A SEISMIC REFRACTION STUDY OF THE ROCKS COVERING THE MØNSTED SALT DOME

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A seismic shallow refraction experiment at the Mønsted salt dome was undertaken to detect the top of Danian limestone. This horizon could be investigated in a short section at the southern flank of the dome. The seismic velocities are in accordance with the results generally known from the upper sediments, but not with the seismic studies of the Paarup salt dome.

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The Mønsted salt dome is situated in the salt dome province which belongs to the northwestern part of the Danish Embayment. The dome is covered by Quaternary and Tertiary deposits and has only faint topographic expressions. The top of the Danian limestone can be traced as a marker horizon using a combination of gravity data with some stratigraphical information from drillings. A reproduction of the model of Madirazza & Fregerslev (1969) is given in fig. 1. The detection of a seismic horizon has become necessary to prove this model. These measurements were carried out in connection with a field course for students in June 1972.

Two profiles were covered with a 720 m long detector-spread. Strings of 6 geophones (Geo Space 11-D, 10 cps), distributed linearly and perpendicular to the profile direction, were connected to 10 of the takeouts. Shotholes were drilled to a depth of 4.5 m at the ends of each profile. Shots II and III defined a profile south of Mønsted and shots IV and V another one northeast of Mønsted (compare with fig. 1). The seismic energy was generated by the explosion of 3 kg charges Trotyl. The seismic signals were recorded partly on paperfilm with a Siemens Oscillomink and partly on magnetic tape with a FM-multiplexing equipment from Lennartz Electronic. A detailed description of the field equipment is given among others by Casten (1972). In addition to the explosion seismic work a weight-dropping experiment (10 kg weight) was carried out on profile A–B near shotpoint V. A 12-channel equipment (ABEM) was used to detect the seismic signals on a profile 120 m long.

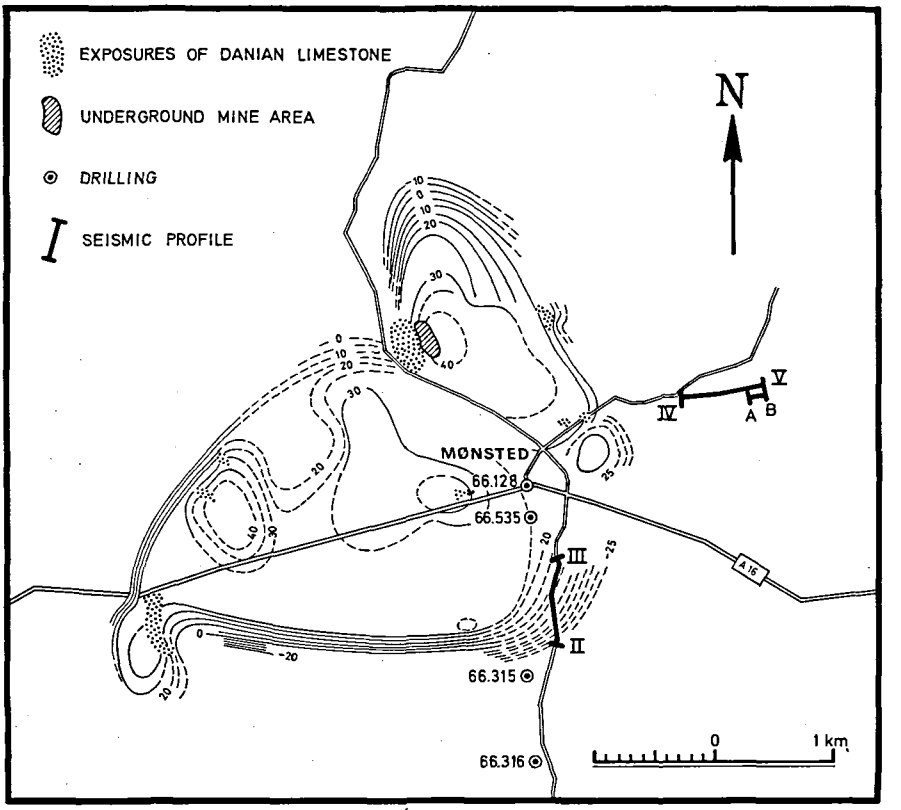

Fig. 1. A model of the Mønsted salt dome showing the surface of Danian limestone. Locations of seismic profiles are indicated.

Altogether 4 different seismic phases could be correlated in the seismogram mountings: the airwave, the direct wave from the surface layer, and two refracted waves from deeper layers. An illustration of one of the seismogram mountings together with the correlations is given in fig. 2. Using the least square method, traveltime curves were calculated from distances and traveltimes. The results are shown in table 1.

As expected, the weight-dropping experiment on the short profile gave information about a near-surface structure, while on the longer profiles only waves which had penetrated greater depths were observed. Therefore the calculation of the seismic model started with profile A–B and continued with the other lines, taking into account the former results. The thickness of layers under the shotpoints and real velocities were calculated from intercept times and apparent velocities.

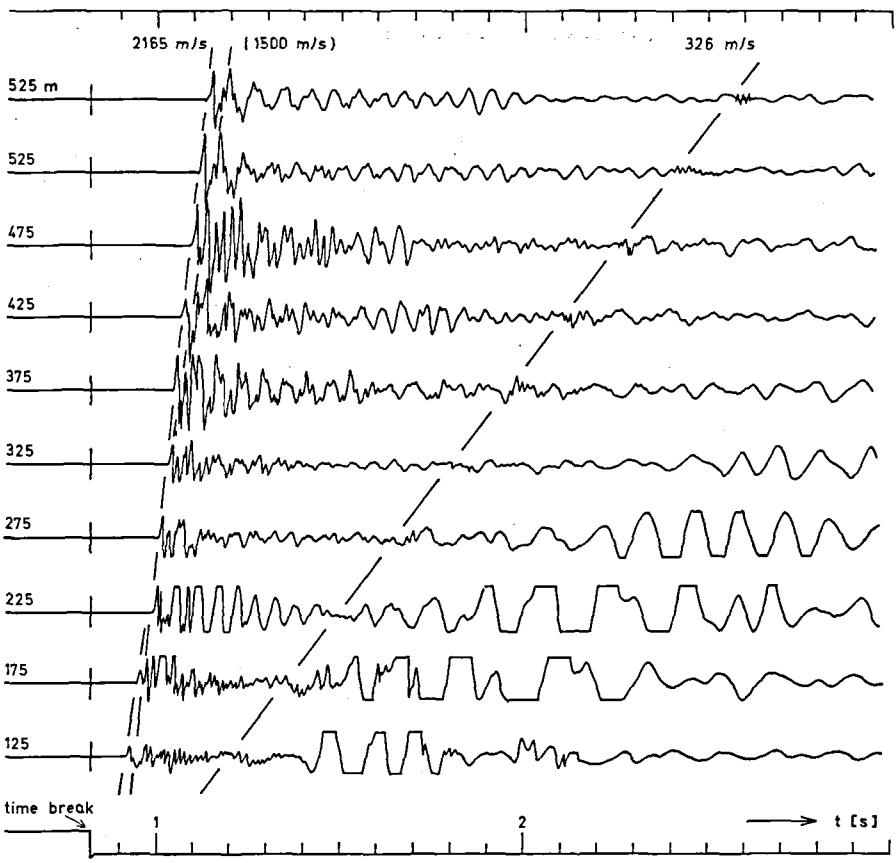

Fig. 2. Mounting of the records from shot III with correlations.

Profile A–B:

The surface layer has a velocity of 500 m/s. The layer is thicker under A (18 m) than under B (16 m). The real velocity of the second layer is 1720 m/s.

Profile IV–V:

The direct wave of the surface layer is assumed to have a velocity of 500 m/s. The layer is 18 m thick under shotpoint IV and 11 m under V. The averaged velocity of layer 2 is 1580 m/s but has an increase with depth from 1550 to 1790 m/s. This means that layer 2 itself is layered or is a transition zone with a velocity gradient.

Table 1. Apparent velocity (v), intercept time (t_i), and total time (T) together with number of observations (N). Velocity and intercept time with standard deviation.

SP	v [m/s]	t_i [s]	T [s]	N
II	2292 ± 226	0.048 ± 0.011	0.342	3
	315 ± 47	−0.035 ± 0.116	2.177	3
III	2165 ± 24	0.054 ± 0.002	0.365	8
	326 ± 1	0.003 ± 0.004	2.073	10
IV	1604 ± 28	0.069 ± 0.004	0.505	10
	321 ± 2	−0.037 ± 0.007	2.148	8
V	1567 ± 29	0.038 ± 0.005	0.484	10
	328 ± 8	−0.129 ± 0.025	2.005	3
A	1763 ± 51	0.070 ± 0.001	0.143	7
	500 ± 0	0.009 ± 0.000	0.269	3
B	1681 ± 38	0.064 ± 0.001	0.141	8
	468 ± 2	0.003 ± 0.000	0.280	3

Profile II–III:

Again the surface layer is assumed to have the velocity of 500 m/s. Its thickness only can be estimated. Therefore a two-layer model was calculated, the velocity for the cover being taken as 1500 m/s. The substratum has a velocity of 2200 m/s and it is calculated that the refractor then is situated at a depth of 50 m.

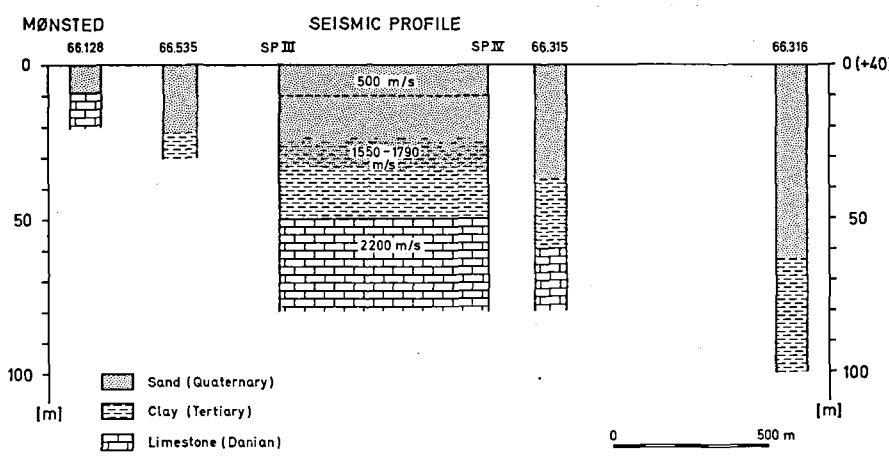

Fig. 3. A cross-section over the southern flank of the Mønsted salt dome combining seismic results with profiles of nearby bore holes. Locations of drillings are to be seen in fig. 1.

Three seismic layers have been investigated. The thin surface layer consists of dry sand and is of variable thickness (5 to 20 m). The second layer has a thickness of about 40 m on profile II–III but more on profile IV–V where its base has not been detected. The velocities from 1550 to 1790 m/s are values for waves in Quaternary and Tertiary deposits. The third detected layer with a velocity of 2200 m/s is Danian limestone. This interpretation is confirmed by the exposures of limestone near the area of the two seismic profiles.

A vertical section of the upper layers along a line running from Mønsted southward can be compiled (fig. 3) by the combination of the seismic model with the simplified profiles of nearby bore holes. The section crosses the southern flank of the salt dome. The top surface of the limestone dips with a gradient of 50 m : 1 km. In the opposite direction the cover thins out. Comparison of the contour lines of the limestone in fig. 1 and the seismic measurements confirms the model at its southern flank.

Nørlund & Brockamp (1934) investigated the upper crustal structure in different areas of Denmark. Summarizing their results the following velocities for the upper layers were observed: for the Quaternary and Tertiary cover of deposits 1300 to 1650 m/s, for the top of Upper Cretaceous 2250 to 2420 m/s, and for the Lower Cretaceous 2900 to 3300 m/s. The velocity of 1580 m/s for the cover of the Mønsted salt dome is in accordance with the above values. While the 2200 m/s from Mønsted is a value for Danian, the above 2250 to 2420 m/s are Upper Cretaceous. This would mean that there is no significant difference in seismic velocity between Danian and Upper Cretaceous.

Seismic soundings at the Paarup salt dome, as described by Lind, Ramberg & Farestveit (1972), show about the same velocity for the covering deposits. But a disagreement between the Cretaceous of the Paarup dome and the results from Mønsted has to be pointed out. At the flanks of the Paarup salt dome a refractor with a velocity of 3200 to 3500 m/s was observed and interpreted as Upper Cretaceous. Comparing this with the upper structure normally observed in Denmark and also in North Germany (Barsch & Reich, 1930) the high velocity of the Cretaceous is from the Lower rather than the Upper Cretaceous. While Danian limestone is a near-surface marker horizon in the Mønsted area, no similar horizon has been detected at the Paarup salt dome.

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Dansk sammendrag

Et seismisk refraktionseksperiment er blevet udført ved Mønsted saltdome for at bestemme dybden til toppen af Danien kalken. Denne horizont kunne undersøges på et kort profil ved domens sydlige flanke. De seismiske hastigheder stemmer overens med de kendte resultater fra de øverste sedimenter, men ikke med resultatet af de seismiske undersøgelser af Pårup saltdomen.

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