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2018.013**

**3D-modelling and visualisation of the
carbonate deposit at Breivoll, Rolla, Troms
county, Norway**

(translated from the original in Norwegian
by geologist emeritus Rognvald Boyd)



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Summary: <p>A 3D model of the most important carbonate zones at Breivoll in the Rolla deposit has been constructed based on the surface mapping and drill-hole data described by Kaspersen (2015). A total of 19 drill holes have been registered in 3D MOVE, including the relevant deviation measurements and analytical data on the Fe+Mn data in the carbonate units. A carbonate with a combined content of Fe + Mn below 250 ppm is considered to be of high quality. Three main "blocks" define three carbonate zones (zone 1, zone 2 and zone 3). Definition of these "blocks" is based on the analysed carbonate contents in the drill holes. Zone 4, which is known from mapping on the surface, has not been modelled because it has not been intersected in any of the drill holes. The part of the deposit which has been drilled shows the following:</p> <ul style="list-style-type: none">• Zone 1 contains ca. 20 million m³ (ca. 60 million tons) of carbonate of all qualities.• Zone 2 contains ca. 63 million m³ (ca. 170 million tons).• Zone 3 contains ca. 64 million m³ (ca. 173 million tons) <p>Partial blocks for the parts of the deposit containing high-quality carbonate (Fe+Mn < 250 ppm) have also been defined within the volumes of zones 1, 2 and 3, in total 13 such blocks. Zone 1 contains 2 such blocks, with a collective volume of 864,300 m³, corresponding to ca. 2.3 million tons. Zone 2 contains 7 such blocks, with a collective volume of 5.7 million m³, corresponding to ca. 15 million tons. Zone 3 contains 4 such blocks, with a collective volume of 8 million m³, corresponding to ca. 22 million tons.</p> <p>Further work should focus on more detailed fieldwork in order to understand the tectonic division of the carbonate zone, an understanding which can be used in a more detailed model. The model shows that the density of the drill holes is very inadequate and that the definition of the deposit in 3D is quite "rough". A programme with a denser distribution of drill holes should be a precondition for further work with the deposit.</p>					
Keyword: Breivoll		Rolla		carbonate	
3D		Modelling		3DMOVE	
volumes					

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1. Introduction

The white calcite marble at Breivoll-Skog on the island of Rolla in Ibestad municipality was assessed by NGU (Korneliussen et. al., 2011) to be a mineral resource with a potential for the development of commercial activity.

The municipality and Troms county pursued NGU's recommendation regarding further investigations, and funding was allocated for a follow-up project. Geological consultant Perry O. Kaspersen was hired by the municipality as leader of the project, in which 19 holes, in total 2234 m, were subsequently drilled (Kaspersen 2015). The available geological information was thereafter compiled by Korneliussen and Raaness (2016).

The land-owners and also the municipality had a serious concern as to whether any future mining activity could be implemented by underground mining in such a way that inconvenience for the local population was acceptable. This issue has not yet been clarified in an acceptable manner. It has been necessary, in order to make progress in this process, to create a 3D-model, which is the background for this project and this report.

The main components are:

- A geological model of the carbonate rocks at Breivoll, on the south-eastern part of Rolla
- Calculation of the volume of the main carbonate zones.
- The calculated volume and tonnage of the carbonate zones which have the best quality, i.e. the zones which, on average, contain less than 250 ppm carbonate-bound (acid soluble) iron (Fe) and manganese (Mn).
- A digital 3D-model which, with some instruction (described in the report), can be used in the further, detailed planning, in the cooperation between the municipality and the ground-owners. Anyone, in principle, will be able to use this model, e.g. private persons who are interested and potential industrial companies.
- A video has also been prepared, for potential use in presentations for ground-owners and other interested persons/groups.

2. Methods

2.1 Organization of data

This work builds on data gathered by K. Nilsen and P. Kaspersen and reported by Kaspersen (2015) and by Korneliussen & Raaness (2015). All the available data was organized for 3D modelling and interpretation.

2.1.1 Location of drill holes and deviation measurement

The coordinates for the surface locations of the drill holes are taken from Kaspersen (2015). The drill holes were initially plotted in 3D with a defined direction and plunge. This gives a straight line in 3D space, but most of the holes are not, in reality, straight. There can be several reasons for this. There may be problems with the drilling equipment or bending of the drill string due to variation in the hardness of the rocks. Deviation is also very common when drilling through several types of rock, especially at the contacts between different types of rock. Measurement of deviation in all drill holes is therefore a normal practice when drilling core in mineral deposits. All the drill holes were, after completion of the drilling programme at Breivoll, measured using equipment which registers their deviation. These data were registered on a separate Excel sheet as XYZ coordinates. All the drill holes on Breivoll were measured for deviation and the drill holes shown in 3D space are corrected for deviation. Deviation in the drill holes was, however, very limited.

2.1.2 Drill core logs

The drilling programme was carried out by the drilling contractor Arctic Drilling Company Ltd. (ADC) in the original geological project (Kaspersen, 2015). The drill cores were, in this work, in part re-logged based on photographs and, in part on physical inspection of the drill cores at NGU's drill core store at Løkken.

Construction of a 3D geological model has necessitated simplification of the existing drill core logs. The core logs reported by Kaspersen (2015) involved the use of 39 different rock names: many of these names were used for fewer than 3 rock units, and many are varieties of the same rock type. Examples include: amphibole-biotite-schist, amphibolite-biotite-schist, biotite schist, biotite gneiss, mica-schist-amphibolite and mica schist. These have all been simplified to "mica schist" in connection with re-logging of the cores. The simplification was carried out, primarily, on the basis of photographs of the cores, but a selection of cores was re-logged in order to ensure the quality of the photograph-based re-logging.

It has been necessary, in addition to examination of the different rock types, to consider the thickness of the different units. One of the purposes in creating a 3D-model is to be able to observe the geometry of the different rock units in relation to the surface of the terrain, in particular the geometry of the economically interesting units. A production company will, in the event of a mining operation, be dependent on the economically viable units having the necessary thickness. We have chosen, as a compromise between the detailed, complex geology and the simplified overview given in this report, to exclude definition of units with a thickness of less than 1m except in cases where these are considered to be important geological "marker" units.

2.2 3D-modelling

The 3D-model uses topographic data from the Norwegian Mapping Authority (Statens Kartverk) (altitude model) in the form of 10m DEM downloaded from www.hoydedata.no. Orthofotos from www.norgebilder.no have been draped on top of the altitude modell and on El Saleh's bedrock map (1969), and K. Nilsen's bedrock map (Kaspersen, 2015). The analytical data from both Kaspersen (2015) and Korneliussen & Raaness (2015) have, in addition, been used as a basis for selection of the best units which have been used in estimating rock volumes.

2.3 MOVEVIEWER

3D-modelling has been carried out using the software program 3D MOVE developed by MIDLAND VALLEY (mve.com). This software was developed for use by geologists and is a sophisticated, professional tool, with many integrated functions. The same company has also developed a free "sister-product", MOVEVIEWER, which allows visualisation of models created in 3D MOVE, but without the possibility of editing these. More information about the software can be found on mve.com. MOVEVIEWER is constructed so that non-geologists should be able to gain access to the model, with the same functions as in 3D MOVE, except for the possibility to edit the models. This paragraph explains how to navigate through the software and how to achieve most in visualising the model. Access to the model can be gained by downloading both the software and the model files from the following ftp link:

<ftp://ftp.ngu.no/pub/Henderson/rolla/>

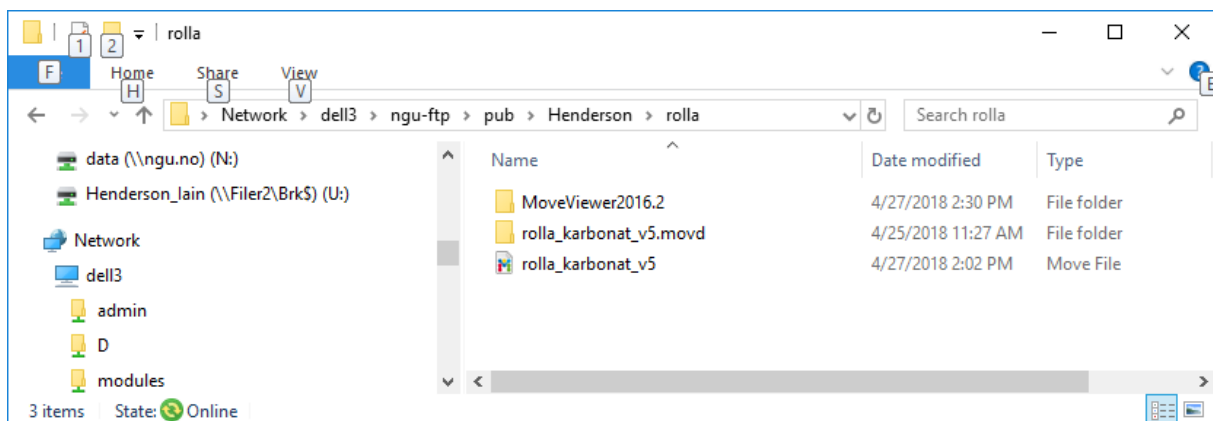


Figure 1: The files and folders in the ftp folder. These must be copied to a local PC and MOVEVIEWER must be installed.

The folder is shown in Figure 1. There are three components. A MOVEVIEWER folder, a folder for all the MOVE-files (.movd) and a 3D-file called *rolla_karbonat_v5*. The MOVEVIEWER folder opens after the files have been stored on a local hard disc. The folder has the form shown in Figure 2.

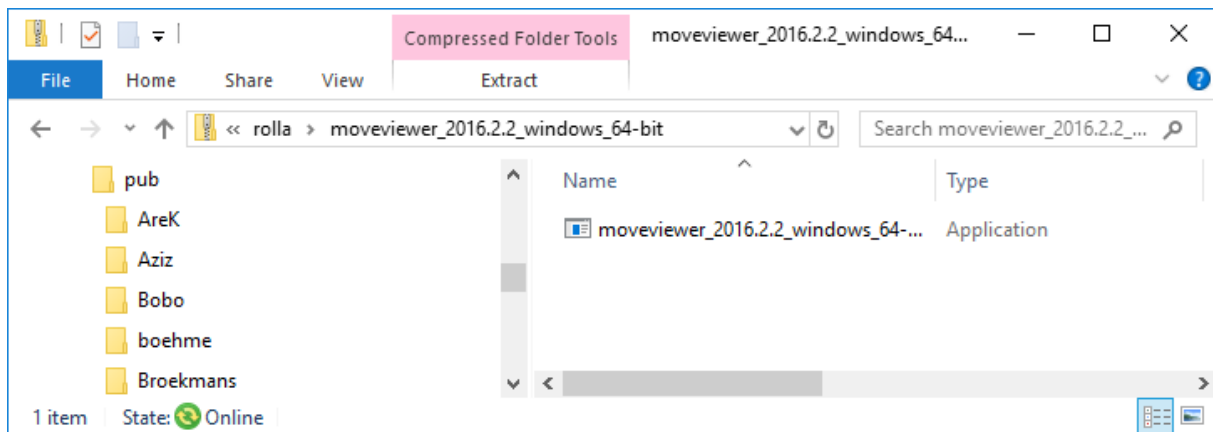


Figure 2: This window appears after clicking on the MOVEVIEWER folder. Double-click on *applikasjonsfilen* and follow the instructions in order to install MOVEVIEWER.

Double click on *moveviewer*. This installs MOVEVIEWER.

After the files are downloaded, MOVEVIEWER opens and then the model-file (*rolla_karbonat_v5*) in MOVEVIEWER. Several menu areas are shown. Figure 3 shows the uppermost menu. The file opens with a white background. One can, for a more convenient image, change the background to black. This can be done in the uppermost menu (Figure 3).

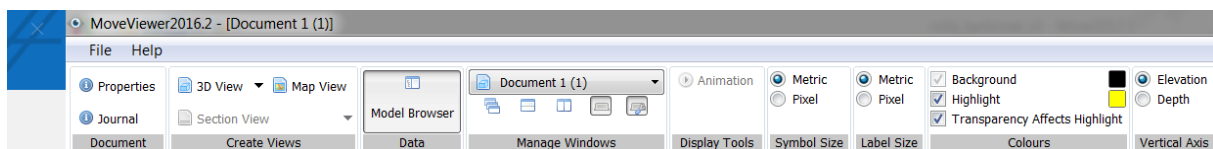


Figure 3: The uppermost menu line in MOVEVIEWER. The most important button here is the one to the right, which changes the background colour.

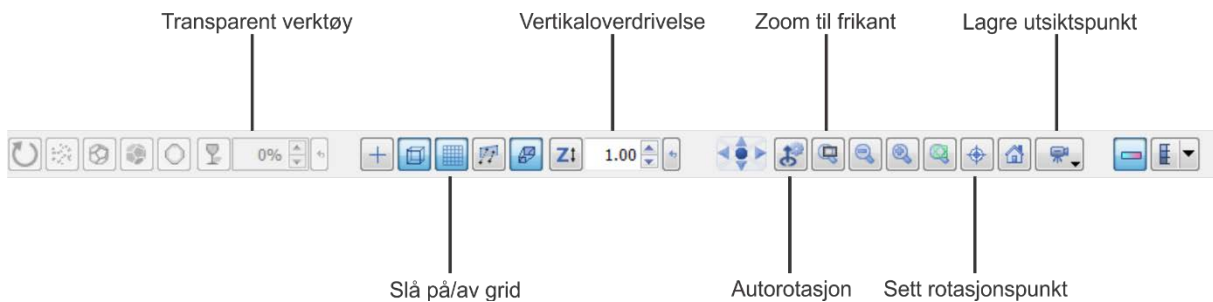


Figure 4: The lowermost menu line in MOVEVIEWER. It contains many buttons the most important of which are described in the following text.

Figure 4 shows the lowermost menu line in MOVEVIEWER. It contains several important buttons which can improve the visualisation experience. Two of the most important functions are *transparent* and *sett rotasjonspunkt*. One can, by clicking on an object, either in the *Layer-menu* to the left (e.g. Figure 7) or in the 3D-window itself, adjust the degree of transparency. One can, by clicking on *sett rotasjonspunkt*, change how the model rotates. This is very important when "zooming in" to see different objects in the model. A triple-button mouse is necessary for allowing investigation of the model; the different mouse buttons are shown in Figure 5.

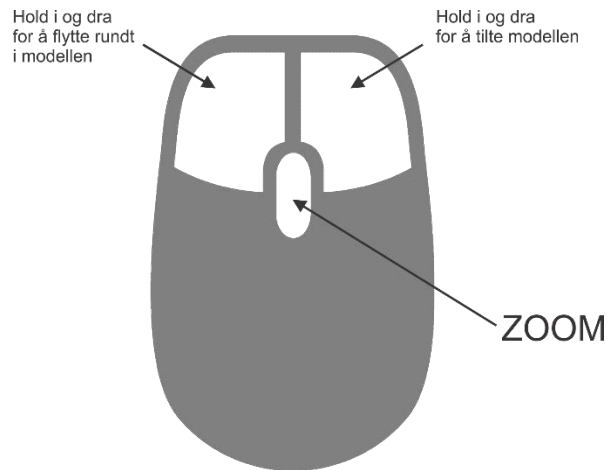


Figure 5: This figure shows the different mouse buttons which must be available to allow use of the model. (Top left: "Hold in and pull in order to move around in the model"). (Top right: "Hold in and pull in order to tilt the model")

Figure 6 shows the appearance of the user interface when it is opened. There is a weakness in the software which causes the construction window to open itself to the right. This can be removed easily so that only the 3D-window is shown.

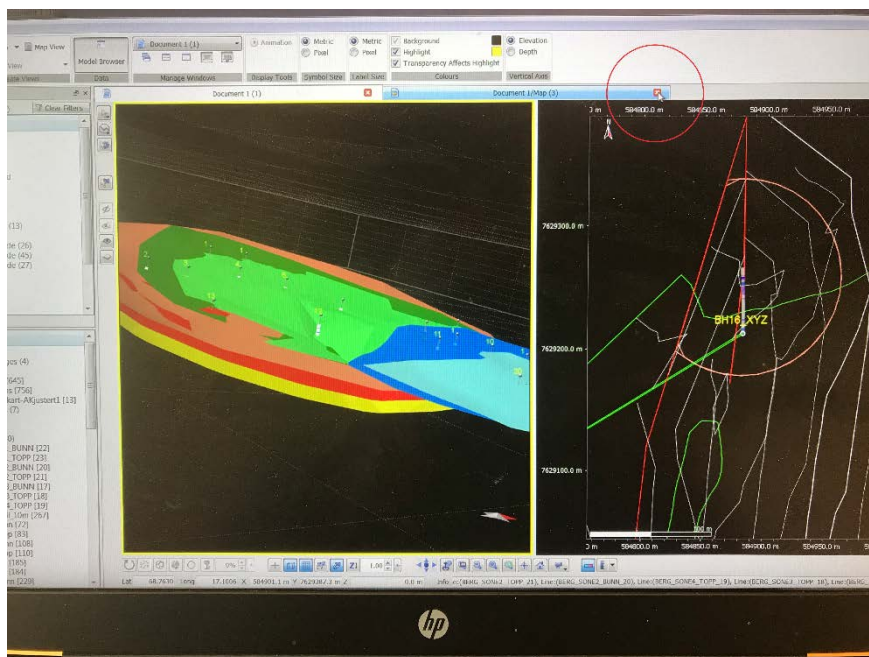


Figure 6: MOVEVIEWER, as it appears when it is opened. The construction window to the right can be removed by clicking on the button shown by a red circle on the figure.

The model itself is built up using many components and structures. The different components in the model are shown in the longest menu to the left. This is the *Layer*-menu which is shown in Figure 7. The components consist of several groups. Uppermost are found the *Linesets* which consist of all the lines in the model. Lowermost are found the *Object Types* which consist of all other objects except lines. Drill holes, surfaces and volumes are found here.

Figure 8 shows all the surfaces created in the model. These include numerous surfaces which are the bottom- and top-surfaces which delimit the volumes which are created finally.

Surfaces and volumes are discussed in more detail in section 3.5.

Lowermost in the *Layer*-menu we find a component called *Tetravolumes* (Figure 9). These are the "final" volumes created with the bottom and top-surfaces as delimiting them. One can, by right-clicking on the volume component in the *Layer*-menu or in the 3D-window itself, access volume information for the individual volumes (Figure 10).

All the components in the model can be "switched" off or on by pressing "off" or "on" in the square beside the component. Several components can be "switched" off/on by following the instructions in Figure 11.

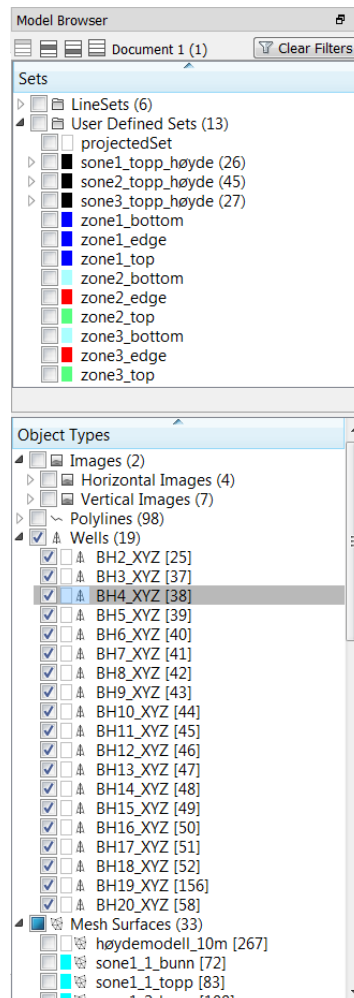


Figure 7: Menu to the left in MOVEVIEWER. It has two main units. The uppermost is 'Sets'. This contains groupings for the various types of lines in MOVEVIEWER. There are, here, in 3D MOVE many construction lines which are the basis for surfaces and volumes. These are not transferred from 3D MOVE. The only lines here are the altitude contours which are related to the constructed surfaces. The lowermost area is 'Object Types'. Here there are *Horizontal Images* (Maps), *Vertical Images* (profiles), *Wells* (Drill holes) and *Mesh Surfaces* (surfaces). All of these can be switched "off" or "on", by clicking on the relevant squares.

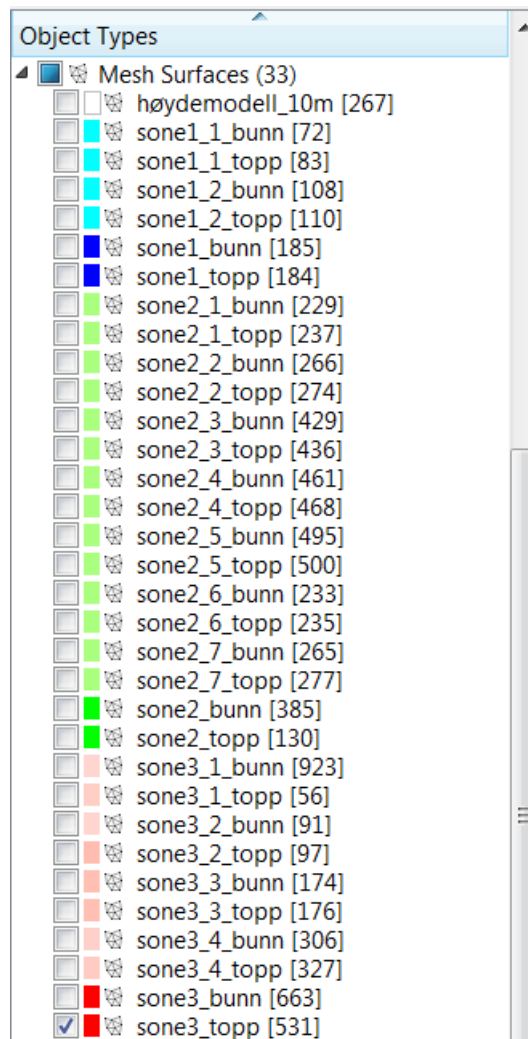


Figure 8: The "object" menu which shows all the surfaces constructed in the model. Blue indicates volume associated with carbonate zone 1, green with carbonate zone 2 and pink/red with carbonate zone 3. Zone 1_bunn is the basal surface for the analysed volume for zone 1. Zone2_1_top is the top surface of the first volume (1 of 7) of high-quality carbonate in zone 2, etc.

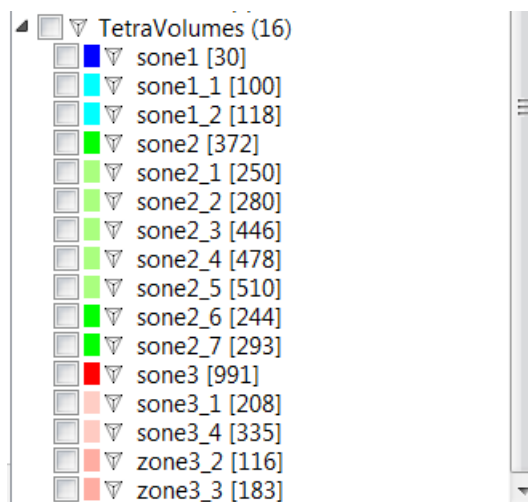


Figure 9: Final volumes constructed from bottom- and top-surfaces in Figure 8 (see lowermost in *Object types*). There are, in total, 16 volumes.

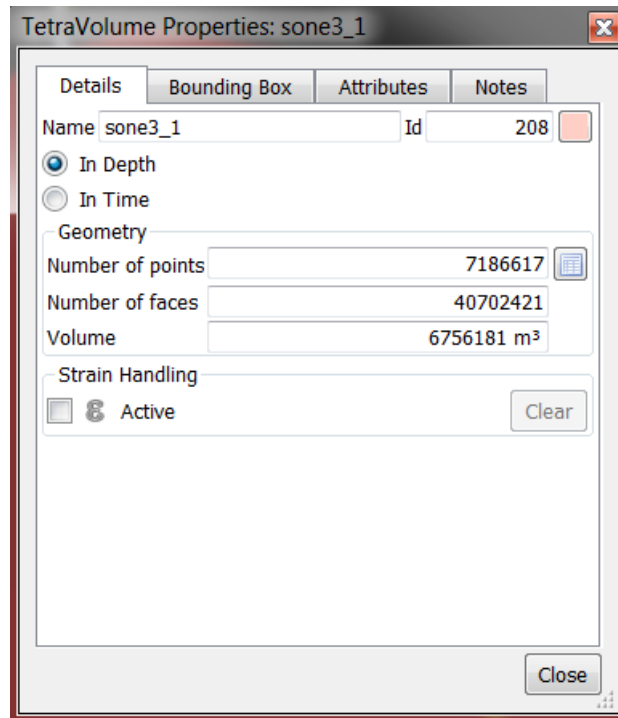


Figure 10: One can, by "right-clicking" on an individual volume (either in the 3D-window or in the *Object*-menu) open a parameter window which shows the calculation of the volume selected. The tonnage is ca. 2.7 X the volume in m³. The tonnage in this example (volum Sone3_1) is 18.2 million tons.

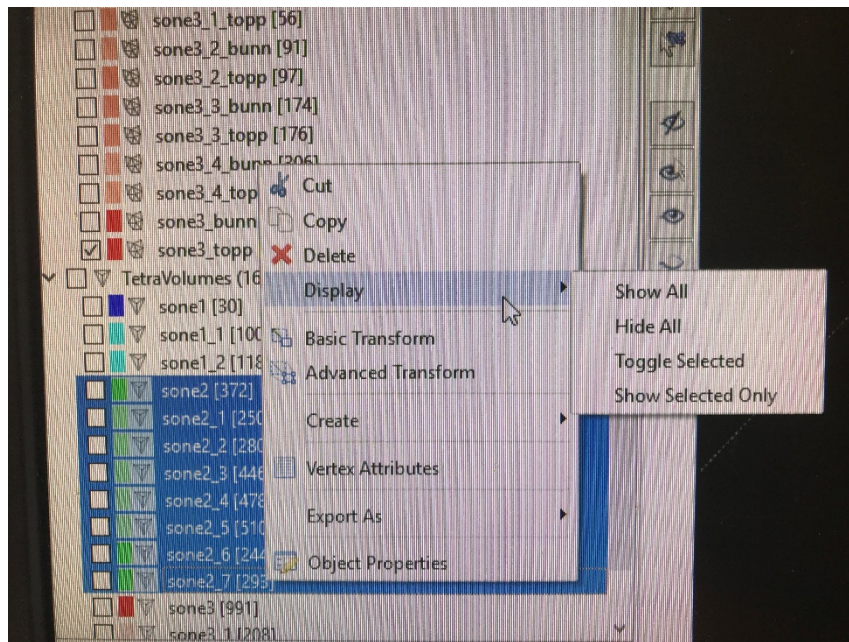


Figure 11: One can, by holding "shift" "in" and, simultaneously, selecting several components followed by "right-clicks", switch several components "off" and "on" at the same time by using *Display* and *Toggle Selected*.

3. Results

This section presents the results of the 3D-modelling of the Rolla carbonates. The model consists of many components which are considered in turn and which explain the construction of the model.

3.1 Altitude model and orthophotos

3D topographic data form the basis for the model. These have been downloaded from *høydedata.no* and consist of 10m DTM for the whole of Rolla (Figure 12). Georeferenced orthophotos are draped on top of the altitude model. The photographs can be switched off or on by clicking on the altitude model, either in the *Layer*-menu or in the 3D-window itself and thereafter on *Overlay* in the lowermost menu (Figure 13). This can also be done with other horizontal photographs.

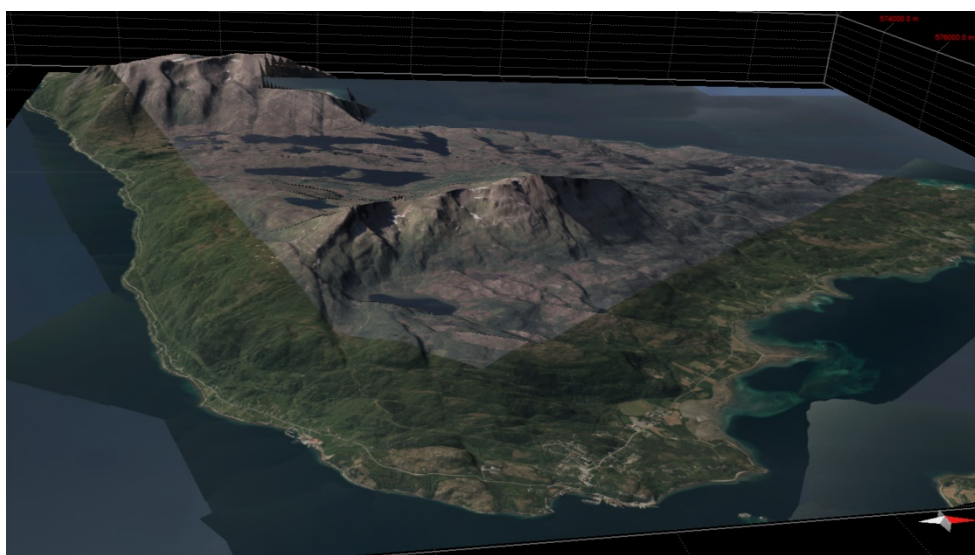


Figure 12: Altitude model draped with orthophotos for the whole of Rolla.

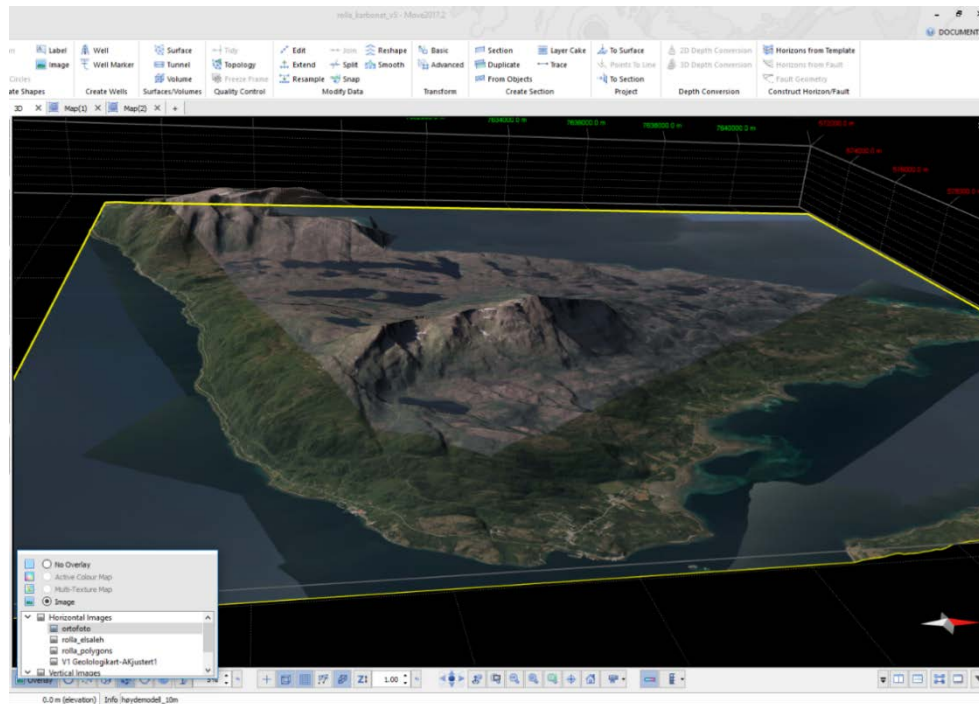


Figure 13: Draping of orthophotos on the altitude model.

3.2 Altitude model and regional geology

Figure 14 shows the altitude model on which is draped a digitalised regional geological map, based on the work of El Saleh (1969). This gives a good impression of how the carbonate units occur in relation to the landscape. One can move back and forth between a straightforward altitude model, orthophotos and regional geology in *Overlay* in the lowermost menu.

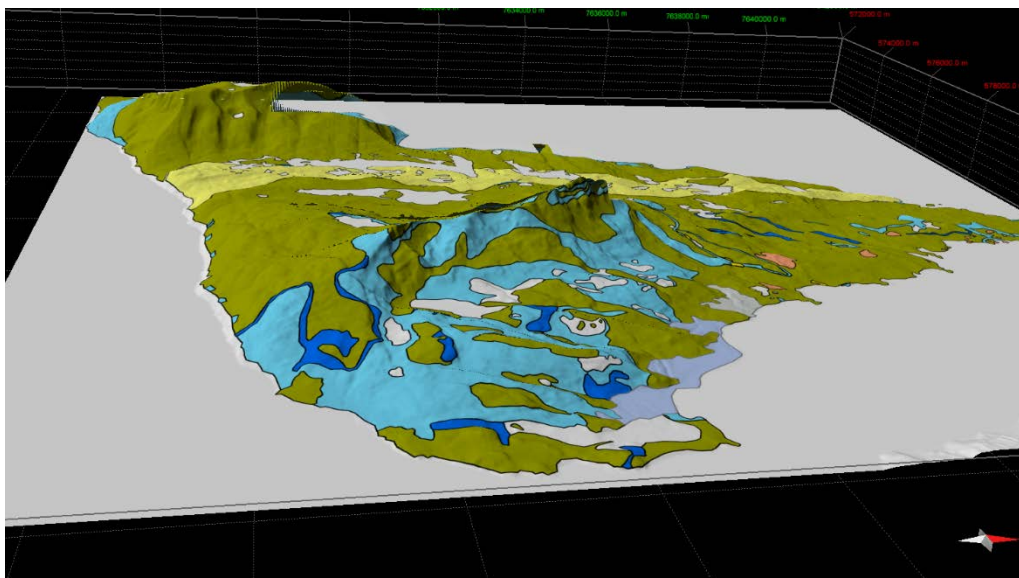


Figure 14: The altitude model draped with the regional geology according to El Saleh (1969). The carbonate layers are shown in blue colours, pale blue for calcite marble and dark blue for dolomite marble.

3.3 Draping of surface mapping

Figure 15 shows the same altitude model draped with a digitalised version of K. Nilsen's detailed surface map (Kaspersen, 2015). This is shown using the same method as for the other layers, by selecting the layer called *VI Geologikart-AKjustert1* in the *Overlay*-function in the lowermost menu. Note that only the part of the altitude model which overlaps with the draped layer is shown. It is important, if one wants to rotate the model, to choose a new rotation point because the rotation point lies in the middle of the altitude model which extends over the whole of Rolla. This can be done by clicking on the *sett rotasjonspunkt*-button in the lowermost menu (close to the right-hand side) which was shown in Figure 4.

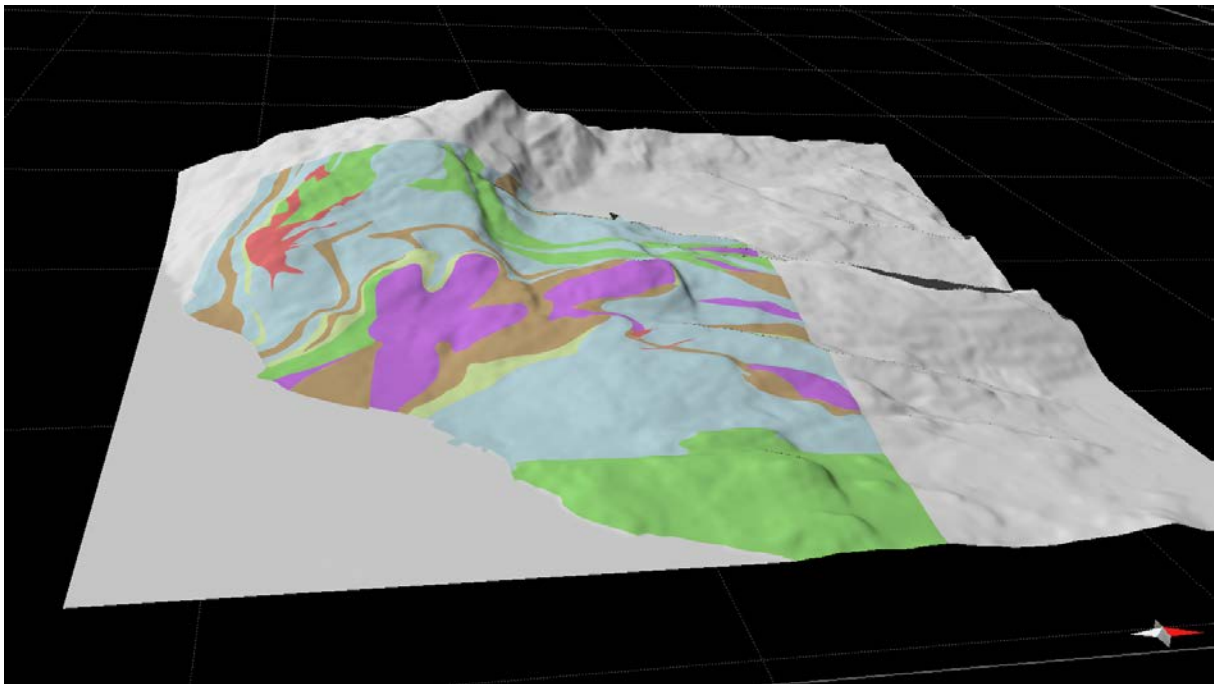


Figure 15: Altitude model on which is draped the surface geological map from Kaspersen (2015).

3.4 Drill holes, deviation measurements and Fe-Mn analyses

It was necessary, after the work on simplification explained in section 2.1, to carry out a comprehensive reorganisation of the Excel files which contain drill hole-data, before loading the data into 3D MOVE. The completed Excel files were loaded into 3D MOVE with the relevant deviation data (originally collected by the drilling contractor ADC) for each drill hole. Geological, analytical and deviation measurements did not exist for drill hole BH15. All the other drill holes have complete data and the completed drill holes are presented in 3D-space in Figure 16. Deviation in the drill holes is, in general, insignificant.

Figure 17 shows how the analytical data are grouped, using BH20 as an example. The analyses are divided into 4 groups based on their Fe+Mn contents (Korneliussen and Raaness, 2017). The white colour shows the parts of the drill cores for which there are no analyses. Geological units which were not analysed are either not marble or are marble cut through by, e.g. pegmatites, and therefore not suitable for extraction for the carbonate industry.

The pale blue colour shows analysed carbonate with the highest contents of Fe+Mn (>500ppm), i.e. the carbonate considered to have the lowest quality. The turquoise colour shows carbonate with a moderate Fe+Mn content (250-500ppm, which is considered as carbonate of medium-grade quality. The dark blue colour shows carbonate with low contents of Fe+Mn (<250ppm), and thus represents carbonate considered to be of high quality.

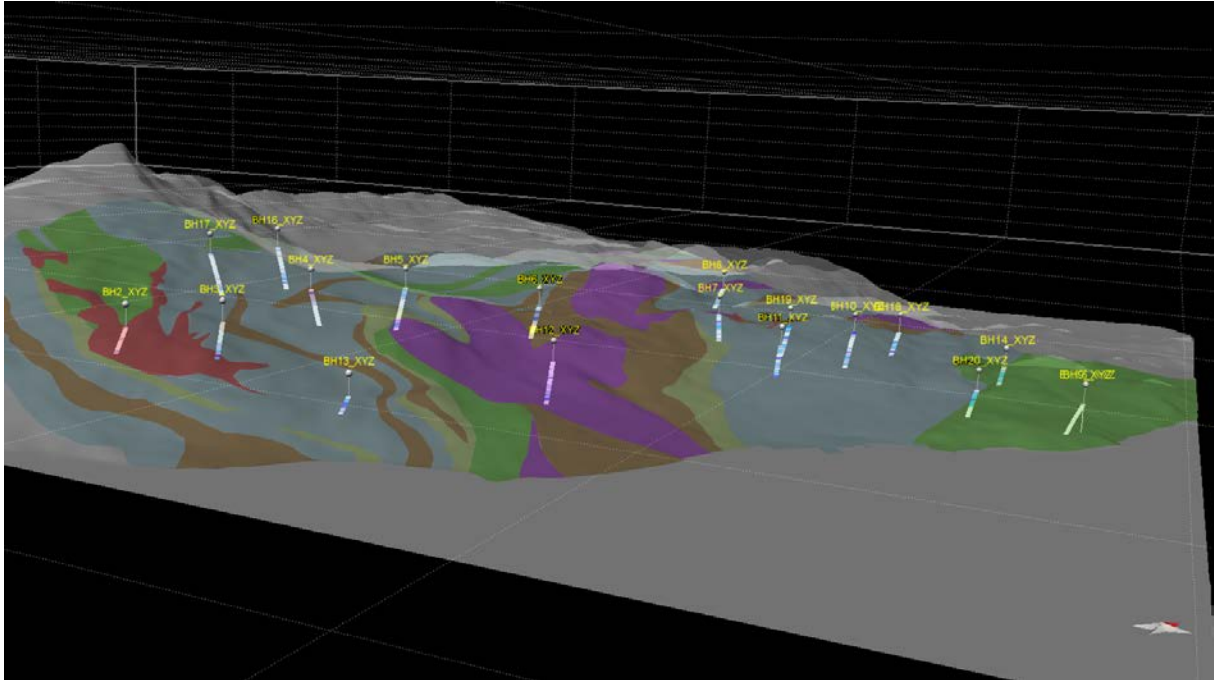


Figure 16: 3D-image from the south, showing the surface geological mapping, viewed in relation to the drill holes. 19 drill holes are entered along with the relevant analytical data, edited information on the drill hole geology and the deviation measurements.

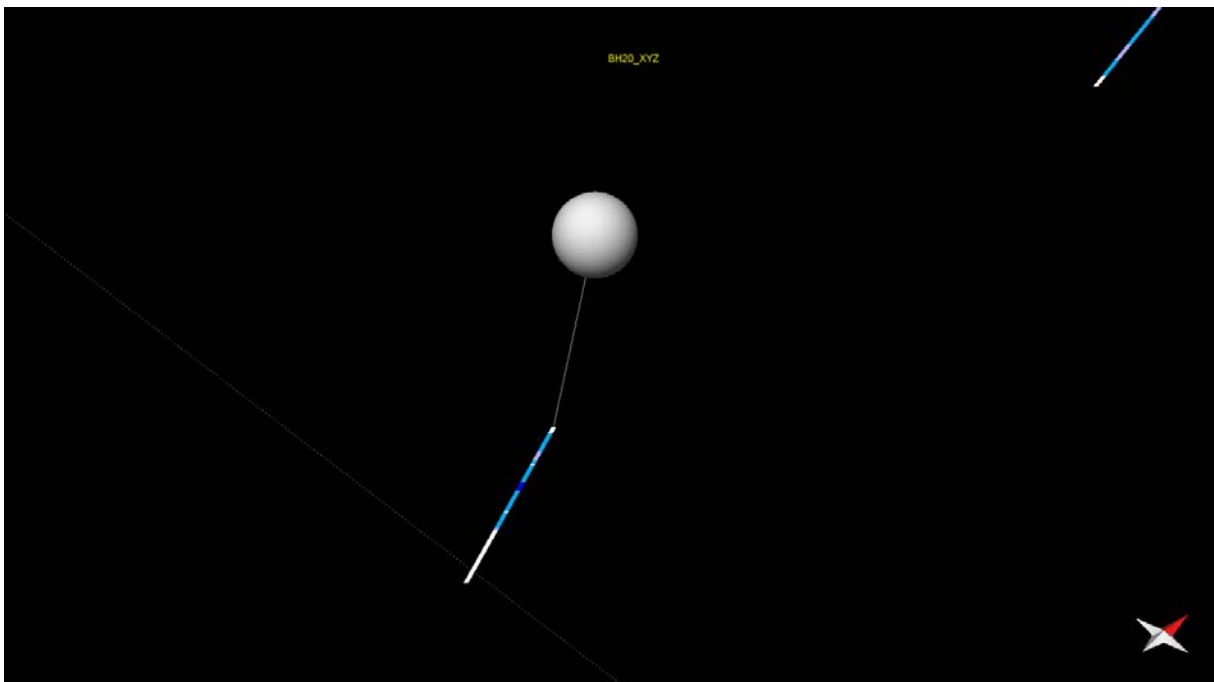


Figure 17: Details from one of the drill holes showing its division based on analytical data. The four colours show divisions based on Fe+Mn contents. White – no analyses, pale blue – low quality, turquoise – average quality, dark blue – high quality.

3.5 Geological model

We have used, in addition to the analytical data from the drill cores, information on the rocks described in the drill-hole logs reported by Kaspersen (2015) and our own simplified logs. We have, on the basis of these data, constructed a simple geological model of the four carbonate layers. Other rock types have been excluded in order to make the orientation of the carbonate layers clearer. Figur 18 shows a 3D-image of the volume which has been constructed on the basis of the top- and bottom-surfaces of the respective carbonate layers which have been analysed. The top and bottom surfaces of Zone 1 are blue (pale-top, dark-bottom), Zone 2 is green (pale-top, dark-bottom), Zone 3 is red (pale-top, dark-bottom) and the top of Zone 4 is yellow. The bottom of Zone 4 is not modelled because it has not been intersected by the drill holes. The figure shows only the surfaces of the tops and bottoms of each zone without the relevant volume calculations.

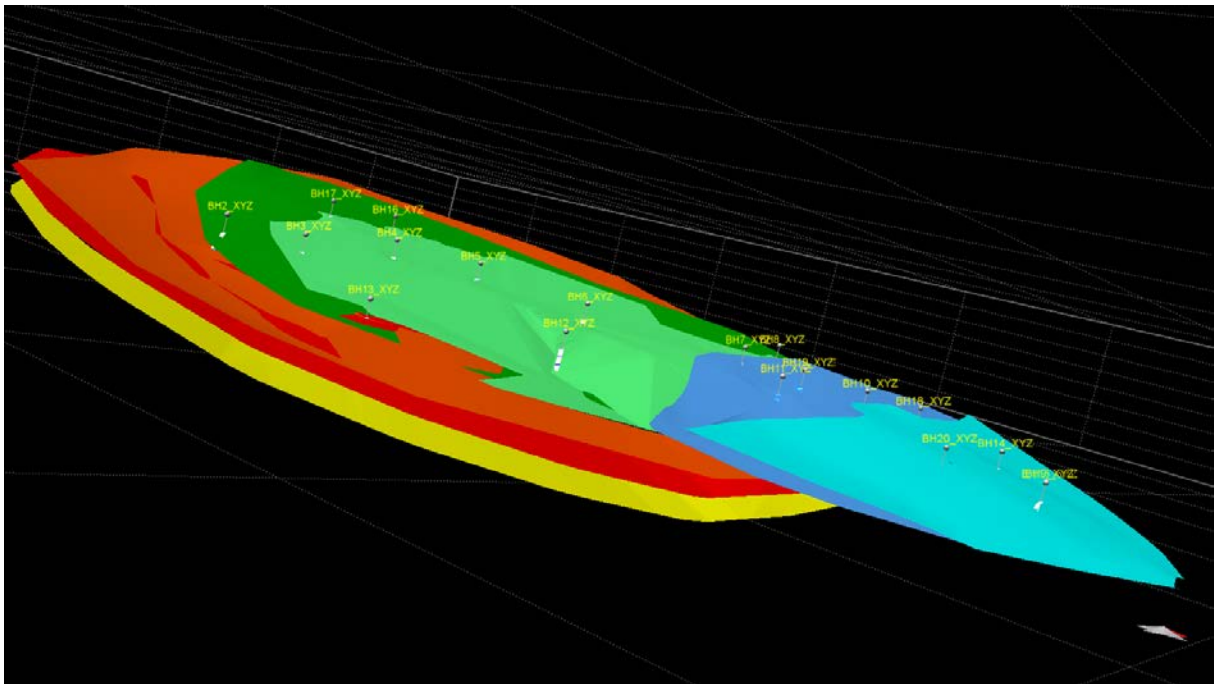


Figure 18: 3D-image, viewed from the south, of a volume based on the top- and bottom-surfaces of the sections analyzed in the drill holes. The top- and bottom-surfaces of Zone 1 are blue (pale blue-top, dark blue-bottom), Zone 2 is green (pale top, dark bottom), Zone 3 is red (pale top, dark bottom) and the top of Zone 4 is yellow.

3.6 Volume calculations based on chemical analyses

The next step was to construct volumes based on the Fe+Mn contents in the analysed carbonate sections in the drill cores. The sections encompass all the drill cores with analytical results shown in blue in Figure 17. The first step was to define the top- and bottom-surfaces for the various carbonate zones. These have been shown earlier in Figure 8 and in the *Object*-menu on the left side of the model. Six surfaces are defined, corresponding, respectively, with the top and bottom of each zone, and are defined as, e.g., Zone1_top and Zone1_bottom. These surfaces have an outline which is limited by the volume in which the drill holes are found, and top and bottom surfaces approach one another so that they wedge out towards the edges of the limiting area.

We have, based on these volumes, created volumes (*voxels*) which have a calculated volume. These volumes are shown in the *Object*-menu and in Figure 19 as Zone 1, Zone 2 and Zone 3. The user, by right-clicking on a volume in the *Object*-menu or on the volume itself in the 3D-window, is given information on the volume in m³. Tonnages are ca. 2.7 x m³ and are shown later, in Table 1.

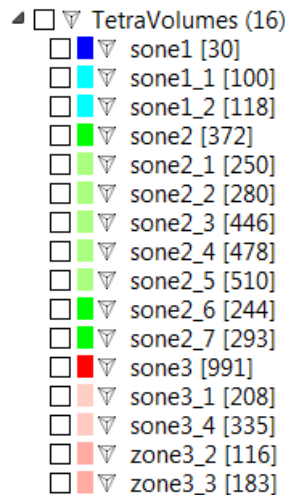


Figure 19: Volumes constructed from the bottom- and top-surfaces of the respective carbonate zones. Right-click on the unit to get information on its volume in m³. The tonnage is ca. 2.7 X the volume in m³.

Zone1 has a volume of ca. 22 Mm³, Zone 2 has a volume of ca. 65 Mm³ and Zone 3 has a volume of ca. 64 Mm³. It must be noted that these are minimum volumes as we take the perimeter of the drill holes as a starting point. Zones 1, 2 and 3 extend beyond this perimeter but have not been drilled.

3.7 Volumes of high-quality carbonate

We have, based on the volumes of the three analysed carbonate levels (1, 2 and 3) constructed individual volumes for carbonate of the highest quality, i.e. carbonate with Fe+Mn < 250 ppm (dark blue intervals in the figures showing the drill holes).

3.7.1 Methods

These volumes can be constructed in several ways: these have been studied in detail so as to ensure that the defined volumes are geologically realistic. The thickness of <250 ppm Fe+Mn-intervals in the drill cores was taken as a starting point: we then calculated a disc-formed plate with a radius based on variations in their thickness of the high-quality interval. We have, after some "trial and error", chosen a solution in which the thickness of the high-quality carbonate decreases outwards from the drill hole. This is implemented by introducing an assumed angle. We have chosen to use an angle of 3° which we believe gives a geologically realistic volume, with some overlap relative to other drill holes. A continuous volume is created where there is overlap. Figure 20 shows a map section from the 3D-model, viewed from above, which shows the different volumes based on the occurrence of best-quality carbonate. We can see 13 different volumes. There are 2 high-quality zones in zone 1: 7 high-quality zones in zone 2 and 4 high-quality zones in zone 3. Zone 2_1 is a zone which can be found and followed in several drill holes and which therefore has a volume with a quite complex form. Most of the volumes constructed are simple and can be described as plate-formed.

Figure 21 shows the same volumes in 3D-space. The result is a quite complex 3D-image, with volumes of different shapes, sizes and with different distances from the surface, some of them located vertically above others.

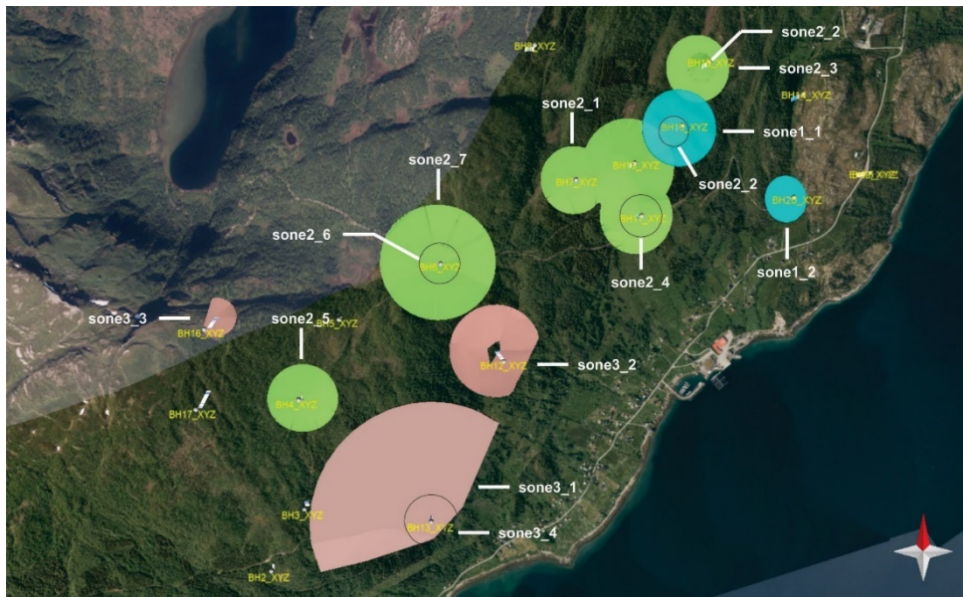


Figure 20: The different volumes have been created based on the highest quality (<250ppm Fe+Mn) carbonate in the drill holes. The volumes are shown in map format and some of them are located on top of others (at different depths). Zone 1-volume is shown in a turquoise colour, Zone 2-volume in green and Zone 3-volume in red.

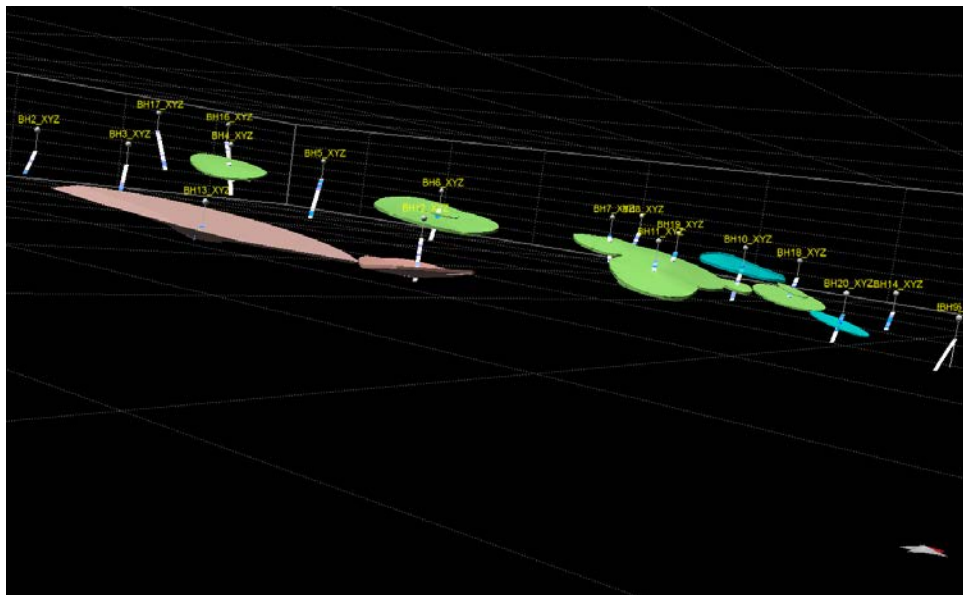


Figure 21: The same volumes as shown in Figure 20 but in 3D-space. Zone 1-volume is to the right and uppermost, Zone 2 in the middle and Zone 3 to the left and lowermost.

Table 1 lists the data on all the 13 volumes of high-quality carbonate zones which have been constructed, based on the zones modelled in Figure 21. All the volumes are based on a grid dimension of 1m. It must be noted that these volume calculations are very approximate as they are based on a quite widely spread pattern of drill holes.

Table 2 shows a calculation of the volumes constructed using a different grid dimension, of 10m. This gives an even coarser volume than that shown in Table 1 but gives file dimensions for the model which are much smaller. These volumes relate to another model file on the ftp page, which is called *rolla_karbonat_v8*. The volume calculations based on the 1m grid dimension are, however, those shown in Table 1 to which reference is made in the following text because it contains the calculations which most closely represent the true situation.

Zone	Volume	Cubic (m ³)	Tonnage (t)
1	1_1	714 179	1 928 283
	1_2	149 291	403 086
	Total Zone 1	863 470	2 331 369
2	2_1	2 305 162	6 223 937
	2_2	32 943	88 946
	2_3	424 756	1 146 841
	2_4	309 813	836 495
	2_5	424 087	1 145 035
	2_6	78 565	212 126
	2_7	2 140 421	5 779 137
	Total Zone2	5 715 747	15 432 517
3	3_1	6 756 181	18 241 689
	3_2	1 129 582	3 049 871
	3_3	59 854	161 606
	3_4	57 705	155 804
	Total Zone 3	8 003 322	21 608 970
Total all zones		14 582 539	39 372 855

Table 1: Overview of the different volumes calculated for the high-quality carbonate zones at Breivoll. The volumes are based on a grid dimension of 1m.

Sone	Volume	Cubic (m ³)	Tonnage (t)
1	1_1	690 210	1 863 567
	1_2	129 192	348 818
	Total Zone 1	819 402	2 212 385
2	2_1	2 174 507	5 871 169
	2_2	24 321	65 667
	2_3	385 694	1 041 374
	2_4	278 646	752 344
	2_5	384 202	1 037 345
	2_6	65 326	176 380
	2_7	2 041 921	5 513 187
	Total Zone2	5 354 617	14 457 466
3	3_1	6 600 659	17 821 779
	3_2	1 051 760	2 839 752
	3_3	46 979	126 843
	3_4	48666	131 398
	Total Zone 3	7 748 064	20 919 773
Total all zones		13 922 083	37 589 624

Table 2: Overview of the different volumes calculated for the high-quality carbonate zones at Breivoll. The volumes are based on a grid dimension of 10m.

It must be noted that this is a very conservative volume calculation and that it is influenced by the very scattered distribution of the drill holes. Extension of the drilling programme, for example between volumes 2_1 and 2_3 towards the northeast could lead to documentation of a considerably larger volume. The same applies to the area southwest of volume 2_1 towards volumes 2_7 and 2_5. Strategically placed drill holes could, in these areas, lead to documentation of a considerably greater volume. This also applies to Zone 3 where there is a lack of drill holes between Zone 3_1 and Zone 3_2.

3.8 Altitude contours

Another type of visualisation which may be useful for land owners, the municipality and others with a potential interest is to use altitude contours which show the depth to the modelled surfaces.

3.8.1 Altitude contours to the top of the analysed volumes

Figure 22 shows the top-surface of the analysed Zone 3 with altitude contours for the altitude above sea level. Altitude contours have also been created for the analysed volumes for Zones 1 and 2. If it is desirable we can also plot the altitude contours as pdf-files and then onto paper. This may be useful during fieldwork in order to show land owners and other interested persons the depth to the individual carbonate zones.

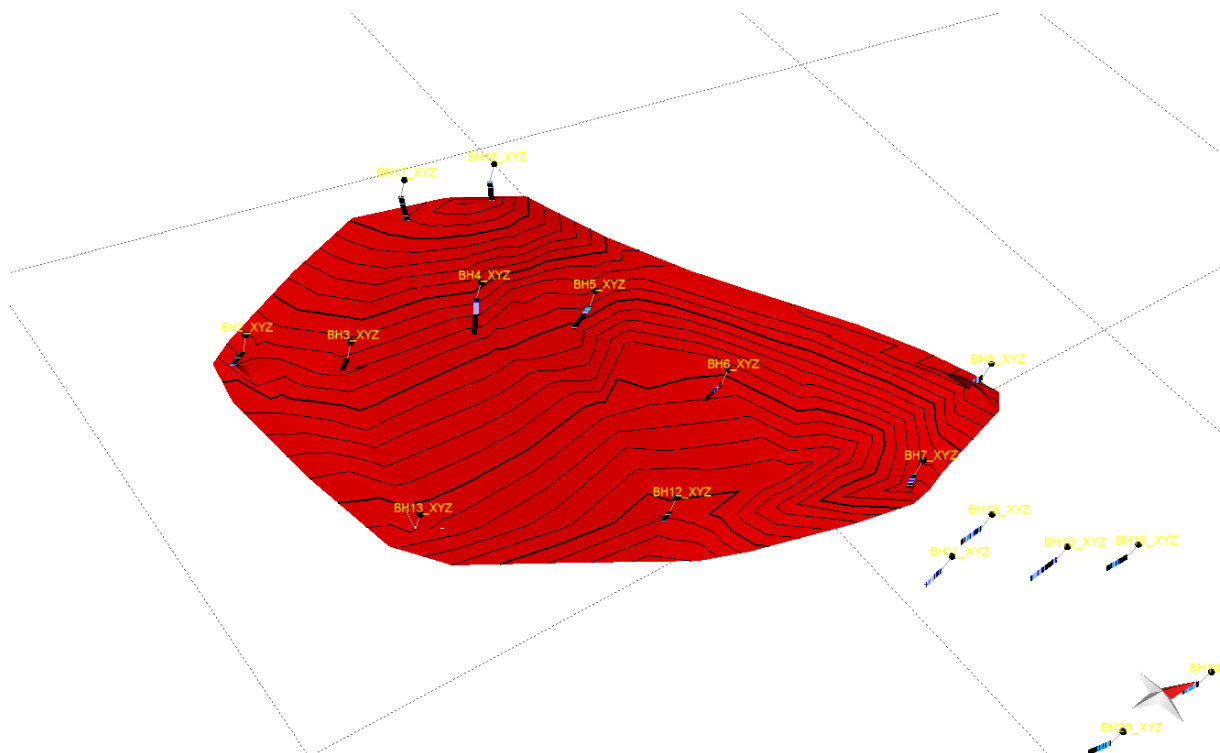


Figure 22: The top surface of Zone 3 (analysed). The altitude contours show the depth beneath the terrain surface, which varies from 270 m.a.s.l. at the highest to 20 m.a.s.l. at the lowest.

The altitude contours for Zones 1, 2 and 3 can be shown by clicking on *Polylines* in the Object-menu on the left-hand side in the Object-menu. This is also shown in Figure 23. One can choose to switch all the altitude contours on by ticking on the *Polylines* square or by shift and click to select only one of the volumes.

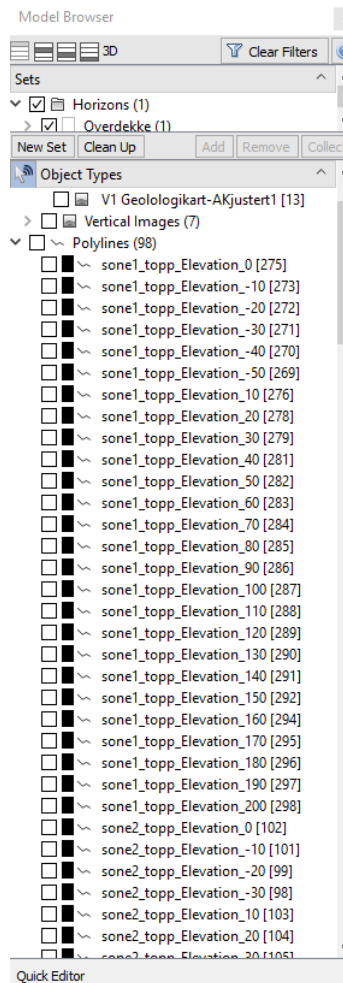


Figure 23: The *Object*-menu on the left-hand side of the MOVEVIEWER software. Open the polylines to show the altitude contours for the analyzed Zones 1, 2 and 3.

3.9 Presentation video

We have, in addition to the 3D-model itself in MOVEVIEWER made a video of the model in *mp4*-format. The file has the name *rolla_karbonat.mp4*. The video shows, first, a regional altitude model of the whole of Rolla with the appropriate orthophoto coverage, and then the model with the regional geology which shows the distribution of carbonates in the whole of Rolla. The next part of the video shows the topography and orthophoto-pictures of the part of Rolla which has been drilled, followed by the drill holes with their Fe+Mn values. This can be a useful product for making the model more easy to understand for land-owners and other interested persons.

4. Conclusions

- A 3D model of the most important carbonate zones (levels) in the Rolla deposit has been constructed based on the data from Kaspersen (2015) which include surface geological mapping, drill hole information and related geological profiles.
- 19 drill holes have been entered into 3D MOVE with the relevant analytical data for the Fe+Mn contents in the rock.
- Three large volumes have been fitted to the three carbonate zones (Zone 1, Zone 2 and Zone 3). These volumes are based on the analyses of the carbonates found in the drill holes. Zone 4 has not been modelled because it was not intersected in any of the drill holes.
- We can, if we look only at the part of the deposit which has been drilled, conclude that Zone 1 contains ca. 22 million m³ (ca. 60 million tons) of carbonate of all qualities.
- Zone 2 contains ca. 63 million m³ (ca. 170 million tons)
- Zone 3 contains ca. 64 million m³ (ca. 173 million tons)
- We have, within the volumes of Zones 1, 2 and 3, created, in addition, part-volumes for the parts of the deposit which contain high-quality carbonate with Fe+Mn < 250ppm. We have, in total, constructed 13 part-volumes of this kind.
- Zone 1 contains two such part-volumes with a combined volume of ca. 864 000m³, corresponding to a tonnage of ca. 2.3 million tons.
- Zone 2 contains seven such part-volumes with a combined volume of ca. 5.7 million m³, corresponding to a tonnage of ca. 15 million tons.
- Zone 3 contains four such part-volumes with a combined volume of ca. 8 million m³, corresponding to a tonnage of ca. 22 million tons

5. Recommendations for further work

The geological part of this 3D-model has been constructed in a relatively simple way. It includes only the most important carbonate layers. The smaller carbonate layers and other rock types are not included. Inclusion of all the different rock types as they are seen on the surface and in the drill-hole cores would require much more time for development of the model.

It is of decisive importance that the municipality and representatives of the land-owners develop experience in use of the digital 3D-model, potentially in cooperation with NGU, so

that they can acquire a deeper insight into the form and occurrence of the potentially valuable carbonate zones.

5.1 Development of a more detailed model

The geological model consists exclusively of the modelled carbonate layers. A more focussed, complex modelling process would be necessary if it was considered desirable to develop a full 3D model including all the geological layers.

5.2 A denser drill hole program

The results of the volume modelling and calculation show that it is difficult to correlate high-quality carbonate sections between the individual drill holes. The density of the pattern of drill holes is simply too low. There is a major uncertainty in the 3D-model relating to the size and lateral extent of the relatively thin high-quality zones. Zone 4 should be intersected in any future drilling program so that it can also be modelled in 3D.

Extension of the network of drill holes between, for example, volumes 2_1 and 2_3 towards the northeast could lead to documentation of a significantly larger volume. The same applies for the area southwest of volume 2_1 towards volumes 2_7 and 2_5. Focussed drilling in these areas could lead to documentation of a much larger volume. This also applies in Zone 3 where there are no drill holes between Zones 3_1 and 3_2.

5.3 More detailed fieldwork

It is characteristic for the Caledonian mountain chain that layers have been thrust over one another during development of the mountain chain. This phenomenon is seen as "ramp structures" in which thrusting has been prevalent and where local increases in the dip of the layers can be seen. This means that one or more of the layers (Zones 1-4) may consist, in fact, of a more complex pattern of several separated layers. This can have great importance for the 3D-pattern (behaviour) of the high-quality carbonate. These thrust zones do not appear in the earlier mapping results (El Saleh, 1969; Kaspersen, 2015). Further mapping should focus on the degree of division of the carbonate layers and on the impact this has on the quality variations in 3D.

6. References

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