logs this should be taken into account.

The Muschelkalk B section in well B480 is not complete, with the B5 unit missing. In a number of wells, situated to the west and to the south of B480, an amount of B5 section is present which ranges in thickness from 4 to 11m. Thickness variations within this unit and within the B4 unit, when it is overlain by Sleen Fm., are due to Early Kimmerian erosion.

The Muschelkalk B section consists of relatively clean dolomites with only minor intercalations of light greenish grey claystones. The massive nature of this package is also reflected by the Gamma Ray log pattern, which differs considerably from the pattern across the underlying A section. Crystallinity of the dolomites ranges from very fine to saccharoidal to slightly saccharoidal to cryptocrystalline. Within the B section, crystallinity becomes finer with depth.

The Muschelkalk B section is characterized by a repetition of meter scale cycles which start at the base with argillaceous and calcareous dolomites and locally claystones, upwards dolomites become cleaner and less calcareous and locally with increased concentrations of gypsum nodules and veins. The relationship between dolomitisation and gypsum occurrences was discussed in the report on B480; here the cleaner dolomites with better developed crystallinities are usually associated with gypsum. In subsequent studies clean and crystalline dolomites were also found without gypsum.

The uppermost unit B5 is well defined in B478; it consists of saccharoidal to very finely crystalline dolomites which are silty and generally with mica (pict 478-183-20d). In the lower part light greenish grey dolomitic claystones are found (pict 478-185-20). In B478, the B5 unit is partly eroded, in other wells as B154a, these claystones also occur in the topmost part. Gypsum occurrences could not be specified from the B478 section because of the presence of caving from Niedersachsen Gp. gypsum. In a sample from B154a, however gypsum nodules and veins were found. Unit B5 is preserved in the south-western part of the area (see subcrop map).

Unit B4 consists of relatively clean saccharoidal to very finely crystalline dolomites which are locally silty with mica and often have gypsum veins in the upper part (pict B480-117-20f). Dolomites in the lower part are more argillaceous and slightly calcareous to calcareous and mainly cryptocrystalline. Originally, the lower boundary of unit B4 was laid at 125m in B480, but for practical reasons it was shifted downward to the top of the low GR readings at 128m which forms a good marker in the area. As already mentioned in the above, the relationship between clean and crystalline dolomites and gypsum is not always clear; a sample from B482 has saccharoidal to very fine crystalline dolomites (pict B482-190-20) and good traces of gypsum nodules and not so much veins. A sample from B154a with crystalline dolomites does not show any gypsum. Also, a sample from B106 is devoid of gypsum. Unit B4 has a fairly uniform thickness of approximately 11m; only in B480 and B472 it is slightly thicker with 13m (see thickness maps). In the latter two wells the unit is unconformably overlain by sediments of the Niedersachsen Group.

Unit B3 is well defined on the Gamma Ray log and it can be followed across the entire area. It is a section of cryptocrystalline (pict B482-200-20) and locally slightly saccharoidal to saccharoidal dolomites which are generally slightly calcareous to calcareous and

locally argillaceous. The cleaner and more crystalline dolomites are non calcareous. Dolomites are locally silty with mica. Locally, traces of gypsum nodules occur (pict B154a-180-20). The basal portion of B3 in B480 is formed by a thin redbrown claystone bed which is well expressed on the Gamma Ray log. As can be seen from the thickness map of unit B3, it does not show much variation in thickness, only in B154a and B193 it is slightly thinner.

Unit B2 is a thin section of cryptocrystalline to saccharoidal non calcareous dolomites (pict B480-148-20) which are slightly argillaceous near the base of the unit or which have thin argillaceous laminae (pict 482-220-20). The unit is easily recognized on the GR log, the thickness map suggests a slight increase in thickness from north west to south east. Unit B1 consists of a section of cryptocrystalline dolomites which are generally slightly calcareous to calcareous (pict B154a-210-20). Only in B515 dolomites in this unit are non calcareous. Dolomites are locally silty with mica and locally argillaceous (pict B480-159-20). Only locally (B482) traces of gypsum nodules and veins are found. The base of the B1 unit is formed by the top of the redbrown claystones of the A4h sub-unit. The very constant thickness of the B1 unit is illustrated in the thickness map.

The Gamma Ray log pattern across the lower Muschelkalk A section is of a more variable nature compared to that of the B section. This is also expressed by the lithologies in the samples. Dolomites are mainly cryptocrystalline and only locally slightly saccharoidal. They are intercalated with redbrown and minor light greenish grey dolomitic claystones. Dolomites are commonly argillaceous and calcareous but the cleaner dolomites that can be also recognized on the Gamma Ray log, are non calcareous. Units and sub-units distinguished can be recognized in all wells in the area, except for the sub-units A4a and A4b, which cannot always be differentiated (e.g. B482). Unit A4 is subdivided into 8 sub-units indicated a – h. The total A4 package has a very constant thickness in the area (see thickness map unit A).

Sub-unit A4h is a thin bed of redbrown silty and dolomitic claystone with mica.

Sub-unit A4g is a section of argillaceous and calcareous dolomites (pict 480-174-20) which are locally silty with mica and which in B483 locally grade to siltstones (pict B483-111-20). Also in B483, locally gypsum nodules and veins are found.

Sub-unit A4f consists of a thin section of cryptocrystalline and slightly saccharoidal to saccharoidal dolomites which are non argillaceous and non calcareous in the upper part (pict B480-176-20). With depth the dolomites become more argillaceous and calcareous. In the section in B480 gypsum nodules and veins are common. Also in B478 and in B482 gypsum nodules are found.

Sub-unit A4e is a thin bed of redbrown and purple grey, silty and dolomitic claystone (pict B483-120-20) with clear to white and pale reddish to orange gypsum nodules and veins.

Sub-unit A4d is a cryptocrystalline dolomite (pict B483-123-20a) which is locally slightly saccharoidal in the upper part. Dolomites are locally silty with mica and they become more argillaceous and more calcareous with depth. The base of the section is formed by a redbrown silty and dolomitic claystone. Traces of gypsum nodules are common and in B480 also traces of veins are present.

Sub-unit A4c is a section of cryptocrystalline dolomites which are slightly sacharoidal in the upper part (pict B483-125-20). Dolomites again become more argillaceous and calcareous with depth. In B480, the section is less calcareous and also has common gypsum nodules which are largely absent in the B483 section. The unit thickness distribution shows a slight increase in thickness in a south-eastern direction but this may not be significant.

Sub-units A4a and A4b can not be differentiated in all wells. The thickness map of the sub-units A4a and A4b together shows a slightly increased thickness in wells in the westernmost part of the area. Sub-unit A4b comprises a thin section of argillaceous and calcareous dolomites which are locally silty with mica (pict B483-130-20). In B480 and B154a, also siltstones occur with a dolomitic / calcareous cement. In the B154a section gypsum nodules are present and in B482 gypsum nodules and veins occur. Sub-unit A4a is a thin bed of redbrown and very light greenish grey calcareous or dolomitic claystone which is silty and gradational with siltstones in B483 and non silty in B480 (pict B480-196-20). Additionally, light grey and light reddish brown calcareous / dolomitic siltstone are found. In B480, orange gypsum nodules are present.

Unit A3 is a section of cryptocrystalline to slightly sacharoidal dolomites, which, especially in the middle part, are argillaceous and locally calcareous. Dolomites are locally silty with mica and are sometimes gradational with siltstones. Larger concentrations of siltstone are present in the lower part of the unit. Locally gypsum nodules are found (pict B483-139-20) and in B480 traces of gypsum veins are present. The thickness map shows increased thicknesses in an easterly and north-easterly direction.

Unit A2 forms the most argillaceous part of the Muschelkalk section. The thickness distribution does not show a particular trend. Sub-unit A2c consists of cryptocrystalline and locally slightly sacharoidal dolomites (pict B483-146-20) which are calcareous and argillaceous in general but locally slightly calcareous and slightly argillaceous. High GR peaks are not only caused by the presence of claystones (pict B480-205-10) but also by concentrations of very light grey to very light greenish grey siltstones with calcareous / dolomitic cement and locally much mica (pict B483-143-20). Claystones have light to medium redbrown, light brownish grey and minor light greenish grey shades with often a mottled appearance. Gypsum nodules are found both related with the claystones and with the dolomites. In B480, next to gypsum nodules also white and amorphous anhydrite / gypsum is found.

Sub-unit A2b is dominated by slightly calcareous to calcareous and argillaceous dolomites (pict B480-213-10) which are cryptocrystalline and locally slightly sacharoidal (pict B483-150-20). Claystones are again mottled light to medium redbrown, light brownish grey and light greenish grey (pict B483-154-20). Large concentrations of siltstones, as they are found in the overlying sub-unit, do not occur. In the B483 section much gypsum nodules and minor veins are present in the basal part of the section. In B480 more of the white and amorphous anhydrite / gypsum is found and only traces of gypsum nodules.

Sub-unit A2a is the most argillaceous part of the A2 unit, especially the basal portion. Claystones are light to medium redbrown and minor light greenish grey and mottled. Dolomites present are cryptocrystalline to slightly sacharoidal and are locally found associated with gypsum nodules and veins (pict B483-161-20). In B480 both gypsum nodules and white and amorphous anhydrite / gypsum is present.

Sub-unit A1 is characterized by large amounts of gypsum nodules (B483) or amorphous white anhydrite / gypsum (B480). Also, dolomite and claystone lithologies can be rich in gypsum nodules and veins (pict B483-166-20, B483-169-20b). The claystone bed in the middle of the section can be recognized in the entire TWR area.

The entire Muschelkalk section reflects deposition in a coastal sebkha environment with emersion and/or non deposition at times, during which dolomitisation of the primary calcareous deposits took place. Dolomitisation was syndimentary to very early diagenetic. Evaporitisation resulted in Mg enriched brines and the original calcareous deposits were dolomitised, together with the formation of calcium sulfates. The gypsum could fill desiccation cracks or was deposited as laminae. In the samples of B480, gypsum veins and nodules co-occur with the dolomitic facies.

The section in B480 has relatively much veins compared to other well sections in which predominantly gypsum nodules occur and it cannot be excluded that the veins represent a later phase, possibly post Sub-Hercynian. Indications for a later vein filling phase were found in B154a which shows syndimentary to very early diagenetic orange gypsum nodules which are cut by clear gypsum veins (pict 154a-250-20 and 20b). Indications for a possible stress related vein growth may be the occasional presence of gypsum crystals which are at an angle with the vein (pict HEN-01-220-20) whereas they are in general found perpendicular to the vein.

Siltstones rich in mica are present in the entire section both in the argillaceous facies and in the dolomite facies. They probably represent sheet flood events and/or small scale fluvial deposits.

In general, crystallinity of the dolomites decreases with depth, saccharoidal dolomites with a very fine crystallinity being found in the topmost units B4 and B5. Deeper, the very fine crystallinity still occurs locally, but a finer, slightly saccharoidal crystallinity becomes predominant. Throughout the section, saccharoidal dolomites occur together in the samples with cryptocrystalline, slightly calcareous and slightly argillaceous dolomites. The repetition is one of small sub cycles starting with a slight rise in sea water level during which argillaceous carbonates were deposited, an ongoing sea level rise during which the cleaner carbonates were deposited, and a following stagnation or slight drop of the water level during which brines became more concentrated and dolomitisation took place. The scale on which this occurs is in the order of a few meters of sediment.

The thickness distribution of a number of units and sub-units show a certain trend, whereas other units have more or less equal thicknesses across the area. Unit A3, which consists predominantly of dolomites is slightly thinner in the westernmost part of the area (wells B154a, B193 and B175). The thicknesses of the total of sub-units A4a and A4b, which are mixed clastic and carbonate, show a slight thickening in the westernmost area. The thickness distribution of unit A4c, which is mainly carbonate, shows a slight thickening towards the east and south east. Thicknesses of B2, which is a relatively clean carbonate is slightly thinner in the westernmost part. Also B3, which consists of relatively clean carbonates is thinner in the westernmost part. Unit B4 is slightly thicker in the south-eastern part. In the case of a complete absence of syndimentary tectonics, any paleo relief would have disappeared in a long lasting setting of shallow water progradational basin infill and it is assumed that some minor movements have taken place.

Microphotographs Muschelkalk Formation



*pict. B478-183-20d: RNMU-B5
very silty sacharoidal dolomite with mica*



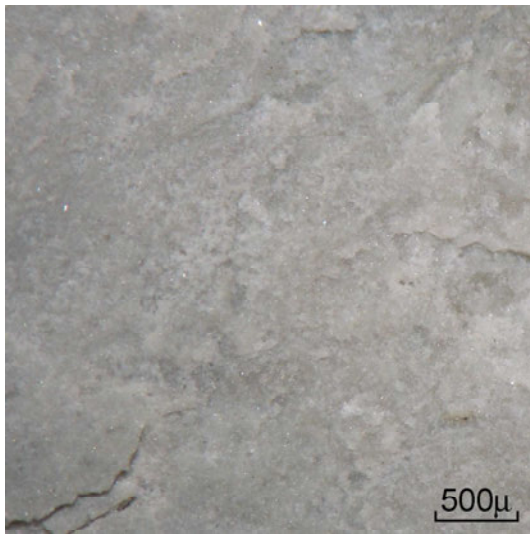
*pict. B478-185-20: RNMU-B5
very light greenish grey calcareous /
dolomitic claystone*



*pict. B480-117-20f: RNMU-B4
sacharoidal dolomite with attached
gypsum vein*



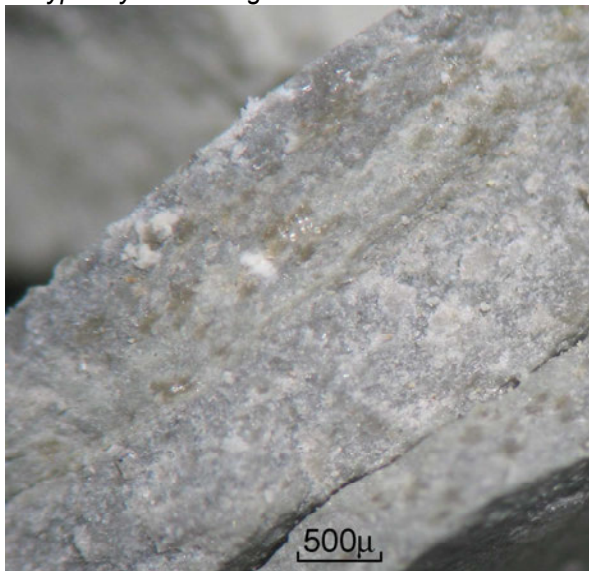
*pict. B482-190-20: RNMU-B4
very fine crystalline dolomite*



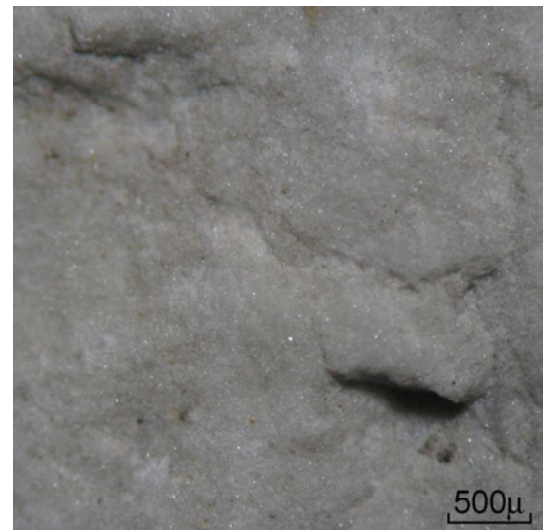
*pict. B482-200-20: RNMU-B3
cryptocrystalline argillaceous dolomite*



*pict. B154a-180-20: RNMU-B3
sacharoidal dolomite with gypsum nodules*



*pict. B482-220-20: RNMU-B2
cryptocrystalline dolomite with argillaceous
laminae*



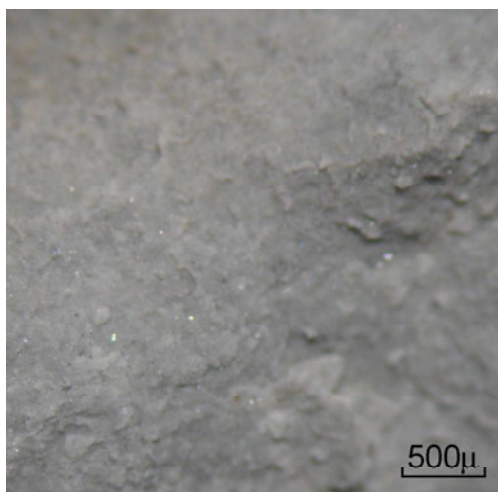
*pict 480-148-20: RNMU-B2
slightly argillaceous slightly sacharoidal
non calcareous dolomite*

*below pict. B154a-210-20: RNMU-B1
calcareous cryptocrystalline dolomite*

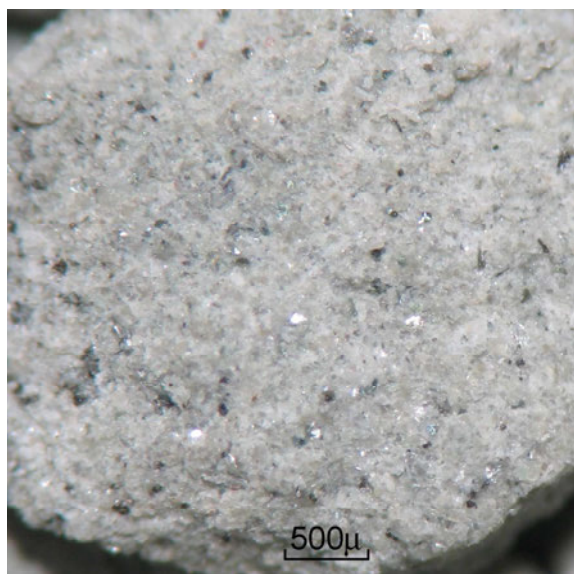


*below pict. B480-159-20: RNMU-B1
sacharoidal argillaceous dolomite with thin
argillaceous laminae*





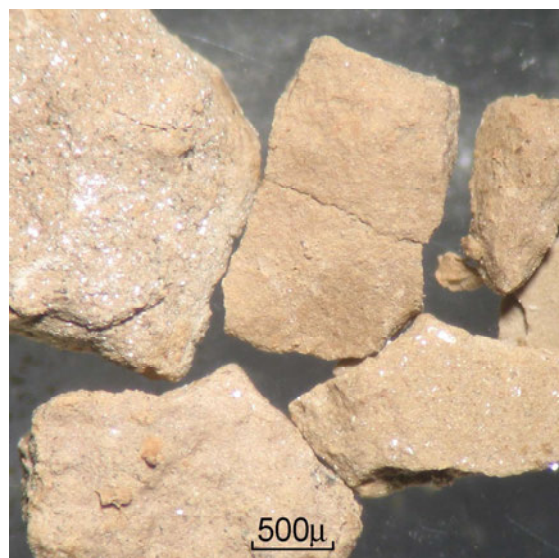
*pict. B480-174-20: RNMU A4g
argillaceous calcareous dolomite*



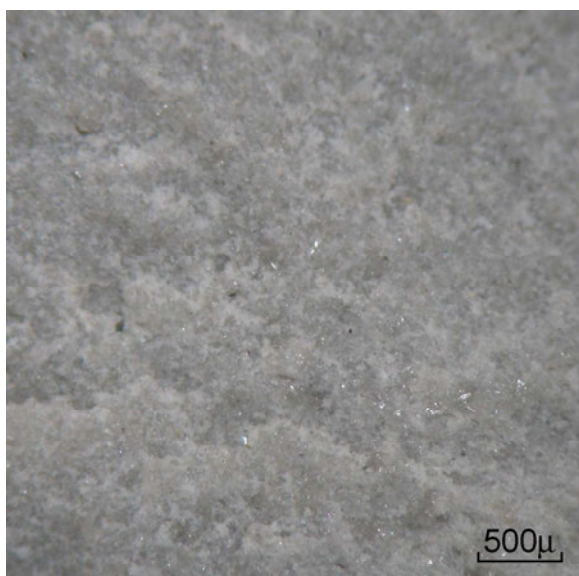
*pict. B483-111-20: RNMU-A4g
argillaceous calcareous very silty
dolomite with very fine mica grading to
siltstone*



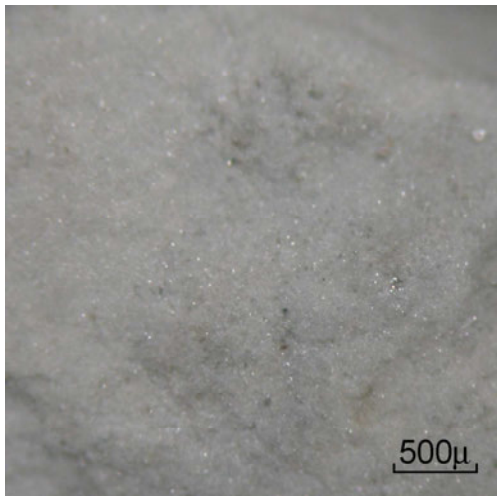
*pict. B480-176-20: RNMU: A4f
non argillaceous, non calcareous sacharoidal
dolomite with gypsum nodule*



*pict. B483-120-20: RNMU-A4e
light to medium redbrown silty claystone
with much mica*



*pict. B483-123-20a: RNMU-A4d
cryptocrystalline dolomite*



*pict. B483-125-20: RNMU-A4c
slightly saccharoidal non calcareous
dolomite*



*pict. B483-130-20: RNMU-A4b
silty calcareous dolomite with mica*



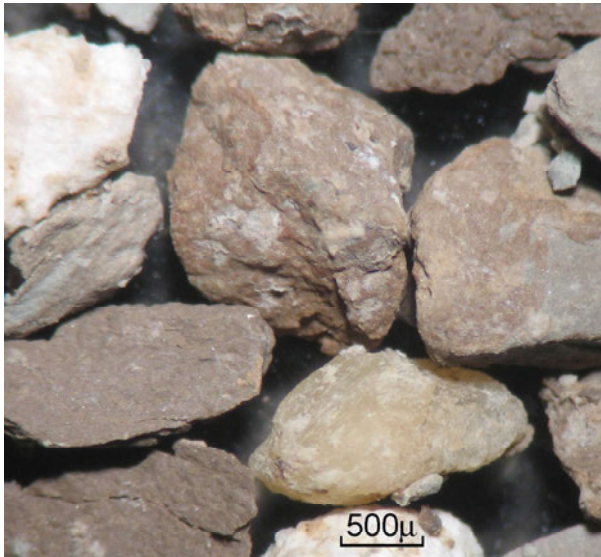
*pict. B480-196-20: RNMU-A4a
light reddish brown non silty claystone*



*pict. B483-139-20: RNMU-A3
silty dolomite with mica and gypsum
crystals/nodules*

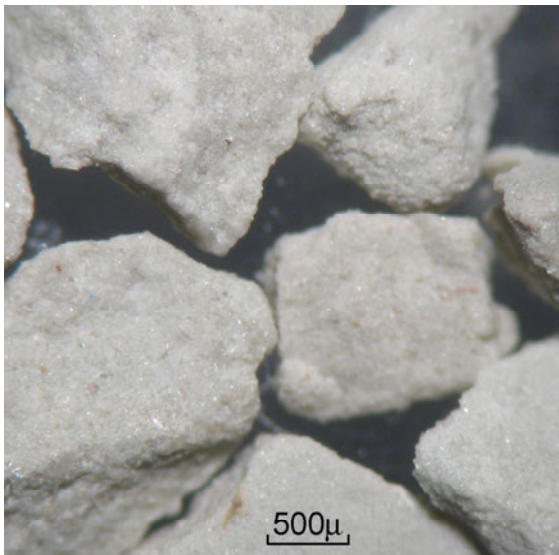
*pict. B483-146-20: RNMU:A2c
slightly saccharoidal calcareous dolomite*





*pict. B480-205-10: RNMU-A2c
mottled red and grey claystones, white
gypsum/anhydrite and pale yellowish gypsum
nodules*

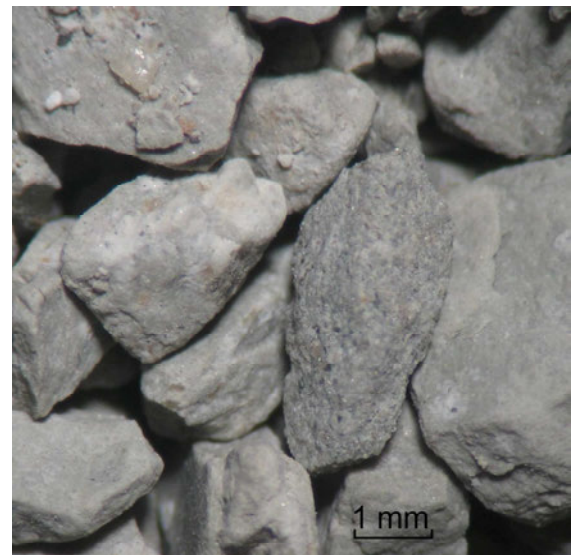
*right, pict B480-213-10: RNMU-A2b
beige to very light brownish grey
cryptocrystalline dolomite and very
light grey siltstone*



*left, pict. B483-150-20: RNMU-A2b
slightly saccharoidal dolomite*



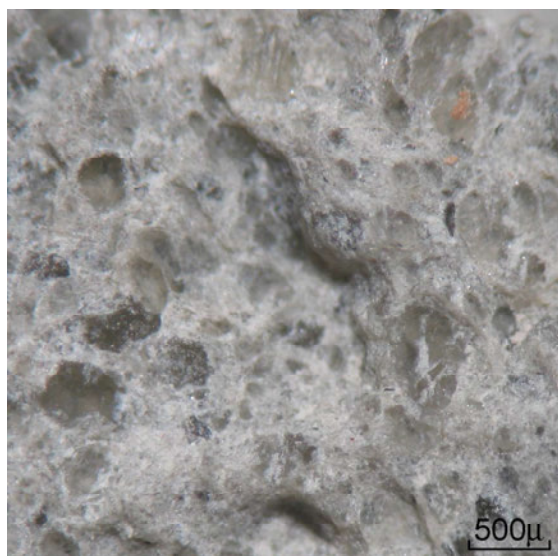
*pict. B483-143-20: RNMU-A2c
siltstone with calcareous / dolomitic
cement and very fine mica*



*right, pict. B483-154-20: RNMU-A2b
mottled very dolomitic claystone*



*pict. B483-161-20: RNMU-A2a
slightly saccharoidal dolomite with
gypsum nodules and veins*

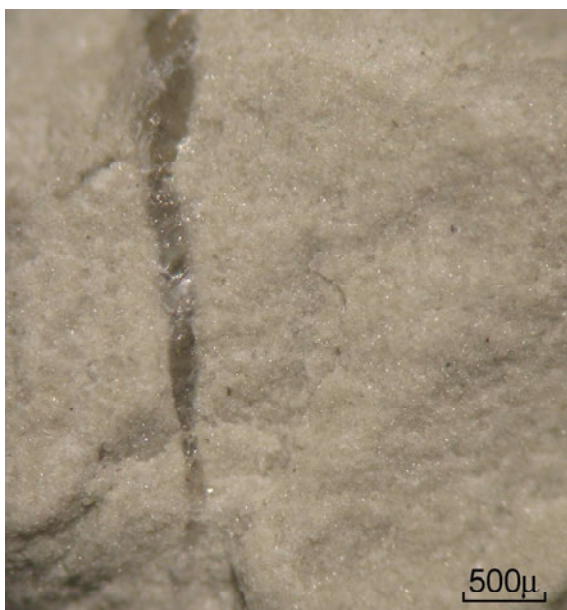


*pict. B483-166-20: RNMU-A1
slightly saccharoidal dolomite with
abundant gypsum nodules*

*right, pict. B483-169-20b: RNMU-A1
dolomitic claystone with gypsum
veins*



*below, pict. HEN-01-220-20
beige slightly saccharoidal dolomite with
gypsum vein with oblique crystals*



*pict. B154a-250-20a:
orange gypsum nodule with
clear gypsum vein*

Reference section Muschelkalk Formation

The section of B483 is the reference section for unit RNMU-A

The section of B480 is the reference section for unit RNMU-B.

See attachments for log representation and unit descriptions.

Thickness RNMU

121 top concordant

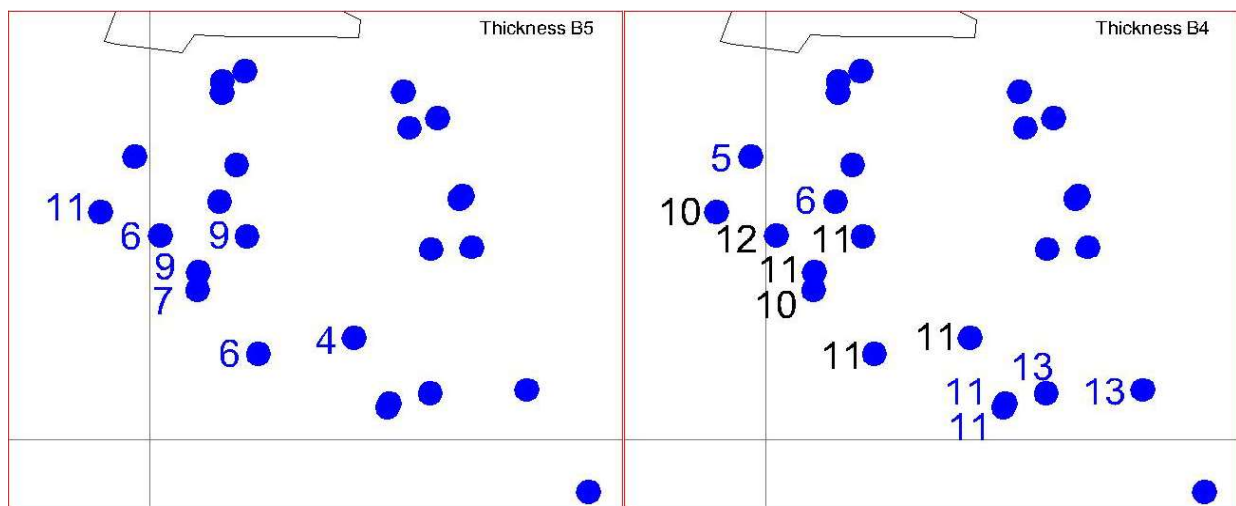
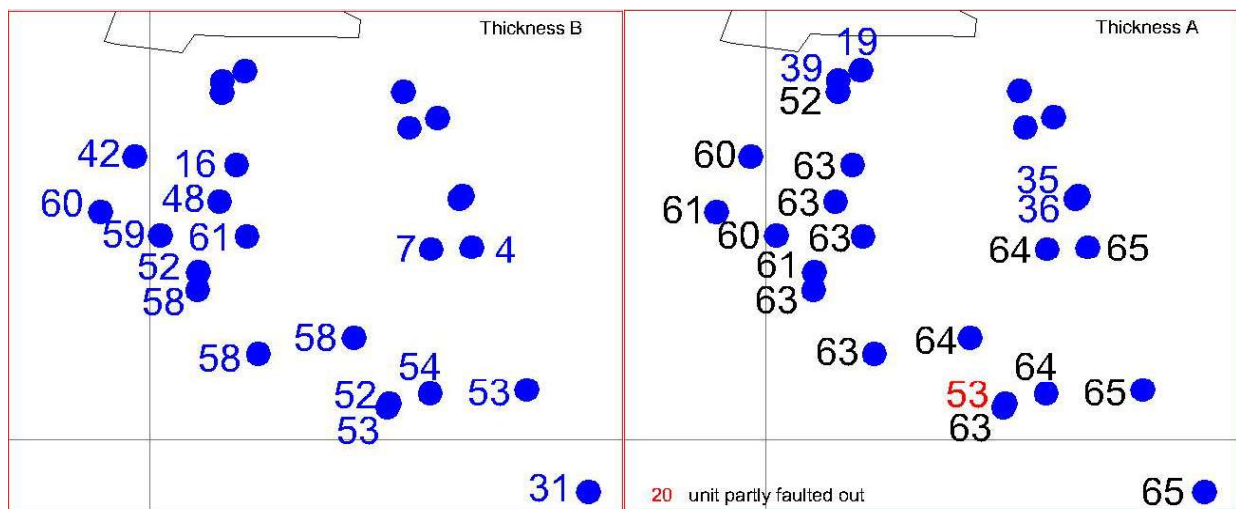
121 top discordant

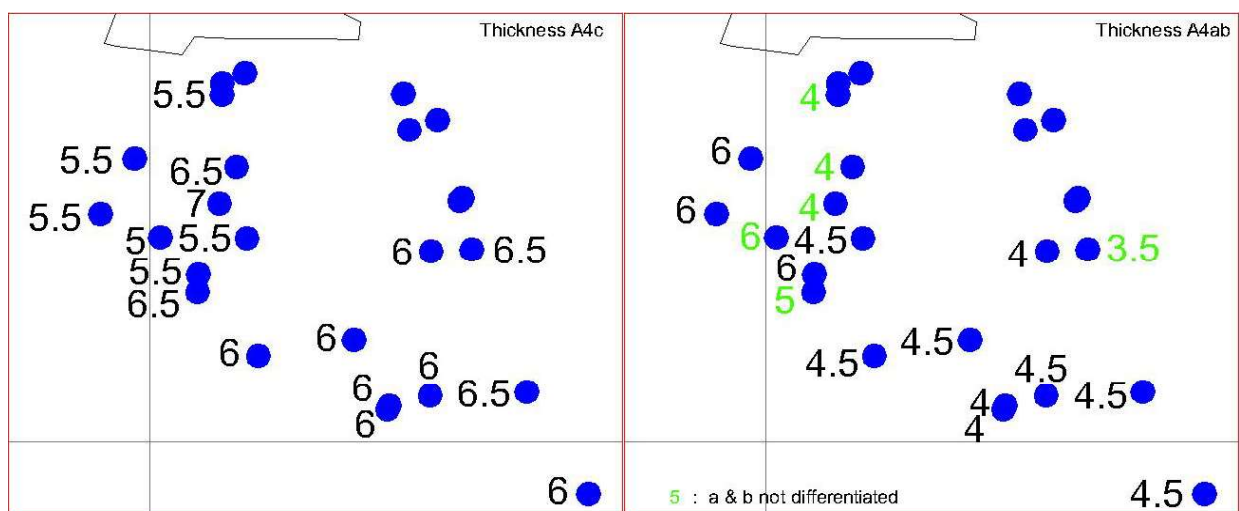
96

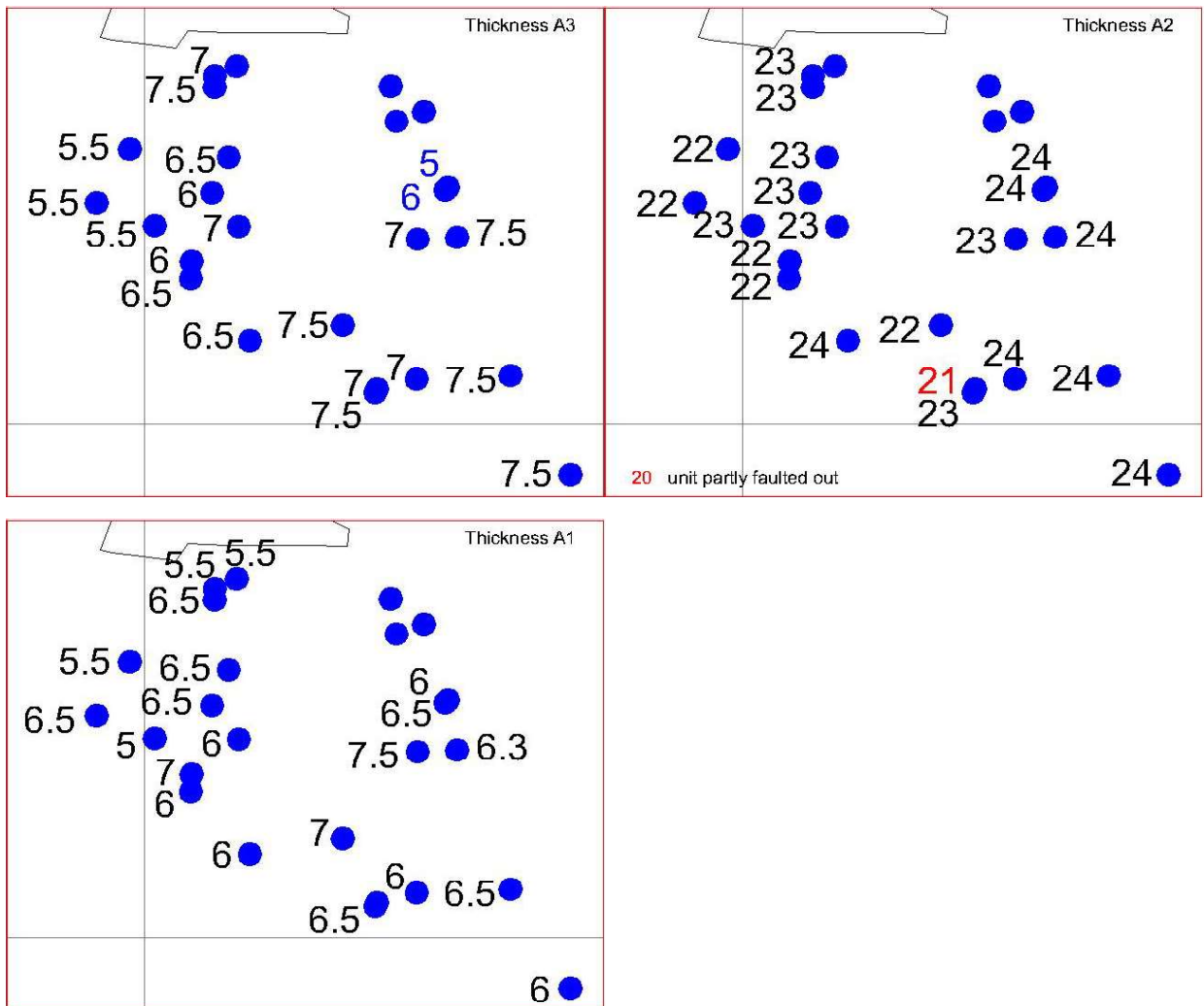
increased truncation

B3

Subcrop map below top Muschelkalk / top Röt unconformity.







Database RNMU

Below thicknesses and depths of units and sub-units with reference to CF and NAP as given in the database, which forms part of the current study.

All values are rounded to one decimal place.

	Muschelkalk Formation							reference depth: m NAP						
	reference depth: m CF							reference depth: m NAP						
	Top RNMU	Base RNMU	Base B5	Base B4	Base B3	Base B2	Base B1	Top RNMU	Base RNMU	Base B5	Base B4	Base B3	Base B2	Base B1
B005	133.1	151.7						113.0	131.6					
B011	134.6	186.7						114.8	166.9					
B015	132.4	171.5						112.8	151.9					
B058	126.6	204.8				128.2	142.1	105.6	183.8				107.2	121.1
B100	124.7	234.9		130.5	151.4	156.2	172.2	103.6	213.8		109.4	130.3	135.1	151.1
B106	119.1	243.7	127.6	138.7	160.0	164.8	180.4	96.8	221.4	105.3	116.4	137.7	142.5	158.1
B154a	156.3	276.4	166.8	177.1	195.8	200.2	215.9	136.1	256.2	146.6	156.9	175.6	180.0	195.7
B175	164.1	283.0	170.1	182.2	203.0	206.5	222.6	143.2	262.1	149.2	161.3	182.1	185.6	201.7
B186	187.1	308.1	194.2	204.5	225.6	230.4	245.3	166.4	287.4	173.5	183.8	204.9	209.7	224.6
B193	175.9	278.2		180.4	198.3	202.4	218.1	155.7	258.0		160.2	178.1	182.2	197.9
B385	133.2	249.2		144.5	165.8	170.5	186.1	107.3	223.3		118.6	139.9	144.6	160.2
B386	132.1	237.0		142.8	163.6	168.8	184.1	106.5	211.4		117.2	138.0	143.2	158.5
B399	96.1	164.2					99.7		137.5					73.0
B414	100.0	136.2							110.0					
B415	100.4	135.2							108.8					
B439														
B442	117.4	238.9	121.8	132.4	154.7	159.5	175.3	92.4	213.9	96.8	107.4	129.7	134.5	150.3
B443														
B472	117.0	234.8		129.5	150.4	155.3	171.0	90.1	207.9		102.6	123.5	128.4	144.1
B478	180.3	301.2	185.8	196.9	217.3	222.3	237.9	156.8	277.7	162.3	173.4	193.8	198.8	214.4
B480	115.4	233.3		127.9	147.8	152.9	168.4	86.8	204.7		99.3	119.2	124.3	139.8
B482	174.6	296.5	183.4	193.9	215.0	219.7	235.4	152.5	274.4	161.3	171.8	192.9	197.6	213.3
B483	99.7	171.9					107.0	74.6	146.8					81.9
B515	122.4	218.1			131.6	136.9	153.0	90.5	186.2			99.7	105.0	121.1

<i>Muschelkalk Formation</i>															
<i>m CF</i>	<i>Top</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>
	<i>A</i>	<i>A4h</i>	<i>A4g</i>	<i>A4f</i>	<i>A4e</i>	<i>A4d</i>	<i>A4c</i>	<i>A4a-b</i>	<i>A4b</i>	<i>A4a</i>	<i>A3</i>	<i>A2c</i>	<i>A2b</i>	<i>A2a</i>	<i>A1</i>
<i>B005</i>													136.0	146.4	151.7
<i>B011</i>	134.6			136.3	137.1	140.2	145.9	150.0			157.4	165.0	170.5	180.0	186.7
<i>B015</i>	132.4							135.6	134.9	135.6	142.8	150.6	156.2	166.0	171.5
<i>B058</i>	142.1	143.3	148.4	153.2	154.2	158.1	164.6	168.7			175.1	182.6	189.0	198.5	204.8
<i>B100</i>	172.2	172.9	179.5	184.5	185.1	188.5	195.7	199.5			205.6	213.9	219.4	228.4	234.9
<i>B106</i>	180.4	181.3	186.5	192.4	193.5	197.1	202.8	207.3	206.3	207.3	214.5	221.7	228.0	237.8	243.7
<i>B154a</i>	215.9	217.0	221.9	227.4	228.4	231.4	236.9	242.9	241.9	242.9	248.2	255.0	261.4	270.1	276.4
<i>B175</i>	222.6	223.5	226.5	234.6	235.3	238.4	243.5	249.3			254.8	262.8	268.2	278.1	283.0
<i>B186</i>	245.3	246.6	251.2	256.9	258.2	261.5	268.1	273.1			279.8	286.3	292.5	302.2	308.1
<i>B193</i>	218.1	219.4	223.9	229.7	230.4	233.7	239.1	245.1	243.8	245.1	250.4	257.8	263.4	272.5	278.2
<i>B385</i>	186.1	187.1	191.0	196.6	198.5	202.2	208.2	212.3	211.3	212.3	219.8	227.7	233.5	242.7	249.2
<i>B386</i>	184.1	185.0	189.0	195.5	196.5	200.0	206.1	210.4	209.3	210.4	217.2	225.0	230.7	237.0	
<i>B399</i>	99.7	100.9	106.1	110.7	113.0	116.2	122.8	126.5			133.9	141.5	147.9	155.6	164.2
<i>B414</i>	100.0										106.1	113.8	120.1	129.6	136.2
<i>B415</i>	100.4										105.5	113.1	118.9	129.1	135.2
<i>B439</i>															
<i>B442</i>	175.3	175.9	181.5	187.6	188.2	191.7	197.7	202.1	201.3	202.1	209.6	216.9	223.0	231.9	238.9
<i>B443</i>															
<i>B472</i>	171.0	172.1	176.2	182.7	183.7	187.3	193.6	198.0	196.7	198.0	205.0	212.4	218.7	228.8	234.8
<i>B478</i>	237.9	238.5	243.8	249.2	250.4	254.1	260.1	264.7	262.9	264.7	271.4	280.0	285.6	295.4	301.2
<i>B480</i>	168.4	169.5	174.5	180.0	180.9	184.6	191.0	195.4	194.2	195.4	203.0	210.5	216.5	226.7	233.3
<i>B482</i>	235.4	236.1	239.8	246.1	246.9	250.3	256.0	261.8			267.6	275.6	280.8	289.7	296.5
<i>B483</i>	107.0	108.2	114.4	118.2	120.1	123.9	130.0	134.1	132.8	134.1	141.1	149.4	154.9	164.4	171.9
<i>B515</i>	153.0	153.9	159.5	164.8	165.8	169.5	175.7	180.1	178.6	180.1	187.8	195.4	201.1	211.9	218.1

<i>m NAP</i>	<i>Top</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>	<i>Base</i>
	<i>A</i>	<i>A4h</i>	<i>A4g</i>	<i>A4f</i>	<i>A4e</i>	<i>A4d</i>	<i>A4c</i>	<i>A4a-b</i>	<i>A4b</i>	<i>A4a</i>	<i>A3</i>	<i>A2c</i>	<i>A2b</i>	<i>A2a</i>	<i>A1</i>
<i>B005</i>															
<i>B011</i>	114.8				116.5	117.3	120.4	126.1	130.2			137.6	137.6	160.2	137.6
<i>B015</i>	112.8								116.0	115.3	116.0	123.2	123.2	146.4	123.2
<i>B058</i>	121.1	121.1	122.3	127.4	132.2	133.2	137.1	143.6	147.7			154.1	154.1	177.5	154.1
<i>B100</i>	151.1	151.1	151.8	158.4	163.4	164.0	167.4	174.6	178.4			184.5	184.5	207.3	184.5
<i>B106</i>	158.1	158.1	159.0	164.2	170.1	171.2	174.8	180.5	185.0	184.0	185.0	192.2	192.2	215.5	192.2
<i>B154a</i>	195.7	195.7	196.8	201.7	207.2	208.2	211.2	216.7	222.7	221.7	222.7	228.0	228.0	249.9	228.0
<i>B175</i>	201.7	201.7	202.6	205.6	213.7	214.4	217.5	222.6	228.4			233.9	233.9	257.2	233.9
<i>B186</i>	224.6	224.6	225.9	230.5	236.2	237.5	240.8	247.4	252.4			259.1	259.1	281.5	259.1
<i>B193</i>	197.9	197.9	199.2	203.7	209.5	210.2	213.5	218.9	224.9	223.6	224.9	230.2	230.2	252.3	230.2
<i>B385</i>	160.2	160.2	161.2	165.1	170.7	172.6	176.3	182.3	186.4	185.4	186.4	193.9	193.9	216.8	193.9
<i>B386</i>	158.5	158.5	159.4	163.4	169.9	170.9	174.4	180.5	184.8	183.7	184.8	191.6	191.6	211.4	191.6
<i>B399</i>	73.0	73.0	74.2	79.4	84.0	86.3	89.5	96.1	99.8			107.2	107.2	128.9	107.2
<i>B414</i>	73.8											79.9	79.9	103.4	79.9
<i>B415</i>	74.0											79.1	79.1	102.7	79.1
<i>B439</i>															
<i>B442</i>	150.3	150.3	150.9	156.5	162.6	163.2	166.7	172.7	177.1	176.3	177.1	184.6	184.6	206.9	184.6
<i>B443</i>															
<i>B472</i>	144.1	144.1	145.2	149.3	155.8	156.8	160.4	166.7	171.1	169.8	171.1	178.1	178.1	201.9	178.1
<i>B478</i>	214.4	214.4	215.0	220.3	225.7	226.9	230.6	236.6	241.2	239.4	241.2	247.9	247.9	271.9	247.9
<i>B480</i>	139.8	139.8	140.9	145.9	151.4	152.3	156.0	162.4	166.8	165.6	166.8	174.4	174.4	198.1	174.4
<i>B482</i>	213.3	213.3	214.0	217.7	224.0	224.8	228.2	233.9	239.7			245.5	245.5	267.6	245.5
<i>B483</i>	81.9	81.9	83.1	89.3	93.1	95.0	98.8	104.9	109.0	107.7	109.0	116.0	116.0	139.3	116.0
<i>B515</i>	121.1	121.1	122.0	127.6	132.9	133.9	137.6	143.8	148.2	146.7	148.2	155.9	155.9	180.0	155.9

Thickness Muschelkalk Formation B (m)							
	RNMU	B	B5	B4	B3	B2	B1
B005	18.6						
B011	52.1						
B015	39.1						
B058	78.2	15.5				1.6	13.9
B100	110	47.5		5.8	20.9	4.8	16
B106	125	61.3	8.5	11.1	21.3	4.8	15.6
B154a	120	59.6	10.5	10.3	18.7	4.4	15.7
B175	119	58.5	6	12.1	20.8	3.5	16.1
B186	121	58.2	7.1	10.3	21.1	4.8	14.9
B193	102	42.2		4.5	17.9	4.1	15.7
B385	116	52.9		11.3	21.3	4.7	15.6
B386	105	52		10.7	20.8	5.2	15.3
B399	68.1	3.6					3.6
B414	36.2						
B415	34.8						
B442	122	57.9	4.4	10.6	22.3	4.8	15.8
B472	118	54		12.5	20.9	4.9	15.7
B478	121	57.6	5.5	11.1	20.4	5	15.6
B480	118	53		12.5	19.9	5.1	15.5
B482	122	52	8.8	10.5	21.1	4.7	15.7
B483	72.2	7.3					7.3
B515	95.7	30.6			9.2	5.3	16.1

Thickness Muschelkalk Formation A (m)																	
	A	A4	A4h	A4g	A4f	A4e	A4d	A4c	A4ab	A4b	A4a	A3	A2	A2c	A2b	A2a	A1
B005	18.6														2.9	10.4	5.3
B011	52.1	15.4			1.7	0.8	3.1	5.7	4.1			7.4	22.6	7.6	5.5	9.5	6.7
B015	39.1	3.2							3.2	2.5	0.7	7.2	23.2	7.8	5.6	9.8	5.5
B058	62.7	26.6	1.2	5.1	4.8	1	3.9	6.5	4.1			6.4	23.4	7.5	6.4	9.5	6.3
B100	62.7	27.3	0.7	6.6	5	0.6	3.4	7.2	3.8			6.1	22.8	8.3	5.5	9	6.5
B106	63.3	26.9	0.9	5.2	5.9	1.1	3.6	5.7	4.5	3.5	1	7.2	23.3	7.2	6.3	9.8	5.9
B154a	60.5	27	1.1	4.9	5.5	1	3	5.5	6	5	1	5.3	21.9	6.8	6.4	8.7	6.3
B175	60.4	26.7	0.9	3	8.1	0.7	3.1	5.1	5.8			5.5	23.3	8	5.4	9.9	4.9
B186	62.8	27.8	1.3	4.6	5.7	1.3	3.3	6.6	5			6.7	22.4	6.5	6.2	9.7	5.9
B193	60.1	27	1.3	4.5	5.8	0.7	3.3	5.4	6	4.7	1.3	5.3	22.1	7.4	5.6	9.1	5.7
B385	63.1	26.2	1	3.9	5.6	1.9	3.7	6	4.1	3.1	1	7.5	22.9	7.9	5.8	9.2	6.5
B386	52.9	26.3	0.9	4	6.5	1	3.5	6.1	4.3	3.2	1.1	6.8	19.8	7.8	5.7	6.3	
B399	64.5	26.8	1.2	5.2	4.6	2.3	3.2	6.6	3.7			7.4	21.7	7.6	6.4	7.7	8.6
B414	36.2											6.1	23.5	7.7	6.3	9.5	6.6
B415	34.8											5.1	23.6	7.6	5.8	10.2	6.1
B442	63.6	26.8	0.6	5.6	6.1	0.6	3.5	6	4.4	3.6	0.8	7.5	22.3	7.3	6.1	8.9	7
B472	63.8	27	1.1	4.1	6.5	1	3.6	6.3	4.4	3.1	1.3	7	23.8	7.4	6.3	10.1	6
B478	63.3	26.8	0.6	5.3	5.4	1.2	3.7	6	4.6	2.8	1.8	6.7	24	8.6	5.6	9.8	5.8
B480	64.9	27	1.1	5	5.5	0.9	3.7	6.4	4.4	3.2	1.2	7.6	23.7	7.5	6	10.2	6.6
B482	61.1	26.4	0.7	3.7	6.3	0.8	3.4	5.7	5.8	0	0	5.8	22.1	8	5.2	8.9	6.8
B483	64.9	27.1	1.2	6.2	3.8	1.9	3.8	6.1	4.1	2.8	1.3	7	23.3	8.3	5.5	9.5	7.5
B515	65.1	27.1	0.9	5.6	5.3	1	3.7	6.2	4.4	2.9	1.5	7.7	24.1	7.6	5.7	10.8	6.2

4.5 Röt Formation

regional code: RNRO

Reference section: B483

Regionally, the Röt Fm. is subdivided into 5 members:

Upper Röt Claystone Mb. (RNROU)

Upper Röt Evaporite Mb. (RNRO2)

Intermediate Röt Claystone Mb. (RNROM)

Main Röt Evaporite Mb (RNRO1)

The Formation conformably overlies the Solling Fm., and is conformably overlain by the Muschelkalk Fm. In the north-eastern part of the TWR area, the Röt Fm is unconformably overlain by sediments of the North Sea Supergroup. In most wells only the top most meters of the Solling Fm. have been penetrated.

In the TWR area, all of the members are recognized. Lithologies of the Röt sections in the study area are similar to those found on a regional scale. The Röt Fm. has been documented well in the sections of B480 and B483 of which the lithologies were studied on the basis of 1 meter spaced cuttings samples (report GL06.0406 and GL07.1001. Of well B478, the lower half of the section was studied with the same detail (rept. GL07.101). Cuttings samples from the wells B515, B482, B154a and HEN-01 have been studied at a 10m interval.

The Main Röt Evaporite and especially the salt sections have been cored in a large number of wells. Of these sections only the non salt lithologies have been studied. Core samples from B480 and from B515 were included in the study. Based on this study an alternative subdivision of the RNRO1 member was suggested and introduced.

In well B031, the entire Röt Fm. was cored and described (rept 135, RGD, 1969), but unfortunately no wireline logs were ran. Biostratigraphical age dating performed by TNO-NITG on samples of B480 states an Upper Scythian to Anisian age for samples from the upper part of the Main Röt Evaporite Mb. to the upper most part of the Röt Fm.

As a result of the detailed lithological studies, the Röt Fm. was subdivided in 23 units and sub-units which can be correlated across the entire study area. The section of Röt Fm. in well B483, which is situated in the mid-eastern part of the area, was chosen as a reference. The main characteristics of the members and their lithological units and sub-units are summarized in the below.

The Upper Röt Claystone Mb. consists of red brown and light greenish grey and minor slightly purplish grey and brownish grey mottled claystones with intercalated siltstone beds and beds with concentrations of gypsum nodules. Gypsum or anhydrite also occurs in a white and amorphous form which may have been caused by the drilling process. In well B480, much more of this amorphous gypsum or anhydrite is present in relation to the amount of gypsum nodules, and it is possible that this has a late diagenetic origin. Within the RNROU section, the amount of gypsum decreases with depth. Siltstones with dolomite cement and/or gypsum/anhydrite cement and mica are found most frequently in the upper and lower parts of the section. Thicknesses of the RNROU section range from 125m to 144m, and the thickness distribution shows an increase from south-west to north-east.

The Upper Röt Claystone Member is subdivided in nine sub-units named A – I from bottom to top.

Unit RNROU-I consists of variegated mottled silty and dolomitic claystones (pict B483-181-20) with beds of gypsum nodules and gypsum / anhydrite which are overlain by a siltstone bed (pict B483-177-20). The base of the unit is formed by a similar succession (pict B483-194-20b) which is very distinct on the Gamma Ray log. Unit I has a fairly uniform thickness distribution; sections in the south-western part of the area are slightly thinner.

Unit RNROU-H forms an excellent marker on the Gamma Ray log. The section consists of predominant red brown silty claystones with siltstone beds and gypsum nodules and anhydrite / gypsum (pict B483-197-10). Slightly thinner sections occur in the south-western part of the area.

Unit RNROU-G is represented by very silty claystones which have more brownish grey shades (pict B483-208-20b) and minor gypsum nodules. Siltstones occur locally and the base of the unit is formed by a siltstone bed. Thicknesses of unit G are again slightly less in the south-western part of the area.

Unit RNROU-F consists of interbedded claystones, siltstones and concentrations of gypsum nodules (pict B483-213-10). Within the unit F a conspicuous low Gamma Ray peak is present; in B483 at 220m. This peak is found in all well sections and it forms a good marker; it represents a siltstone bed. In well B478, the sample of this peak contains fair amounts of dolomite, but also increased amounts of gypsum and gypsum nodules are found. The thickness distribution is fairly uniform; slightly thinner sections are found in the south-western part of the area.

Unit RNROU-E is formed by a section of variegated claystones and siltstones. In B483 much gypsum nodules are present, which are much less frequent in the section in B480. The thickness distribution does not show any particular trend.

Unit RNROU-D is a section with more brownish grey claystones (pict B483-247-20) with siltstones which locally grade to very fine sandstones, and locally concentrations of gypsum nodules. In the unit in B480, less gypsum is present. The base of the unit is formed by a siltstone bed. The thickness distribution shows slightly thicker sections in the northern and north-western part of the area

Unit RNROU-C is the section which has relatively high Gamma Ray readings. The unit is subdivided into 3 sub-units, C1 – C3. The thickness distribution shows thinner sections in the south-western part of the area.

Sub-unit C3 consists of more light red brown and locally predominantly light greenish grey claystones which are slightly silty to silty to very fine to fine sandy (pict B483-260-10, B483-257-20). High concentrations of light greenish grey claystones seem to coincide with high Gamma Ray peaks. Traces of fine to medium loose quartz grains are commonly present in the samples. Sub-unit C3 sections are thicker in the south-eastern part of the area.

Sub-unit C2 is defined as the interval with the highest Gamma Ray readings within the C unit. Claystones are slightly silty to silty and locally very fine to fine sandy (pict B483-277-

10, B483-270-20). Light greenish grey claystones predominate at levels with high GR readings. Only traces of siltstone and gypsum are present but the low Gamma Ray peak at 278m in B483 represents high concentrations of gypsum nodules. The thickness distribution does not show any particular trend.

Claystones in sub-unit C1 are again of a more silty and more dolomitic nature with minor siltstone intercalations (pict B483-294-20) and locally with gypsum nodules (pict B483-287-10). Predominantly light greenish grey claystones again coincide with the highest Gamma Ray readings. Thicker sections of C1 occur in the central and northern part of the area.

Unit RNROU-B consists of locally very silty claystones with minor siltstone intercalations (pict B483-302-20) and minor gypsum nodules. Gamma Ray readings are fairly high and more or less in line with the overlying sub-unit C1, but the top of unit B can be recognized by the low Gamma Ray peak which represents a siltstone bed. Locally, slight traces of crystalline anhydrite are found (pict B483-298-10).

Unit RNROU-A is formed by a section of variegated claystones in which the amount of intercalated siltstone beds increases with depth. Also more common in the lower part are crystalline gypsum or anhydrite which is dolomitic and silty (pict B483-308-20b). Units A and B cannot always be separated and the thickness distribution is given for the two units together. Sections in the western part of the area are slightly thinner.

The Upper Röt Evaporite Member (RNRO2) is a thin section of crystalline anhydrite which is locally silty and dolomitic. Thicknesses vary between 0.7m and 2.1m. The thickness distribution does not show any trend (B483-313-20).

The Intermediate Röt Claystone Mb. (RNROM) is subdivided into two units A and B which can be easily separated on the Gamma Ray log. The thickness distribution of the total of RNROM indicates slightly thicker sections in the north-eastern and eastern part of the area.

Unit B consists of variegated claystones with siltstone beds (pict B483-321-20, B483-322-20) and locally gypsum nodules. The base of the section is formed by lower Gamma Ray readings which are caused by increased amounts of siltstone and gypsum nodules. In B480 this basal part was cored (pict B480-388.28-10). Sections in the north-eastern and eastern part of the area are slightly thicker.

Unit A was cored entirely in B480; lithologies are laminated claystones with locally gypsum nodules and anhydrite laminae (pict B480-392.17-10b) and locally siltstone laminae. The thickness distribution shows slightly thicker sections in the eastern part of the area.

The Main Röt Evaporite Mb. (RNRO1) is subdivided into 5 lithological units named A – E; units A – D are the halite sections. Each halite section has a basal non-halite sub-unit which is designated 1. The entire section was cored in B480 and lithologies are briefly described in the below. The thickness distribution of the RNRO1 Mb. shows thinner sections in the northern half of the area and in the westernmost part.

Unit RNROU-E consists of crystalline anhydrite which is locally slightly argillaceous and locally silty with mica (pict B480-402.91-10). High Gamma Ray peaks represent laminated claystones which are non to very slightly dolomitic. Locally gypsum / anhydrite nodules

are present (pict B480-412.05-10) and locally halite crystals (pict B480-409.51-10). The thickness distribution shows slightly thinner sections in the southern and south-western part of the area.

Sub-unit D2 (salt D) is a clear to grey to reddish and orange halite with locally hematite and polyhalite. Locally argillaceous laminae are present.

Sub-unit D1 consists of a non calcareous or dolomitic laminated and locally mottled claystone with thin siltstone and halite laminae (pict B480-417.91-10) and thin anhydrite laminae.

Sub-unit C2 (salt C) is an interval of grey halite which is locally anhydritic and locally slightly argillaceous; in the lower part and at the base polyhalite and hematite occur. In the lower part, the halite is locally yellowish white and locally anhydritic or with claystone laminae. In the basal part a 15cm thick silty and dolomitic claystone bed is present.

Sub-unit C1 is a mottled silty and dolomitic claystone (pict B480-441.75-10) which is locally anhydritic or with anhydrite nodules. Near the top and near the base of the interval, more anhydrite is present.

Sub-unit B2 (salt B) is a grey to dark grey and in the lower part lighter grey halite interval with locally grey anhydrite beds and laminae and locally greenish grey claystone laminae.

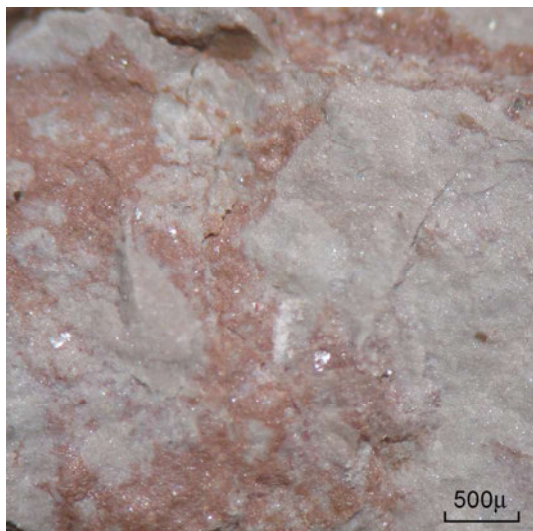
Sub-unit B1 consists of a cryptocrystalline slightly argillaceous and locally anhydritic dolomite (pict B480-447.2-20) with locally very thin more anhydritic laminae. In well B478 the cuttings sample from this interval contains a slightly dolomitic anhydrite. The lithology of a cuttings sample from the interval from B483 is dolomite (pict B483-382-20) and the core sample from B1 from B515 is also dolomite (pict. B515-434.78-10).

Sub-unit A2 (salt A) is a section of light and dark grey and locally white halite with locally anhydrite or claystone laminae and locally anhydrite and claystone clasts.

Sub-unit A1 is a thin bed of grey anhydrite. A core sample from B515 also shows pale reddish shades (pict B515-466.74-10). In well B480 this bed is approximately 40cm thick. On Gamma Ray logs only, the anhydrite cannot be distinguished which is the reason that the sub-unit is not indicated on most well logs and in the database.

It can be concluded that the units and sub-units of RNROU and RNROM in general are thinner in the south-western part of the area. As it was suggested for Muschelkalk deposits, slight syndepositional tectonic movements may have occurred.

Microphotographs Röt Formation



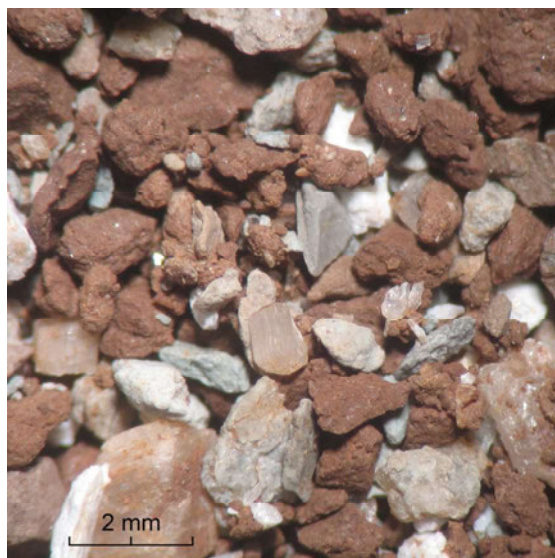
*pict. B483-181-20: RNROU-I
mottled purple grey and redbrown claystone*



*pict. B483-177-20: RNROU-I
siltstone with much mica*



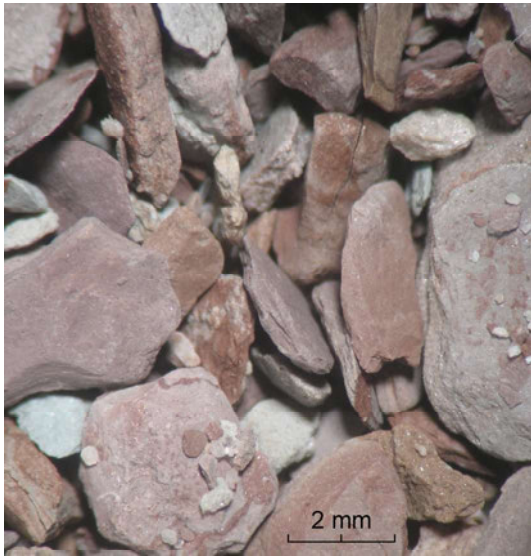
*pict B483-194-20b
light purple grey claystone, gypsum
nodules and siltstone with mica*



*pict B483-197-10: RNROU-H
predominantly redbrown claystone with
anhydrite/gypsum and gypsum nodules*



*pict. B483-208-20b: RNRROU-G
light grey, medium red brown and slightly
purple grey mottled, slightly silty and silty
dolomitic claystones with very fine mica*



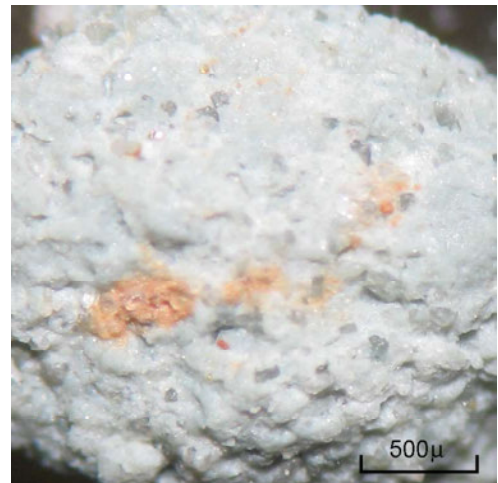
*left pict. B483-213-10: RNROU-F
slightly purple grey claystone*



*pict. B483-247-20: RNROU-D
laminated claystone and siltstone*



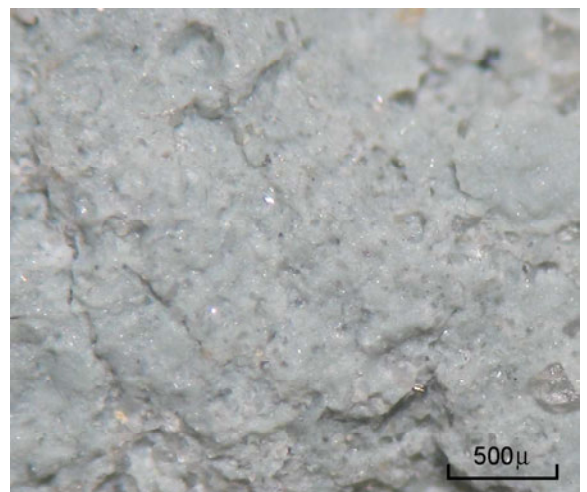
*pict. B483-260-10: RNROU-C3
predominantly light redbrown
claystone*



*pict. B483-257-20: RNROU-C3
light greenish grey claystone with
very fine to fine quartz grains*



*pict. B483-277-10: RNROU-C2
mottled fissile/platy claystone with very
fine mica*



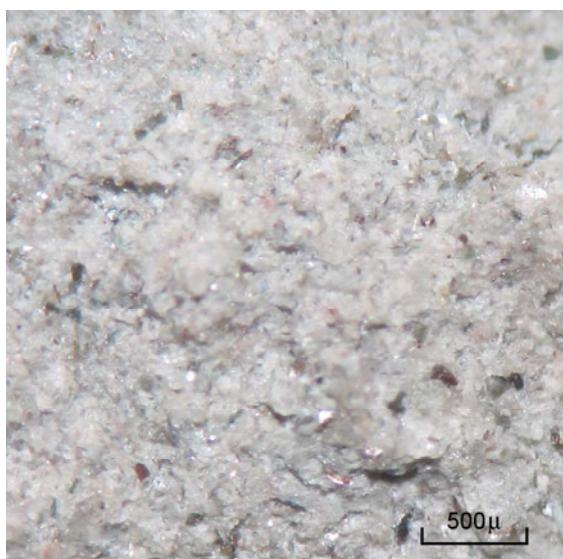
*pict. B483-270-20: RNROU-C2
very fine to fine sandy claystone*



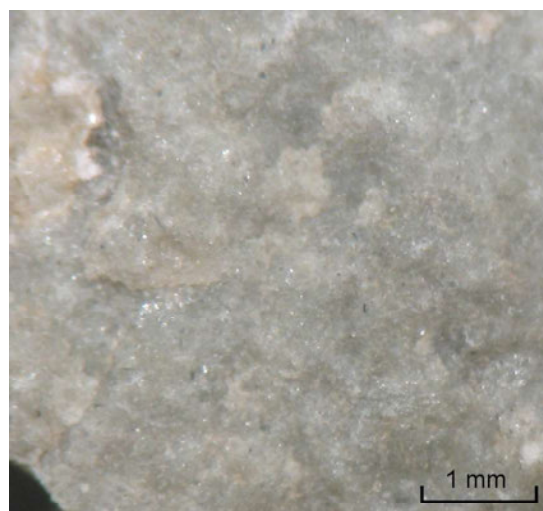
*pict. B483-294-20: RNROU-C1
siltstone / very fine sandstone with
dolomite / gypsum / anhydrite cement*



*pict. B483-287-10: RNROU-C1
silty light greenish grey claystone with
gypsum nodules*



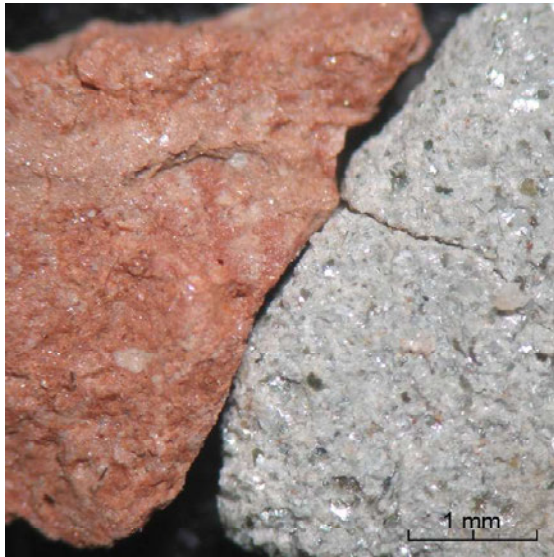
*pict. B483-302-20: RNROU-B
siltstone with very fine mica*



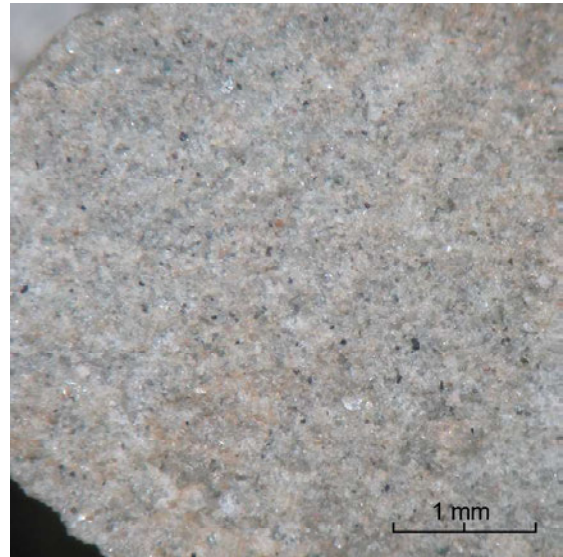
*pict. B483-298-10: RNROU-B
very light grey crystalline anhydrite*



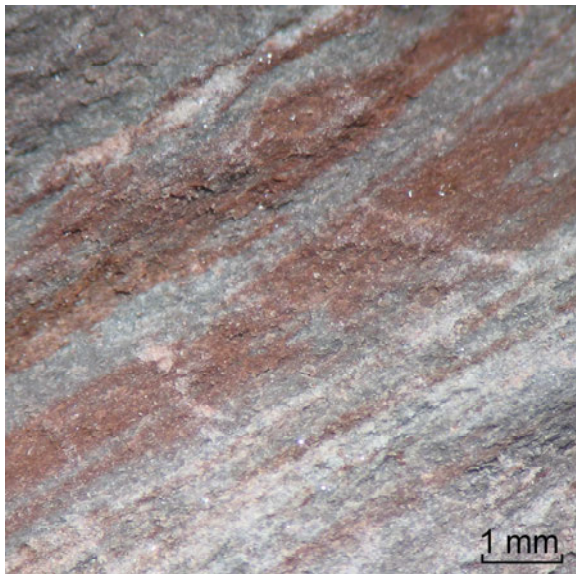
*pict. B483-308-20b: RNROU-A
dolomite / gypsum / anhydrite*



*pict. 321-20: RNROM-B
light greenish grey siltstone with much mica
and light redbrown mottled claystone*



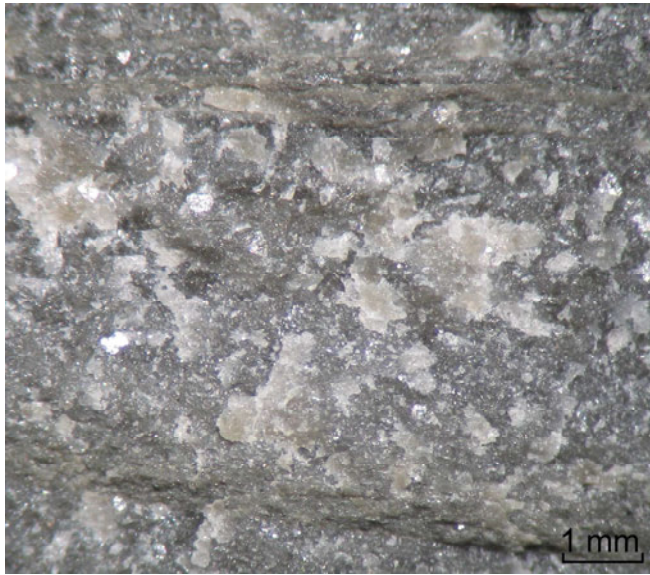
*pict. 322-20: RNROM-B
gypsum / anhydrite cemented siltstone with
very fine mica*



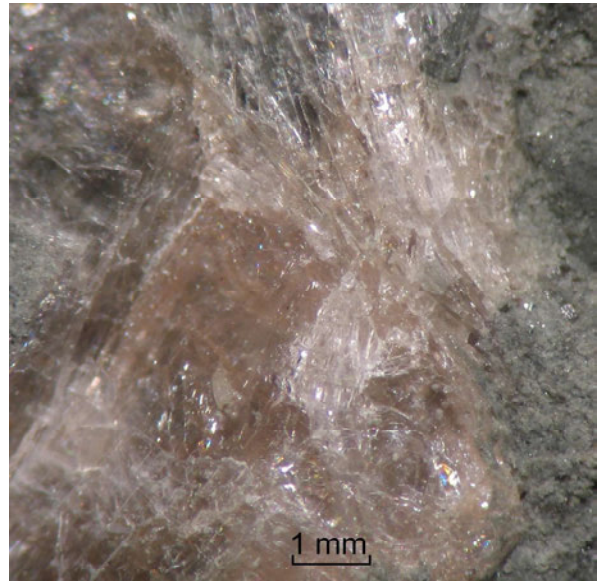
*pict. B480-388.28-10: RNROM – B
laminated reddish brown en light grey
claystone with very light grey siltstone
laminae*



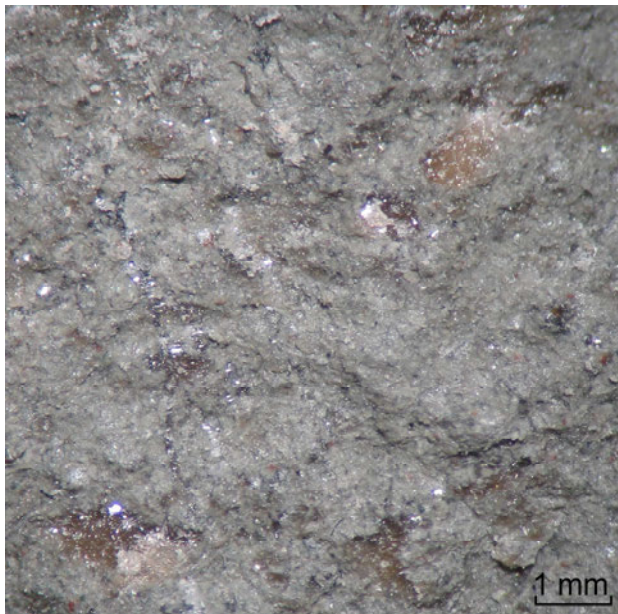
*pict. B480-392.17-10b: RNROM – A
red brown claystone with anhydrite laminae*



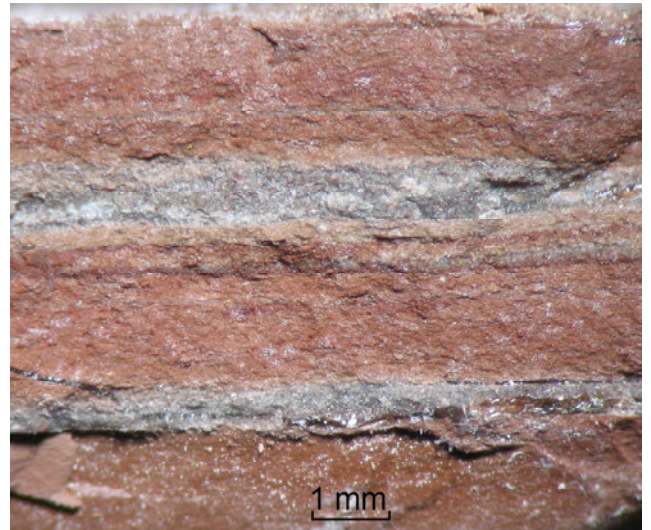
*pict. B480- 402.91-10: RNRO1- D2
anhydrite with very thin claystone laminae*



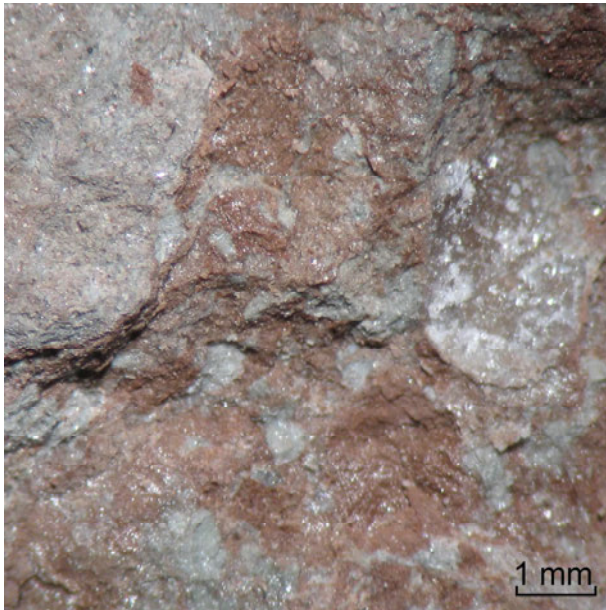
*pict. B480-409.51-10: RNRO1 – D2
claystone with halite crystals*



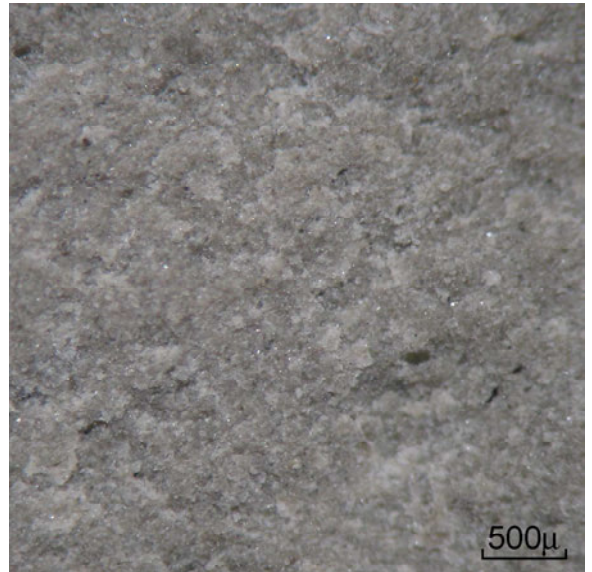
*pict. B480- 412.05-10: RNRO1 – D2
gypsum/anhydrite nodules in silty
claystone with mica*



*pict. B480-417.91-10: RNRO1 – D2
red brown claystone with very light grey siltstone
laminae and very thin salt laminae*



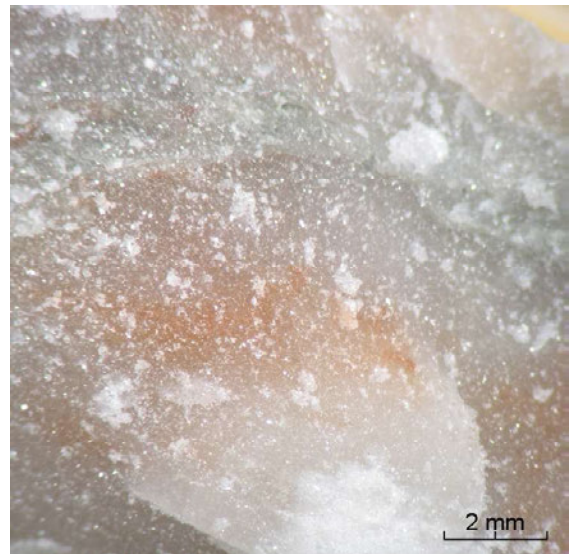
*pict. B480-441.75-10: RNRO1 – B2
mottled claystone with locally very fine
mica and anhydrite nodules*



*pict. B480-447.2-20: RNRO1 – A2
very light grey – beige dolomite,
cryptocrystalline, slightly argillaceous,
locally anhydritic*



*pict. B480-382-20: RNRO1-B1
dolomite*



*pict. B515-466.74-10: RNRO1-A1
locally pale reddish anhydrite*



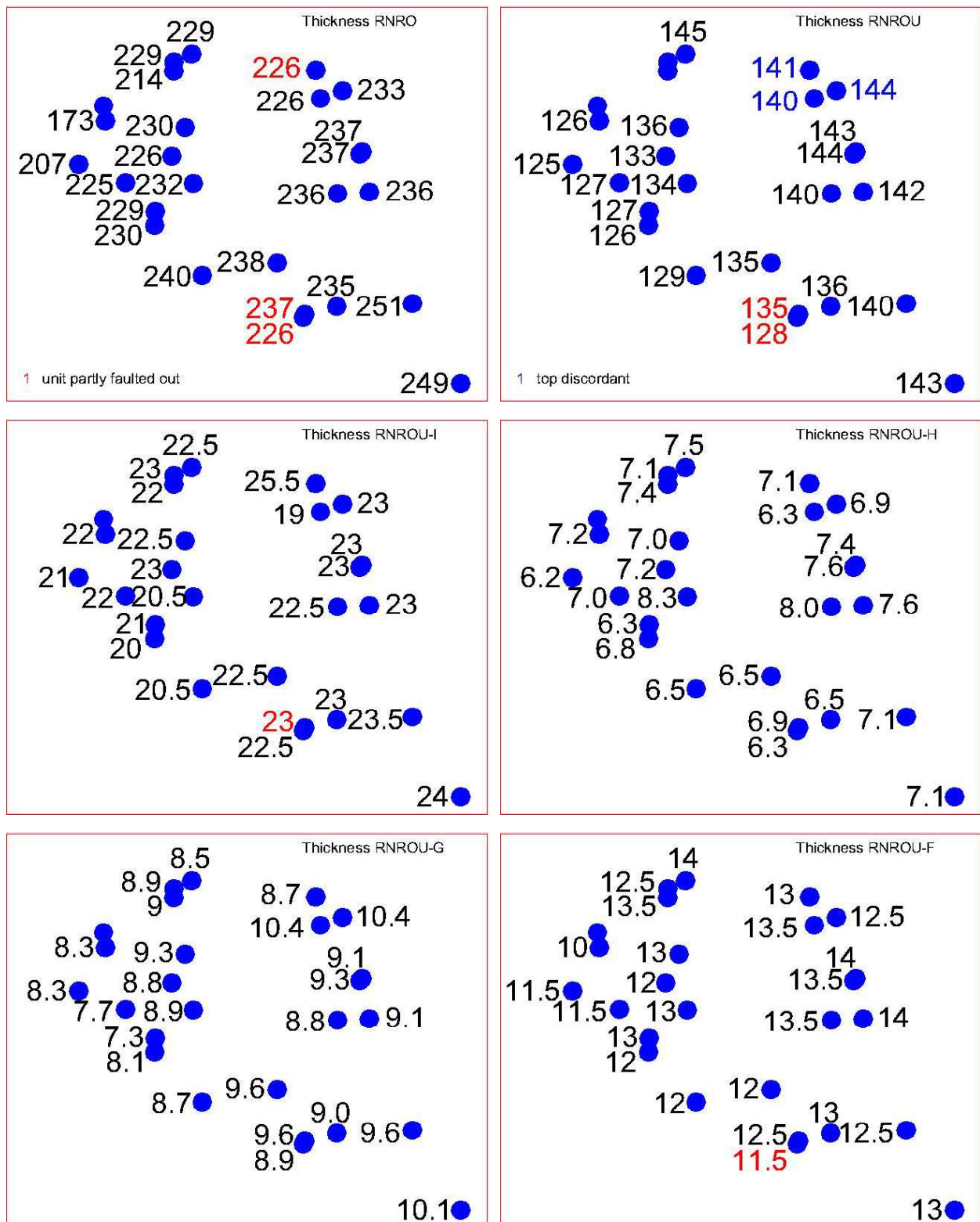
*pict. B483-313-20: RNRO1-A2
dolomitic and silty anhydrite*

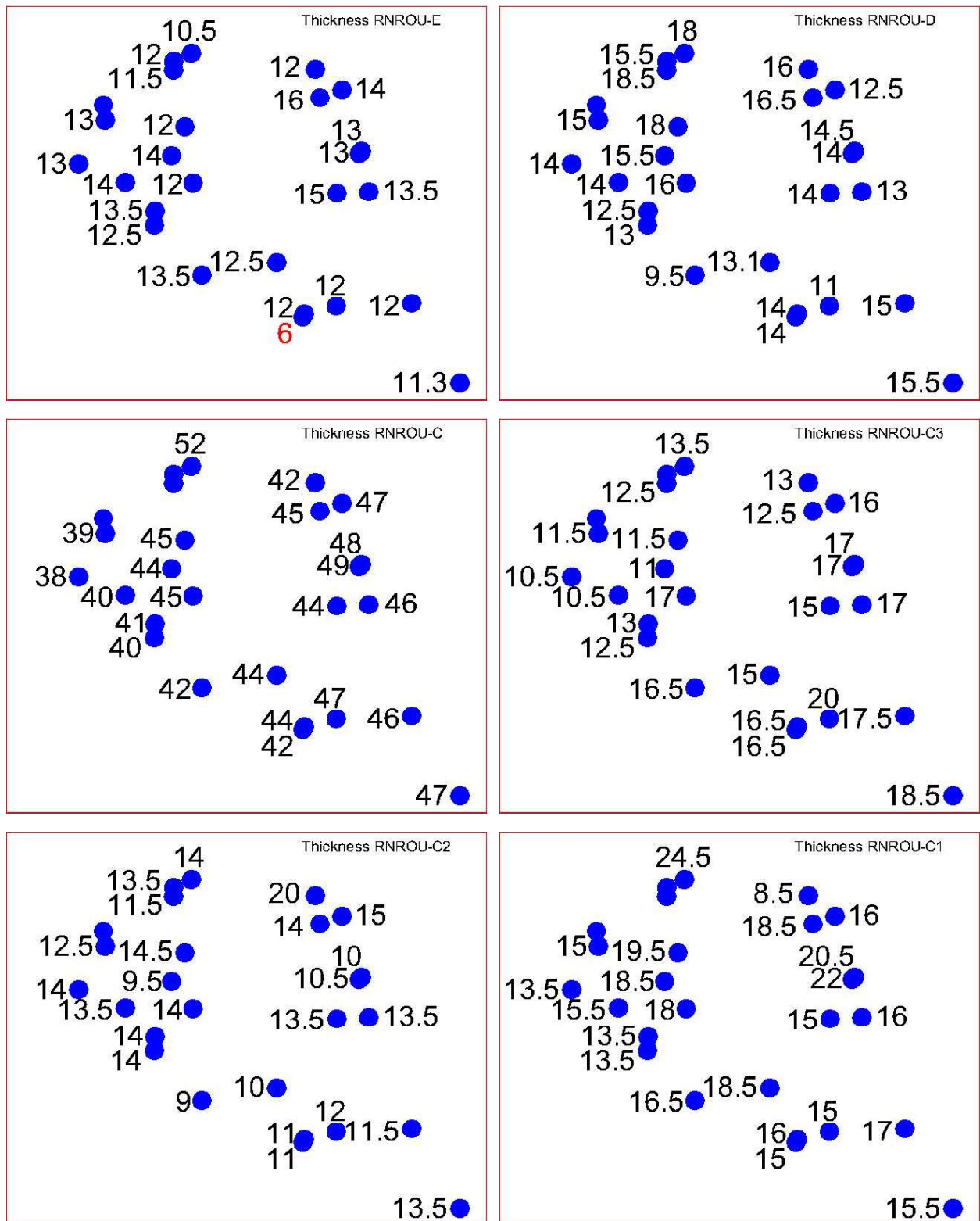
Reference section Röt Formation

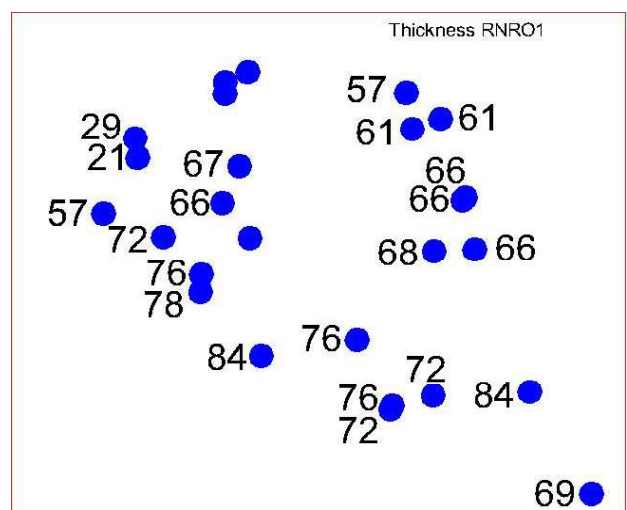
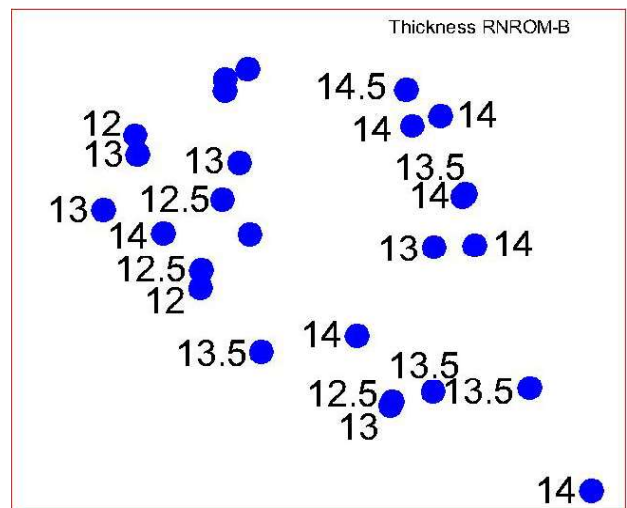
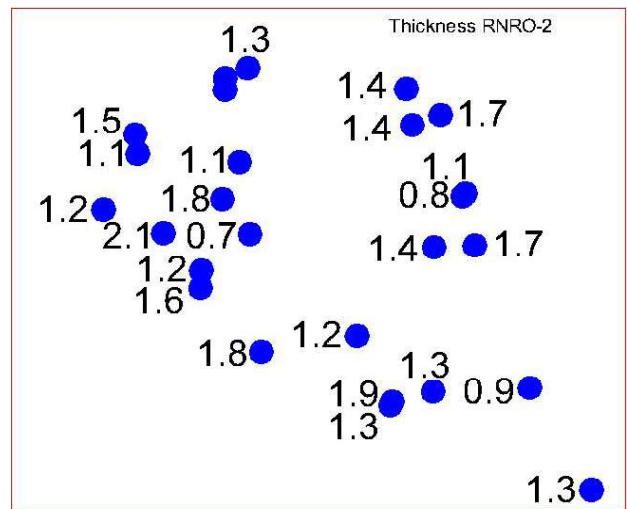
The section of B483 is the reference section for the Röt Formation in the area.

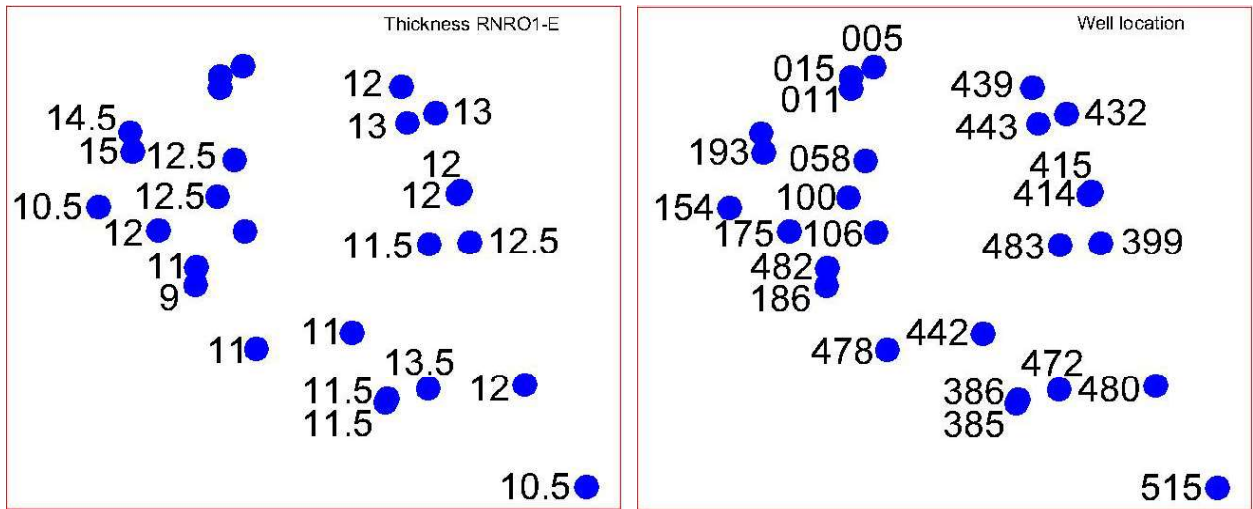
See attachments for log representation and unit descriptions.

Thickness distribution of the Röt Formation and units









Database RNRO

Below thicknesses and depths of units and sub-units with reference to CF and NAP as given in the database which forms part of the current study.

All values are rounded to one decimal place.

Röt Formation													
<i>reference depth: m CF</i>													
	Top	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
	RNRO	RNRO	RNROU	I	H	G	F	E	D	C	C3	C2	C1
HEN-01													
B005	151.7	380.3	296.8	174.2	181.7	190.2	204.1	214.7	232.9	284.9	246.3	260.5	284.9
B011	186.7	400.2	292.2	208.6	216.0	225.0	238.3	250.0	268.5	292.2	280.8	292.2	
B015	171.5	400.6	250.3	194.3	201.4	210.3	222.8	234.8	250.3				
B058	204.8	434.3	340.7	227.5	234.5	243.8	256.7	268.8	286.6	331.3	297.9	311.6	331.3
B100	234.9	460.7	368.1	257.7	264.9	273.7	285.5	299.4	315.1	359.3	326.2	340.6	359.3
B106	243.7	476.1	377.2	264.3	272.6	281.5	294.5	306.7	322.8	367.3	339.7	349.3	367.3
B154a	276.4	483.1	401.4	297.4	303.6	311.9	323.4	336.3	350.3	388.1	360.9	374.7	388.1
B175	283.0	508.2	410.3	304.9	311.9	319.6	331.2	345.1	359.3	399.0	369.8	383.5	399.0
B186	308.1	537.9	434.1	328.2	335.0	343.1	355.0	367.5	380.4	420.4	392.9	407.1	420.4
B193	278.2	450.7	403.8	300.3	307.5	315.8	325.7	338.9	353.8	393.2	365.4	378.1	393.2
B385	249.2	475.4	376.9	271.6	277.9	286.8	298.4	304.3	318.6	361.0	335.1	346.2	361.0
B386	237.7	475.0	372.5	260.5	267.4	277.0	289.4	301.4	315.5	359.2	332.1	343.0	359.2
B399	164.2	400.2	306.0	187.3	194.9	204.0	217.9	231.6	244.8	291.1	261.6	275.0	291.1
B414	136.2	373.1	280.1	159.2	166.8	176.1	189.7	202.8	217.0	266.3	234.1	244.5	266.3
B415	135.2	371.9	278.6	158.2	165.6	174.7	188.9	201.7	216.1	263.7	233.1	243.0	263.7
B432	108.2	341.1	252.0	131.4	138.3	148.7	161.3	175.5	188.2	235.2	204.2	219.0	235.2
B439	110.9	337.2	251.9	136.6	143.7	152.4	165.5	177.7	193.7	235.4	206.9	226.9	235.4
B442	238.9	476.6	373.9	261.5	268.0	277.6	289.5	301.8	314.9	358.5	329.9	340.1	358.5
B443	111.2	339.4	251.4	130.0	136.3	146.7	160.4	176.5	193.2	238.3	205.5	219.7	238.3
B472	234.8	470.1	370.9	257.7	264.2	273.2	286.1	298.0	308.9	355.7	328.7	340.7	355.7
B478	301.2	541.3	430.1	321.8	328.3	337.0	349.1	362.4	372.1	413.9	388.4	397.2	413.9
B480	233.3	484.2	373.6	256.9	264.0	273.6	286.0	298.1	313.0	359.1	330.5	342.2	359.1
B482	296.5	525.3	423.9	317.4	323.7	331.0	343.8	357.4	369.8	410.6	382.9	397.1	410.6
B483	171.9	407.4	311.9	194.5	202.5	211.3	224.9	239.7	253.5	297.1	268.6	282.3	297.1
B515	218.1	467.3	361.3	242.3	249.4	259.5	272.5	283.8	299.3	346.6	317.9	331.3	346.6

Röt Fm. m CF	Top RNRO2	Base RNRO2	Top RNROM	Base RNROM	Base RNROM-B	Base RNROM-A	Top RNRO1	Base RNRO1	Base RNRO1-E
HEN-01	400.5	402.0	402.0	424.7	413.9	424.7	424.7	454.0	439.2
B005	296.8	298.1						380.3	
B011								400.2	
B015									
B058	340.7	341.8	341.8	367.1	355.0	367.1	367.1	434.3	379.4
B100	368.1	369.9	369.9	394.5	382.2	394.5	394.5	460.7	407.2
B106	377.2	377.9	377.9	390.4					
B154a	401.4	402.6	402.6	426.6	415.6	426.6	426.6	483.1	437.2
B175	410.3	412.4	412.4	436.2	426.5	436.2	436.2	508.2	448.2
B186	434.1	435.7	435.7	459.5	447.5	459.5	459.5	537.9	468.4
B193	403.8	404.9	404.9	429.2	418.0	429.2	429.2	450.7	444.2
B385	376.9	378.2	378.2	403.9	391.3	403.9	403.9	475.4	415.6
B386	372.5	374.4	374.4	398.7	387.1	398.7	398.7	475.0	410.3
B399	306.0	307.7	307.7	334.6	321.8	334.6	334.6	400.2	347.1
B414	280.1	280.9	280.9	307.2	294.8	307.2	307.2	373.1	319.1
B415	278.6	279.7	279.7	305.9	293.0	305.9	305.9	371.9	318.0
B432	252.0	253.7	253.7	280.1	267.7	280.1	280.1	341.1	293.1
B439	251.9	253.3	253.3	280.7	267.8	280.7	280.7	337.2	292.8
B442	373.9	375.1	375.1	400.4	389.3	400.4	400.4	476.6	411.2
B443	251.4	252.8	252.8	278.9	266.8	278.9	278.9	339.4	292.1
B472	370.9	372.2	372.2	398.2	385.8	398.2	398.2	470.1	411.5
B478	430.1	431.9	431.9	457.0	445.2	457.0	457.0	541.3	468.2
B480	373.6	374.5	374.5	400.6	388.1	400.6	400.6	484.2	412.7
B482	423.9	425.1	425.1	449.3	437.4	449.3	449.3	525.3	461.1
B483	311.9	313.3	313.3	339.6	326.1	339.6	339.6	407.4	351.1
B515	361.3	362.6	362.6	389.7	376.6	389.7	389.7	467.3	400.4

Röt Fm. RNRO1 m CF	Top Salt D	Base D1	Base Salt C	Base C1	Base Salt B	Base B1	Base Salt A	Base A1	Base undiff	Top RNSO
HEN-01									454.0	454.0
B005			350.7	351.9	356.6	357.3	379.5	380.3		380.3
B011			374.9	375.5	379.5	380.3	399.2	400.2		400.2
B015			364.7	366.0	370.7	371.4	400.6			400.6
B058		384.3	404.7	406.3	410.6	411.3	433.3	434.3		434.3
B100		410.9	431.6	433.6	438.0	439.2	460.7			460.7
B106	417.7	421.8	440.0	443.8	447.6	448.6	476.1			476.1
B154a	437.7	441.5	460.6	461.7	467.1	468.0	483.1			483.1
B175	449.0	453.3	472.0	474.5	479.4	480.1	508.2			508.2
B186	468.9	472.3	496.1	497.3	504.4	505.3	537.9			537.9
B193							450.7			450.7
B385	416.1	421.2	440.7	443.5	447.1	448.6	475.4			475.4
B386	413.2	418.2	436.7	439.4	443.2	444.7	475.0			475.0
B399		351.0	371.6	373.6	378.1	379.1	400.2			400.2
B414	319.5	323.9	342.8	345.2	349.9	350.8	373.1			373.1
B415		321.5	341.7	344.3	348.7	349.8	371.9			371.9
B432		297.1	311.8	314.5	318.9	319.8	341.1			341.1
B439		296.7	311.5	313.6	318.3	319.3	337.2			337.2
B442	414.0	418.9	438.8	440.2	444.5	445.8	476.6			476.6
B443		295.7	314.5	316.5	321.2	322.1	339.4			339.4
B472		415.5	435.4	437.7	441.4	443.4	470.1			470.1
B478	470.9	476.0	494.1	496.0	500.2	501.1	540.1	541.3		541.3
B480	415.3	419.6	440.5	442.2	446.7	447.7	484.2			484.2
B482	464.8	469.0	488.2	489.7	494.3	495.2	525.3			525.3
B483	352.9	357.2	374.9	377.5	381.6	382.4	407.4			407.4
B515	403.2	407.9	428.7	430.9	435.0	436.1	467.3			467.3

Röt Fm. m NAP	Top RNRO	Base RNRO	Base RNROU	Base I	Base H	Base G	Base F	Base E	Base D	Base C	Base C3	Base C2	Base C1
HEN-01													
B005	131.6	360.2	276.7	154.1	161.6	170.1	184.0	194.6	212.8	264.8	226.2	240.4	264.8
B011	166.9	380.4	272.4	188.8	196.2	205.2	218.5	230.2	248.7	272.4	261.0	272.4	
B015	151.9	381.0	230.7	174.7	181.8	190.7	203.2	215.2	230.7				
B058	183.8	413.3	319.7	206.5	213.5	222.8	235.7	247.8	265.6	310.3	276.9	290.6	310.3
B100	213.8	439.6	347.0	236.6	243.8	252.6	264.4	278.3	294.0	338.2	305.1	319.5	338.2
B106	221.4	453.8	354.9	242.0	250.3	259.2	272.2	284.4	300.5	345.0	317.4	327.0	345.0
B154a	256.2	462.9	381.2	277.2	283.4	291.7	303.2	316.1	330.1	367.9	340.7	354.5	367.9
B175	262.1	487.3	389.4	284.0	291.0	298.7	310.3	324.2	338.4	378.1	348.9	362.6	378.1
B186	287.4	517.2	413.4	307.5	314.3	322.4	334.3	346.8	359.7	399.7	372.2	386.4	399.7
B193	258.0	430.5	383.6	280.1	287.3	295.6	305.5	318.7	333.6	373.0	345.2	357.9	373.0
B385	223.3	449.5	351.0	245.7	252.0	260.9	272.5	278.4	292.7	335.1	309.2	320.3	335.1
B386	212.1	449.4	346.9	234.9	241.8	251.4	263.8	275.8	289.9	333.6	306.5	317.4	333.6
B399	137.5	373.5	279.3	160.6	168.2	177.3	191.2	204.9	218.1	264.4	234.9	248.3	264.4
B414	110.0	346.9	253.9	133.0	140.6	149.9	163.5	176.6	190.8	240.1	207.9	218.3	240.1
B415	108.8	345.5	252.2	131.8	139.2	148.3	162.5	175.3	189.7	237.3	206.7	216.6	237.3
B432	84.4	317.3	228.2	107.6	114.5	124.9	137.5	151.7	164.4	211.4	180.4	195.2	211.4
B439	87.7	314.0	228.7	113.4	120.5	129.2	142.3	154.5	170.5	212.2	183.7	203.7	212.2
B442	213.9	451.6	348.9	236.5	243.0	252.6	264.5	276.8	289.9	333.5	304.9	315.1	333.5
B443	87.3	315.5	227.5	106.1	112.4	122.8	136.5	152.6	169.3	214.4	181.6	195.8	214.4
B472	207.9	443.2	344.0	230.8	237.3	246.3	259.2	271.1	282.0	328.8	301.8	313.8	328.8
B478	277.7	517.8	406.6	298.3	304.8	313.5	325.6	338.9	348.6	390.4	364.9	373.7	390.4
B480	204.7	455.6	345.0	228.3	235.4	245.0	257.4	269.5	284.4	330.5	301.9	313.6	330.5
B482	274.4	503.2	401.8	295.3	301.6	308.9	321.7	335.3	347.7	388.5	360.8	375.0	388.5
B483	146.8	382.3	286.8	169.4	177.4	186.2	199.8	214.6	228.4	272.0	243.5	257.2	272.0
B515	186.2	435.4	329.4	210.4	217.5	227.6	240.6	251.9	267.4	314.7	286.0	299.4	314.7

Röt Fm. m NAP	Top RNRO2	Base RNRO2	Top RNROM	Base RNROM	Base RNROM-B	Base RNROM-A	Top RNRO1	Base RNRO1	Base RNRO1-E
HEN-01	400.5	402.0	402.0	424.7	413.9	424.7	424.7	454.0	439.2
B005	276.7	278.0						360.2	
B011								380.4	
B015									
B058	319.7	320.8	320.8	346.1	334.0	346.1	346.1	413.3	358.4
B100	347.0	348.8	348.8	373.4	361.1	373.4	373.4	439.6	386.1
B106	354.9	355.6	355.6	368.1					
B154a	381.2	382.4	382.4	406.4	395.4	406.4	406.4	462.9	417.0
B175	389.4	391.5	391.5	415.3	405.6	415.3	415.3	487.3	427.3
B186	413.4	415.0	415.0	438.8	426.8	438.8	438.8	517.2	447.7
B193	383.6	384.7	384.7	409.0	397.8	409.0	409.0	430.5	424.0
B385	351.0	352.3	352.3	378.0	365.4	378.0	378.0	449.5	389.7
B386	346.9	348.8	348.8	373.1	361.5	373.1	373.1	449.4	384.7
B399	279.3	281.0	281.0	307.9	295.1	307.9	307.9	373.5	320.4
B414	253.9	254.7	254.7	281.0	268.6	281.0	281.0	346.9	292.9
B415	252.2	253.3	253.3	279.5	266.6	279.5	279.5	345.5	291.6
B432	228.2	229.9	229.9	256.3	243.9	256.3	256.3	317.3	269.3
B439	228.7	230.1	230.1	257.5	244.6	257.5	257.5	314.0	269.6
B442	348.9	350.1	350.1	375.4	364.3	375.4	375.4	451.6	386.2
B443	227.5	228.9	228.9	255.0	242.9	255.0	255.0	315.5	268.2
B472	344.0	345.3	345.3	371.3	358.9	371.3	371.3	443.2	384.6
B478	406.6	408.4	408.4	433.5	421.7	433.5	433.5	517.8	444.7
B480	345.0	345.9	345.9	372.0	359.5	372.0	372.0	455.6	384.1
B482	401.8	403.0	403.0	427.2	415.3	427.2	427.2	503.2	439.0
B483	286.8	288.2	288.2	314.5	301.0	314.5	314.5	382.3	326.0
B515	329.4	330.7	330.7	357.8	344.7	357.8	357.8	435.4	368.5

Röt Fm. RNRO1 m NAP	Top Salt D	Base D1	Base Salt C C2	Base C1	Base Salt B B2	Base B1	Base Salt A A2	Base A1	Base undiff	Top RNSO
HEN-01	D2	D1	C2	C1	B2	B1	A2	A1	undiff	RNSO
B005			330.6	331.8	336.5	337.2	359.4	360.2	454.0	454.0
B011			355.1	355.7	359.7	360.5	379.4	380.4		360.2
B015			345.1	346.4	351.1	351.8	381.0			380.4
B058		363.3	383.7	385.3	389.6	390.3	412.3	413.3		381.0
B100		389.8	410.5	412.5	416.9	418.1	439.6			413.3
B106	395.4	399.5	417.7	421.5	425.3	426.3	453.8			439.6
B154a	417.5	421.3	440.4	441.5	446.9	447.8	462.9			453.8
B175	428.1	432.4	451.1	453.6	458.5	459.2	487.3			462.9
B186	448.2	451.6	475.4	476.6	483.7	484.6	517.2			487.3
B193							430.5			517.2
B385	390.2	395.3	414.8	417.6	421.2	422.7	449.5			430.5
B386	387.6	392.6	411.1	413.8	417.6	419.1	449.4			449.5
B399		324.3	344.9	346.9	351.4	352.4	373.5			449.4
B414	293.3	297.7	316.6	319.0	323.7	324.6	346.9			346.9
B415		295.1	315.3	317.9	322.3	323.4	345.5			345.5
B432		273.3	288.0	290.7	295.1	296.0	317.3			317.3
B439		273.5	288.3	290.4	295.1	296.1	314.0			314.0
B442	389.0	393.9	413.8	415.2	419.5	420.8	451.6			451.6
B443		271.8	290.6	292.6	297.3	298.2	315.5			315.5
B472		388.6	408.5	410.8	414.5	416.5	443.2			443.2
B478	447.4	452.5	470.6	472.5	476.7	477.6	516.6	517.8		517.8
B480	386.7	391.0	411.9	413.6	418.1	419.1	455.6			455.6
B482	442.7	446.9	466.1	467.6	472.2	473.1	503.2			503.2
B483	327.8	332.1	349.8	352.4	356.5	357.3	382.3			382.3
B515	371.3	376.0	396.8	399.0	403.1	404.2	435.4			435.4

Röt Fm. thickness	RNR	ORN	ROU								
HEN-01	total	total	I	H	G	F	E	D	C	C3	C2
B005	228.6	145.1	22.5	7.5	8.5	13.9	10.6	18.2	52.0	13.4	14.2
B011	213.5	105.5	21.9	7.4	9.0	13.3	11.7	18.5		12.3	11.4
B015	229.1	78.8	22.8	7.1	8.9	12.5	12.0	15.5			
B058	229.5	135.9	22.7	7.0	9.3	12.9	12.1	17.8	44.7	11.3	13.7
B100	225.8	133.2	22.8	7.2	8.8	11.8	13.9	15.7	44.2	11.1	14.4
B106	232.4	133.5	20.6	8.3	8.9	13.0	12.2	16.1	44.5	16.9	9.6
B154a	206.7	125.0	21.0	6.2	8.3	11.5	12.9	14.0	37.8	10.6	13.8
B175	225.2	127.3	21.9	7.0	7.7	11.6	13.9	14.2	39.7	10.5	13.7
B186	229.8	126.0	20.1	6.8	8.1	11.9	12.5	12.9	40.0	12.5	14.2
B193	172.5	125.6	22.1	7.2	8.3	9.9	13.2	14.9	39.4	11.6	12.7
B385	226.2	127.7	22.4	6.3	8.9	11.6	5.9	14.3	42.4	16.5	11.1
B386	237.3	134.8	22.8	6.9	9.6	12.4	12.0	14.1	43.7	16.6	10.9
B399	236.0	141.8	23.1	7.6	9.1	13.9	13.7	13.2	46.3	16.8	13.4
B414	236.9	143.9	23.0	7.6	9.3	13.6	13.1	14.2	49.3	17.1	10.4
B415	236.7	143.4	23.0	7.4	9.1	14.2	12.8	14.4	47.6	17.0	9.9
B432	232.9	143.8	23.2	6.9	10.4	12.6	14.2	12.7	47.0	16.0	14.8
B439	226.3	141.0	25.7	7.1	8.7	13.1	12.2	16.0	41.7	13.2	20.0
B442	237.7	135.0	22.6	6.5	9.6	11.9	12.3	13.1	43.6	15.0	10.2
B443	228.2	140.2	18.8	6.3	10.4	13.7	16.1	16.7	45.1	12.3	14.2
B472	235.3	136.1	22.9	6.5	9.0	12.9	11.9	10.9	46.8	19.8	12.0
B478	240.1	128.9	20.6	6.5	8.7	12.1	13.3	9.7	41.8	16.3	8.8
B480	250.9	140.3	23.6	7.1	9.6	12.4	12.1	14.9	46.1	17.5	11.7
B482	228.8	127.4	20.9	6.3	7.3	12.8	13.6	12.4	40.8	13.1	14.2
B483	235.5	140.0	22.6	8.0	8.8	13.6	14.8	13.8	43.6	15.1	13.7
B515	249.2	143.2	24.2	7.1	10.1	13.0	11.3	15.5	47.3	18.6	13.4

Röt Fm. thickness	RNROU			RNRO2 RNROM			RNRO1		
	C1	A-B	B	A	total	B	A	total	E
HEN-01					1.5	22.7	11.9	10.8	29.3
B005	24.4	11.9			1.3				
B011									
B015									
B058	19.7	9.4			1.1	25.3	13.2	12.1	67.2
B100	18.7	8.8			1.8	24.6	12.3	12.3	66.2
B106	18.0	9.9			0.7	12.5			
B154a	13.4	13.3	7.2	6.1	1.2	24.0	13.0	11.0	56.5
B175	15.5	11.3	5.9	5.4	2.1	23.8	14.1	9.7	72.0
B186	13.3	13.7	6.8	6.9	1.6	23.8	11.8	12.0	78.4
B193	15.1	10.6	5.0	5.6	1.1	24.3	13.1	11.2	21.5
B385	14.8	15.9	6.4	9.5	1.3	25.7	13.1	12.6	71.5
B386	16.2	13.3	4.3	9.0	1.9	24.3	12.7	11.6	76.3
B399	16.1	14.9	6.4	8.5	1.7	26.9	14.1	12.8	65.6
B414	21.8	13.8	5.2	8.6	0.8	26.3	13.9	12.4	65.9
B415	20.7	14.9	6.8	8.1	1.1	26.2	13.3	12.9	66.0
B432	16.2	16.8	9.0	7.8	1.7	26.4	14.0	12.4	61.0
B439	8.5	16.5	10.2	6.3	1.4	27.4	14.5	12.9	56.5
B442	18.4	15.4	6.3	9.1	1.2	25.3	14.2	11.1	76.2
B443	18.6	13.1	7.1	6.0	1.4	26.1	14.0	12.1	60.5
B472	15.0	15.2	6.2	9.0	1.3	26.0	13.6	12.4	71.9
B478	16.7	16.2	8.7	7.5	1.8	25.1	13.3	11.8	84.3
B480	16.9	14.5	6.4	8.1	0.9	26.1	13.6	12.5	83.6
B482	13.5	13.3	6.3	7.0	1.2	24.2	12.3	11.9	76.0
B483	14.8	14.8	5.6	9.2	1.4	26.3	12.8	13.5	67.8
B515	15.3	14.7	5.4	9.3	1.3	27.1	14.0	13.1	77.6

Röt Fm. thickness	RNRO1 Salt-D		Salt-C		Salt-B		Salt-A		Salt undiff
	D2	D1	C2	C1	B2	B1	A2	A1	
HEN-01									14.9
B005			17.3	1.2	4.7	0.7	22.2	0.8	
B011			18.0	0.6	4.0	0.8	18.9	1.0	
B015			19.0	1.3	4.7	0.7	29.2		
B058			20.4	1.6	4.3	0.7	22.0	1.0	
B100		3.7	20.7	2.0	4.4	1.2	21.5		
B106	1.9	4.1	18.2	3.8	3.8	1.0	27.5		
B154a	0.5	3.8	19.1	1.1	5.4	0.9	15.1		
B175	0.8	4.3	18.7	2.5	4.9	0.7	28.1		
B186	0.5	3.4	23.8	1.2	7.1	0.9	32.6		
B193							6.5		
B385	0.5	5.1	19.5	2.8	3.6	1.5	26.8		
B386	2.9	5.0	18.5	2.7	3.8	1.5	30.3		
B399		3.9	20.6	2.0	4.5	1.0	21.1		
B414	0.4	4.4	18.9	2.4	4.7	0.9	22.3		
B415		3.5	20.2	2.6	4.4	1.1	22.1		
B432		4.0	14.7	2.7	4.4	0.9	21.3		
B439		3.9	14.8	2.1	4.7	1.0	17.9		
B442	2.8	4.9	19.9	1.4	4.3	1.3	30.8		
B443		3.6	18.8	2.0	4.7	0.9	17.3		
B472		4.0	19.9	2.3	3.7	2.0	26.7		
B478	2.7	5.1	18.1	1.9	4.2	0.9	39.0	1.2	
B480	2.6	4.3	20.9	1.7	4.5	1.0	36.5		
B482	3.7	4.2	19.2	1.5	4.6	0.9	30.1		
B483	1.8	4.3	17.7	2.6	4.1	0.8	25.0		
B515	2.8	4.7	20.8	2.2	4.1	1.1	31.2		

List of Studies and information available

List of Studies & Information made available by AKZO

- ' NITG 05-074-C: Palynologische 'fingerprint' van AKZO boring 480, TNO-NITG, 2005
- ' 545, Voorlopige Biostratigrafie van het Jura Traject van boring TWR-386 (AKZO); RGD, 1992
- ' Rapport nr 65, 66, 67 en 68; Onderzoek naar de aanwezigheid van Jura of Onder-Krijt in de KNZ boringen 106, 133, 140 en 171; RGD, year 1969
- ' rapport NR 68, Stratigrafische Interpretatie van een kerntraject uit boring KNZ 171; RGD, 1969
- ' Rapport 135; Boring 31 der Koninklijke Nederlandse Zoutindustrie.; RGD, 1953
- ' Some remarks on selected palynomorphs near the Jurassic-Cretaceous boundary in the Netherlands, Herngreen et al, 1976
- ' Salt Resources in the Netherlands as Surveyed mainly by AKZO; Harsveldt, 1978
- ' OS 94-22-B; Acquisition and processing of well measurement in well B399 of AKZO Hengelo, TNO-NITG, 1994
- ' The development, Geology and Lithology of the Central-Northern Part of the Hengelo Rock Salt Solution Mining Area and its Geotechnical Characterisation; Van Lange, 1994
- 'MP-93-002; Subsidence over Solution Cavities in Salt in the Twenthe-Rijn Concession Area; Bekendam, 1996
- 'NITG 97-69C; Kartering Twenthe –Rijn, Uitbreiding Twenthe-Rijn en Buurse Concessie, TNO-NITG, 1997. including database
- ' 005.40306/01.02; Boorgatmeting te Enschede (Overijssel); Standaard, spectraal en dichtheidsmeting (juli '00), TNO-NITG, 2000
- ' NITG 02-194-C; Actualisering van de bestaande geologische kaarten van de concessie Adolf van Nassau en van de concessies Twenthe-Rijn, Buurse en Uitbreiding Twenthe-Rijn; TNO-NITG, 2002., including database-4oct2002
- ' 5145031243; Stratigraphisch-sedimentologische und mineralogisch-geochemische Untersuchungen des Rotsalzes. Kavernenfeld Hengelo, Bohrung 480; BGR Hannover, 2004
- 'S05B0013, Boorlog interpretatie basis Tertiair, Syncera GeoData B.V., 2005
- ' Statussheets of all wells studied
- ' Wireline logs of all wells studied
- ' Boorrapporten B478, B480, B483, B515
- ' Sample material
- ' original well logs of wells B001- B011, B058

Studies Geowulf Laboratories

title	wells	sample type/interval
course 1999	B472	cuttings/10m
course 2006	B442	cuttings/10m
GL06.0406; Lithological Study Cutting Samples, Well B480, 2006	B480	cuttings/1m
GL06.0601; Lithological Study Core Samples, Well B480, 2006	B480	core/1m
GL07.101; Lithological Study B478, 2007	B478	cuttings/1m

B472, B442, B480 (see previous studies)

GL07.102; Lithological Study of Salt A – B480

GL07.1001; Correlation Project Eastern part TWR Area & Lithological Study B483, B515

B483 cuttings/1m

B515 cuttings/10m

B399, B385, B386, B432, B439, B443, B414, B415, no samples

B480 (see previous studies)

GL07.1002; Base North Sea Supergroup (Base Tertiary), in the Hengelo brine field

B479, B482, B485 cuttings/3 per well

B431, B441, B445, B446, B447, B484 no samples

B478, B483, B442 see previous studies

GL08.101; Gamma Ray cut-off Analysis Anhydrite – E

B478, B480, B482, B483, HEN-01, B515 no samples

GL08.501, Correlation study, western part

HEN-01, B001, B011, B106, B175,

B186, B154a, B482 cuttings, 2 – 10m

B005, B031, B058, B100 no samples

previously studied wells

Other

The study is based on the regional geology as described in the 'Geological Atlas of the Subsurface of the Netherlands. Sheet X: Almelo – Winterwijk, TNO-NITG, 1998