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G. BRINCKMEIER AND W. ELBERSKIRCH†

ABSTRACT

This essay shows the alternate cooperation between geology and geophysics in the discovery and exploration of the Eldingen oilfield, Niedersachsen, Germany. After regional gravimetric and refraction seismic surveys failed to give encouragement for further investigations, a geologic conception incited a new period of geophysical investigations. This time reflection seismic was applied, and this resulted in the discovery of a dome (anticline) in the deeper beds. In this dome or anticline oil has already been found with the first well. Further drilling showed the necessity of two more investigations to increase accuracy. These surveys led to the final contour map.

GENERAL GEOLOGICAL POSITION

The Eldingen oilfield is situated near the village of the same name, approximately 23 km northeast of Celle (Figure 1). In the surrounding region the following geological units are known. The so-called Pompeckj Block is separated from the Niedersachsen Trough in the south by a great lineament marked at some places by great overthrusts. The boundary line between these two units runs NW and SE almost through the Celle region and is marked by the saltplugs of Meissendorf (V), Wolthausen (VI), the structure of Altencelle-Oppershausen (A-O), the saltplug of Wienhausen (XIV) and further by the structures of Hardesse (Hd), and Vordorf (Vd).

The Pompeckj Block is characterized by a very thick and complete Upper Cretaceous section, including the uppermost Lower Cretaceous, the so-called Alb. The latter has transgressed partly with an angular unconformity, mostly, however, without it over middle and lower Liasic or Keuper. In general the Lower Cretaceous is normally not at all, or only weakly, developed.

In the Niedersachsen Trough there is, however, a strong development of Lower Cretaceous with underlying Malm, Dogger, and Liasic. The Upper Cretaceous is usually not completely developed, and only parts of the Campan or Maestricht with their upper layers are present at some places, transgressing over older formations.

The Pompeckj Block, which extends to the north as well as to the northwest and southeast, is in certain parts traversed by smaller troughs, in which Dogger, Malm, and partly Lower Cretaceous, beside complete Liasic, are deposited and preserved.

One of these troughs is the Gifhorn Trough, the axis of which trends from the saltplug Broistedt-Wendeburg (XXVI) via the saltplugs Gifhorn (XX) and Vorhop (XVI) as well as Wittingen in a northeast direction through this area.

The Niedersachsen Trough contains the well known oilfields of Wietze (Wt), Fuhrberg (Fb), Nienhagen (Nh), Oelheim (Oh), Oberg (Ob), and several newer

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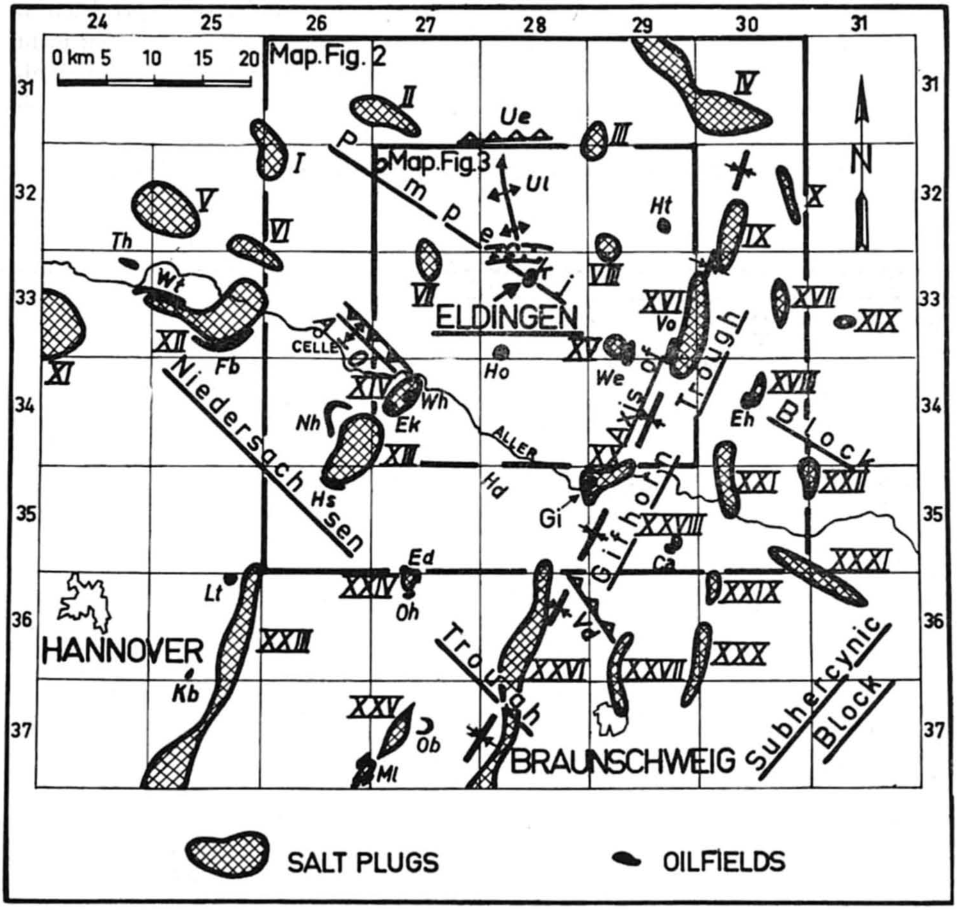

FIG. 1. Eldingen area, general situation. Numbers and letters refer to the text.

ones, and the Gifhorn Trough has lately also produced several oilfields, such as Gifhorn (Gf), Wesendorf (We), Calberlah (Ca), and Ehra (Eh). The oilfields of Hohne (Ho), Hankensbüttel (Ht) and Vorhop (Vp) have been discovered after the finding of Eldingen.

The saltplugs have ascended in the axis of the Gifhorn-Syncline, and according to geologic conceptions there should have been oil in favourable structures at the flanks of the trough.

REGIONAL GEOPHYSICAL SURVEYS

The geophysical exploration of this region took place in several intervals before and during World War II. Following 1934 all Northern Germany—naturally including the nearer and wider surroundings of the Eldingen oilfield—was investigated by the so-called Geophysikalische Reichsaufnahme under the supervision of the Reichsamt für Bodenforschung (RfB), (director of the Geophysical Department was the late Prof. Dr. Barsch, assistant director Prof. Dr. Reich). The Geophysikalische Reichsaufnahme applied gravimetric methods, using the gravity meter as well as the torsion balance, and fan refraction seismograph.

The torsion balance was especially used for detailing areas which had been proved as unusually interesting by the preceding gravity meter survey. The gravity

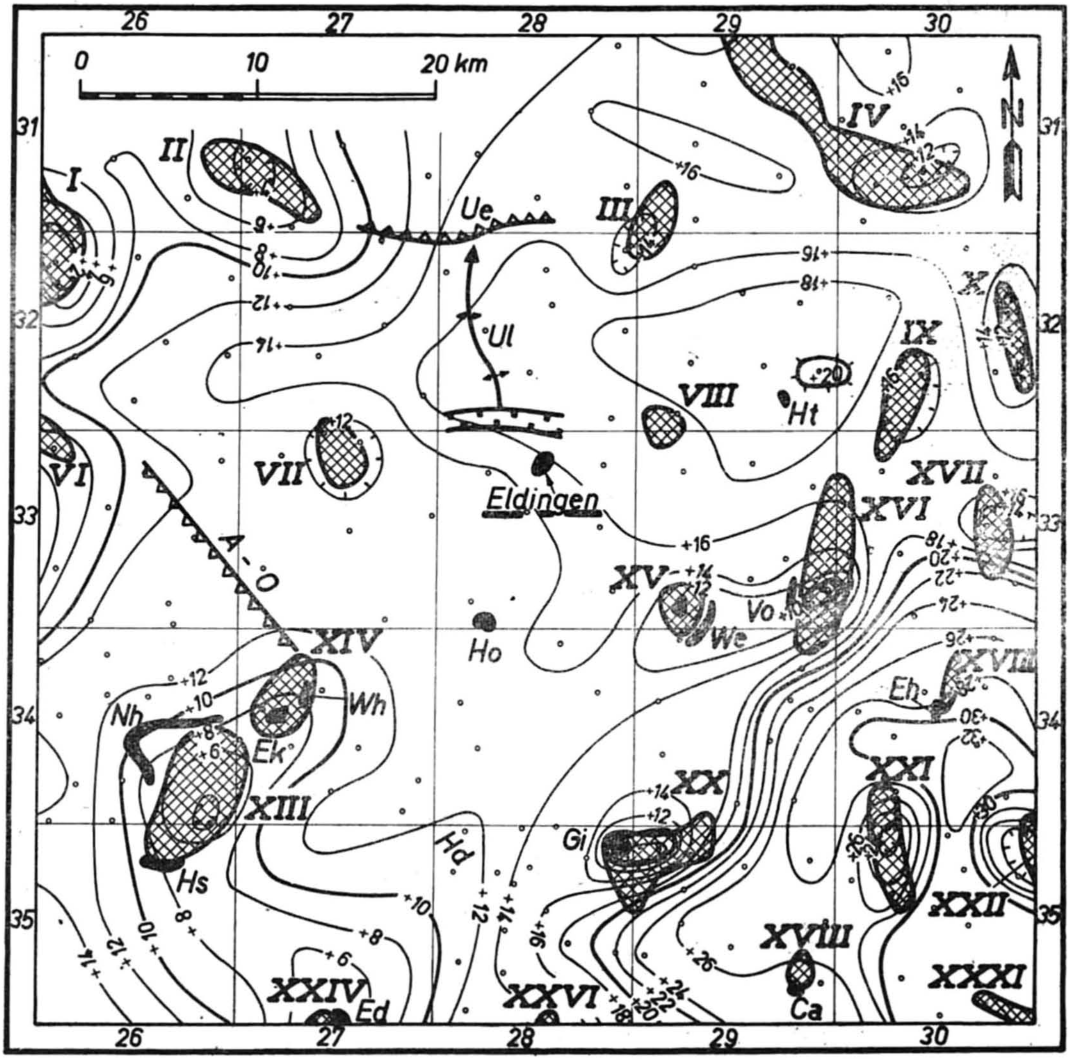

FIG. 2. Eldingen area, gravity meter map by Geoph. Reichsaufnahme 1936-1944. Geological data added by the authors.

meter investigations were carried out by means of Thyssen gravity meters by the "Seismos," in a way that five measuring points were placed on the German standard map, scale 1:25,000, comprising an area of about 110 qkm. According to later experience, this network was far too wide to show details.

The results reached hereby are displayed on the map (Figure 2) in accordance with a map, scale 1:200,000, which was issued to the industry by the RfB. In its southeastern corner Figure 2 shows a considerable gravity maximum, which is limited northwestwards by a NE and SW trending zone with a strong gravity gradient. The zone of strong gravity gradient turns off to SE in the north as well as in the south by forming almost a right angle. This gravity maximum is the northeast ending of the maximum, which extends in SE direction. This gravity maximum is apparently caused by an old body of igneous rocks at great depth, which, however,

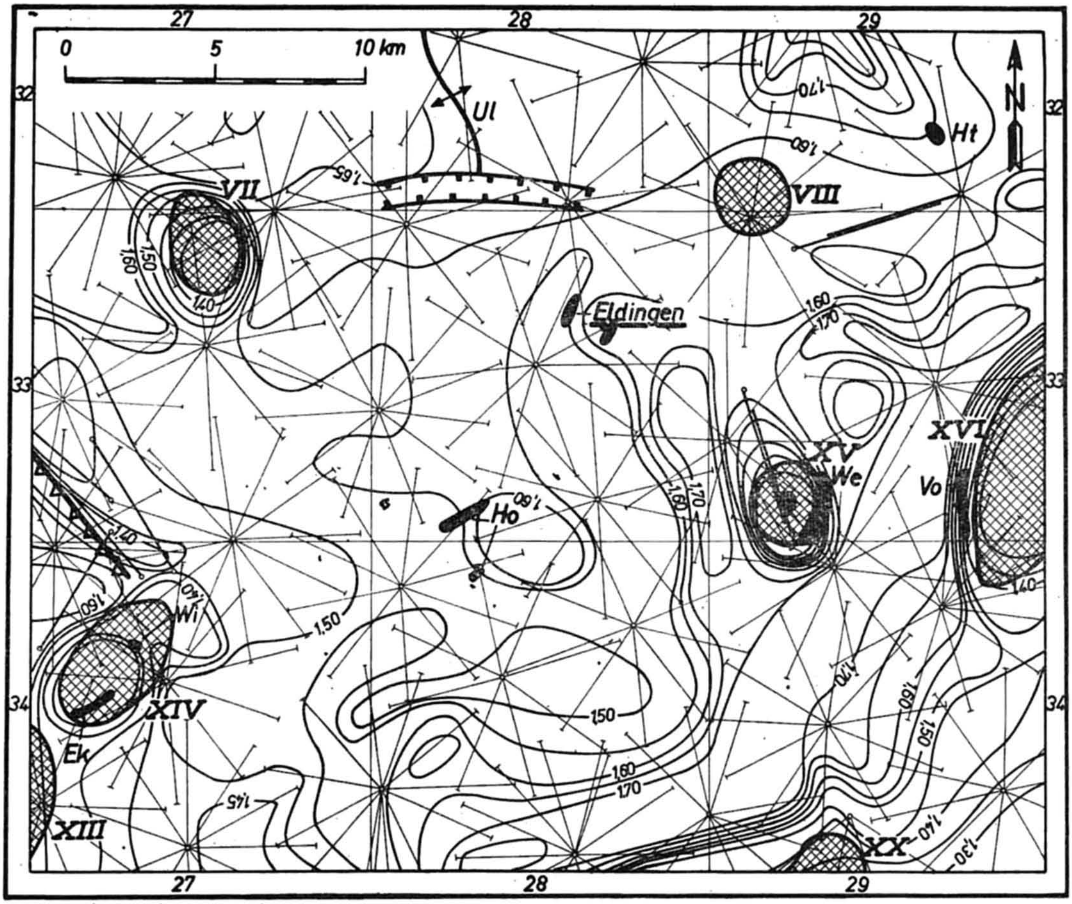

FIG. 3. Eldingen area, refraction seismic map by Geoph. Reichsaufnahme 1936-1944. Geological data added by the authors.

does not affect the younger tectonics of the region in question. The major part of the map is composed of areas which are gravimetrically only weakly differentiated. Several small minima can be recognized which are established by one or two gravity meter stations only. The northwest and southwest corners merely contain stronger differentiated gravimetric areas, but the present geologic units, the Niedersachsen Trough, the Pompeckj Block, and the Gifhorn Trough, cannot be recognized in the gravity picture. The small minima are caused by saltplugs.

The actual shape, however, of the saltplugs cannot—due to the frequently only undistinct gravimetric limits—be recognized from the isogams. Sometimes saltplugs cannot be recognized at all, as VIII (Oerrel) or XIX (Ehra).

REGIONAL REFRACTION SURVEY

The second step of the geophysical exploration was the investigation of the area by applying the fan shooting seismic method (Figure 3). From every shotpoint, in usually nine different rays of 4-5 km length each, travel times were recorded and thereby the isochrones were constructed by the well known procedure which is especially developed by H. Reich. Special profile lines with complete travel time curves established the velocities.

By constructing the isochrones the areas with especially short travel times are strongly marked. They are usually more or less limited and mark places where rocks with high velocities almost reach the surface. Under the prevailing circumstances the short time areas usually mark saltplugs which penetrated the Lower Cretaceous and reached the overlying Tertiary. Regions with long travel times do not contain saltplugs.

Minor saltplugs can in unfavourable cases be overlooked by this method; the saltplug Oerrel (VIII) for instance was not discovered with seismic refractions. The structure is relatively small and the updoming of the Upper Cretaceous above the saltplug rather unimportant. Besides, the center of the fan, i.e. the shotpoint, was situated on top of the structure so that the single refraction rays could reach the uplift in the Upper Cretaceous only in the outer parts, and therefore the effect of the shortening of the travel times was too trifling to be noticed.

DETAILED GEOPHYSICAL SURVEYS

Shortly after the stabilisation of economics in 1948 the geophysical investigations in the Eldingen area were taken up again, this time by a private company, the Gewerkschaft Elwerath. The leading idea, developed by Dr. Roll, chief geologist of the Elwerath, was that on the flanks of the already oilbearing Gifhorn Trough there should be greater accumulations of oil, if favourable structures were present there. This third period of geophysical investigations consisted in reflection seismic work, first in a regional frame and later on in more and more detailed framework.

During the first (more regional) reflection survey of parts of the flank of the Gifhorn Trough the Eldingen structure was discovered in 1948 as a dome or anticline of the Mesozoic under the flat lying Tertiary, and the first well was productive.

The reflection seismic investigation in connection with the developing of the field by bores constantly raised new problems, especially regarding the tectonics, which proved more and more complicated. In the following five years, therefore, the reflection seismic investigations were applied again twice each time using improved instruments, better ways of measuring, and better shooting techniques.

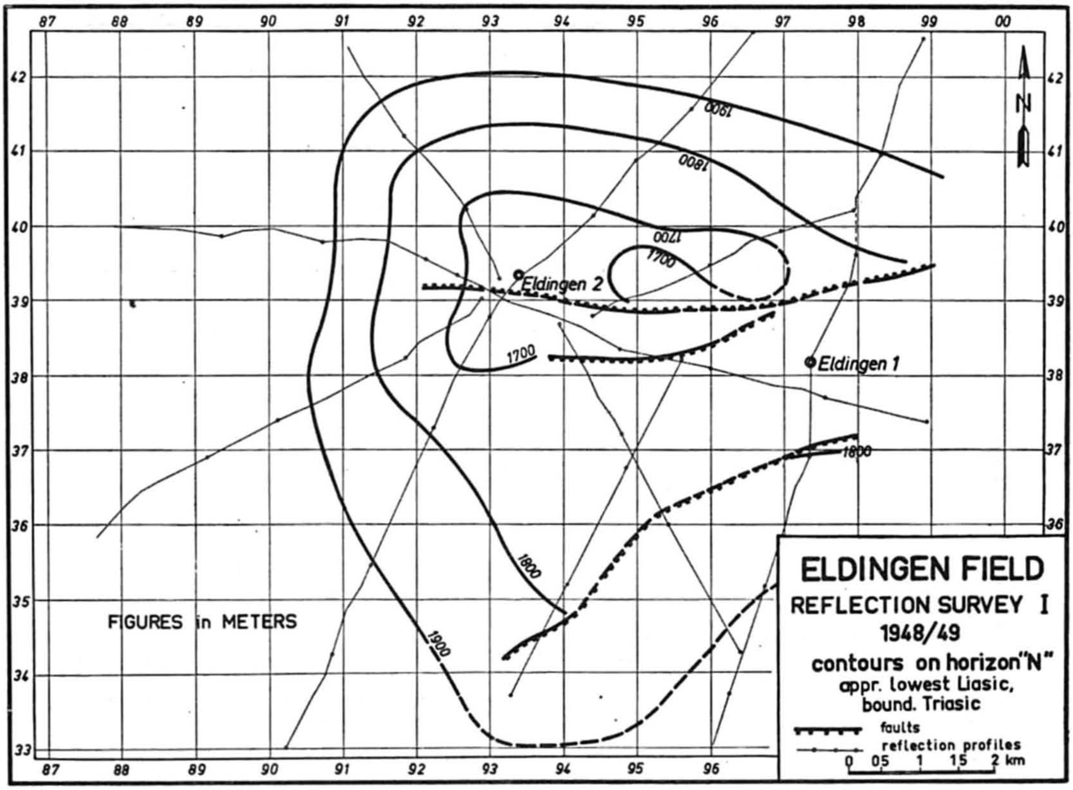

FIG. 4. Eldingen Field, reflection seismic survey I (by Seismos) 1948/49; contour map on horizon N = approximate boundary face of Liasic/Triasic.

FIRST REFLECTION SURVEY

The first survey took place in 1948-49 by Seismos (party leader G. Teudesmann) with rather old equipment. The method used was continuous profiling with central shooting and about 300 m shot-point distances. The map (Figure 4) shows the result of this investigation as a subsurface contour map (the maps show only every 5th shotpoint). The displayed horizon (N) forms a flat dome, which is broken up by several faults striking apparently in a northeast and westsouthwest direction.

The wells located on the base of the plan, Eldingen No. 1 and No. 2, and the velocity survey in the first drill hole, placed the horizon N in the boundary region of Liasic and Rhaet (uppermost Triasic). Eldingen No. 1 struck oil in the sandstones of the lower Liasic; while Eldingen No. 2 was dry, although the reservoir rock was reached in a higher position than Eldingen No. 1.

By this, the stratigraphic conditions of the region became clearer. A normal succession of Triasic and Liasic is folded up to a broad flat dome, which is cut off by an angular unconformity formed by the transgression of the Alb. The thickness

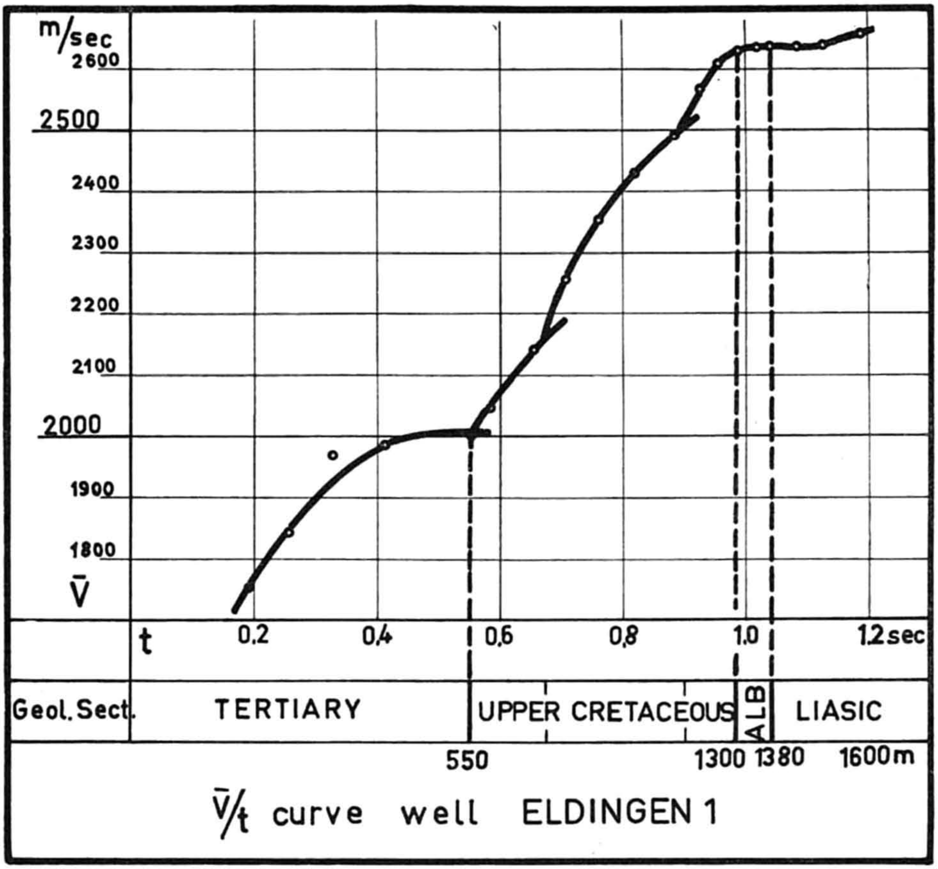

FIG. 5. Eldingen No. 1, Velocity survey well, v̄t curve.

of the Liasic on the top is about 150 m and increases to the flanks and in small grabens to about 350 m. The updoming of the Alb (uppermost Lower Cretaceous) is more flat than that in the beds below the unconformity, so that higher and higher beds of the Liasic are cut off on the outer flanks of the dome under the unconformity.

SECOND REFLECTION SURVEY

The result of later drilling indicated inconsistencies with the contours and faults drawn on the map, so that another reflection seismic survey was inevitable. The second reflection seismic investigation, more detailed than the first one, was started in the spring of 1950.

This time the Seismos (party leader G. Teudesmann) brought in more modern equipment, by which far better results were reached. Special attention was paid to

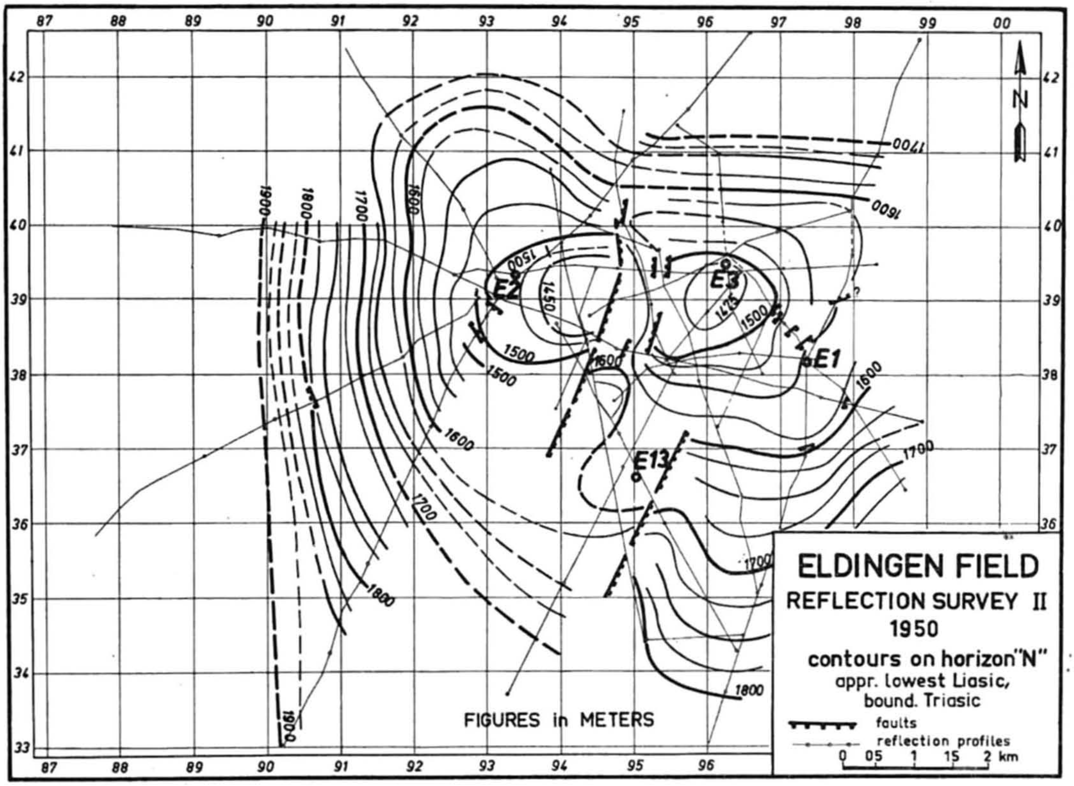

FIG. 6. Eldingen Field, reflection seismic survey II (by Seismos) 1950; contour map on horizon = approximate boundary face Liasic/Triasic.

the reflection marking about the boundary face between Liasic and Rhaet, in the following called "N," which is the nearest reflection to the oilbearing sandstones. This reflection "N" could be observed well recorded nearly over the whole structure. It is always visible as a broad band of several cycles, which can be separated into several reflections. During the first investigations difficulties arose since not always all reflections, respectively phases, could be noticed and therefore the recognition of faults, respectively the phase-true correlation, became either most difficult or absolutely impossible. But this horizon is the only one in which faults were present at all (Figure 9). These difficulties could be overcome later on only by improving the instrumentation during a third reflection seismic investigation.

The contour map (Figure 6) shows the result of the second reflection seismic survey. The structure, seen as a whole, has not changed, but single elements are already distinguished—especially a graben on the top of the dome, dividing an eastern and a western high block of the mapped horizon (N).

In the meantime two more subfields had been discovered by wells. The first one was found by Eldingen No. 1 in a fault block (so-called Eastern Block) in the eastern part of the structure; the second one was discovered in a considerably higher position, on the Main Block (Eldingen No. 3). Between those two there is an oilfree block with a position of the Liasic sandstones lower than on the Main Block and higher than on the Eastern Block. The third one, which is economically uninteresting, however, lies in a small closure in the southwestern part of the Main Block and is designated in the map by E 13. It was here confirmed that even smaller faults are very important for the occurrence of oil and the limitation of the subfields.

Surrounding Eldingen No. 1 there were some faults, which at that time, however, could not be recognized with the instruments and methods applied because of the insufficient closeness of the observation net.

THIRD REFLECTION SURVEY

In 1952 the third period of investigation was started by the Prakla with still better suited equipment (party leader R. Garber and H.-J. Trappe) which expanded to a new and thorough investigation. It was then possible to trace the faults sufficiently accurately and, with a few exceptions, the horizon "N" phase true all over the area, thereby clearing the details of the structure satisfactorily. The results are shown in the contour map (Figure 7) for the horizon "N." A typical seismogram of these investigations is shown in Figure 8.

A cross-section (Figure 9) shows all important stratigraphical and tectonic elements of the structure. The identification of the reflecting horizons, which can be recognized and continuously followed on the seismograms, has been accomplished by correlation with those of other regions in Northern Germany.

Beside the reflection "N" already mentioned and recognized as marking the boundary face between Liasic and Triasic, there are on the records quite a number of other reflections indicating higher and deeper beds of the succession. In the cross section six other reflections are especially marked and designated by letters.

The reflection B corresponds to the boundary Tertiary against Upper Cretaceous, the reflection C to a bed in the Cenomanien or Turonian (change of very hard limestones to soft marls). There follows 100 to 150 m below C a weak and sometimes difficult to recognise reflection (in the cross-section without letter) marking the unconformity below the Alb.

Under N follow three reflections with characteristic intervals, V, W, and X.

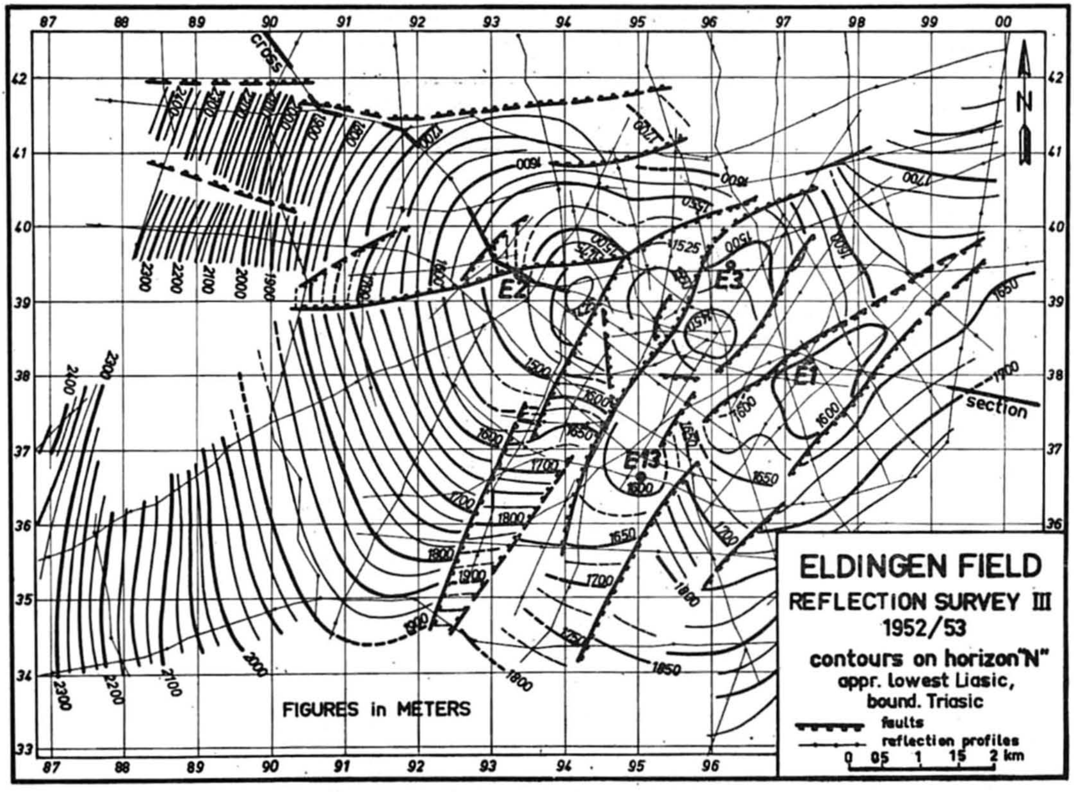

FIG. 7. Eldingen Field, reflection seismic survey III (by Prakla) 1952/53; contour map on horizon N = approximate boundary face Liasic/Triasic—by R. Garber and H.-J. Trappe.

They belong to the Lower Triasic (the so-called Buntsandstein) and are mostly good. The lowest reflection Z characterizes the lower boundary face of the Permian salt and the beginning of the basement (folded and faulted Paleozoic and primary rocks). All those mentioned reflections are recognizable over a great part of Northern Germany and are very characteristic (Elberskirch 1952).

The variable space in the cross-section between the reflecting horizons X and Z is characteristic of the behavior of the Permian salt masses between the saltplugs in Northern Germany. It indicates the remaining salt not used up by the building of the saltplugs and shows the forming of salt pillows which give rise to anticlines and domes between the saltplugs, the so-called "Zwischenstrukturen." Those "Zwischenstrukturen" are sometimes accentuated by the behaviour of two other salt formations, belonging to the Roet (uppermost Buntsandstein) and the Keuper (Upper Triasic). In the section (Figure 9) there is no strong evidence of it, but not far northeast of the Eldingen field the Unterluess anticline (Ul, in the map Figure 1) is probably caused by the swelling of Keuper salt.

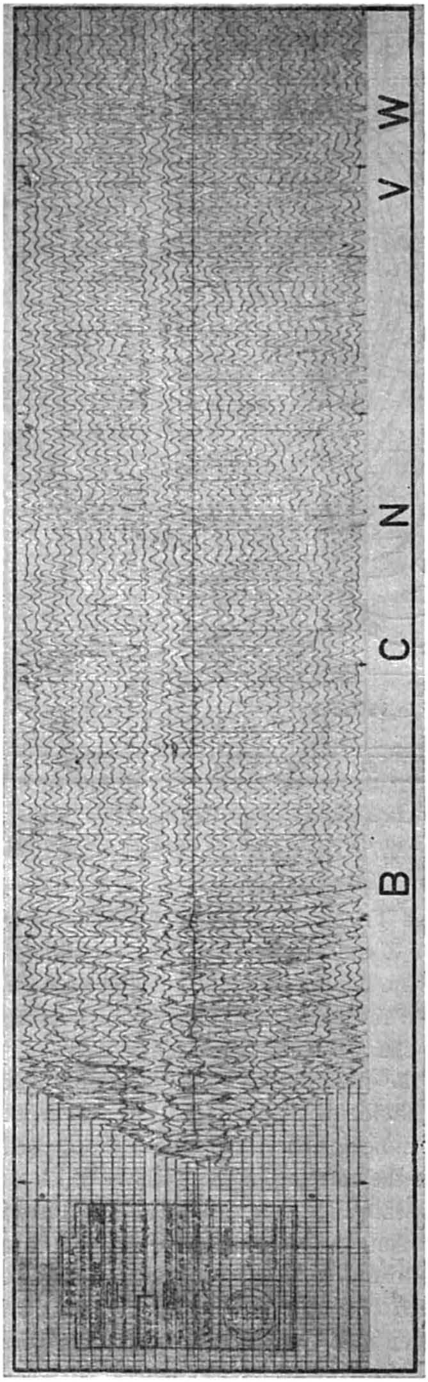

FIG. 8. Typical seismogram of survey III (Prakla). Reflections of the main horizons (except X and Z) are marked.

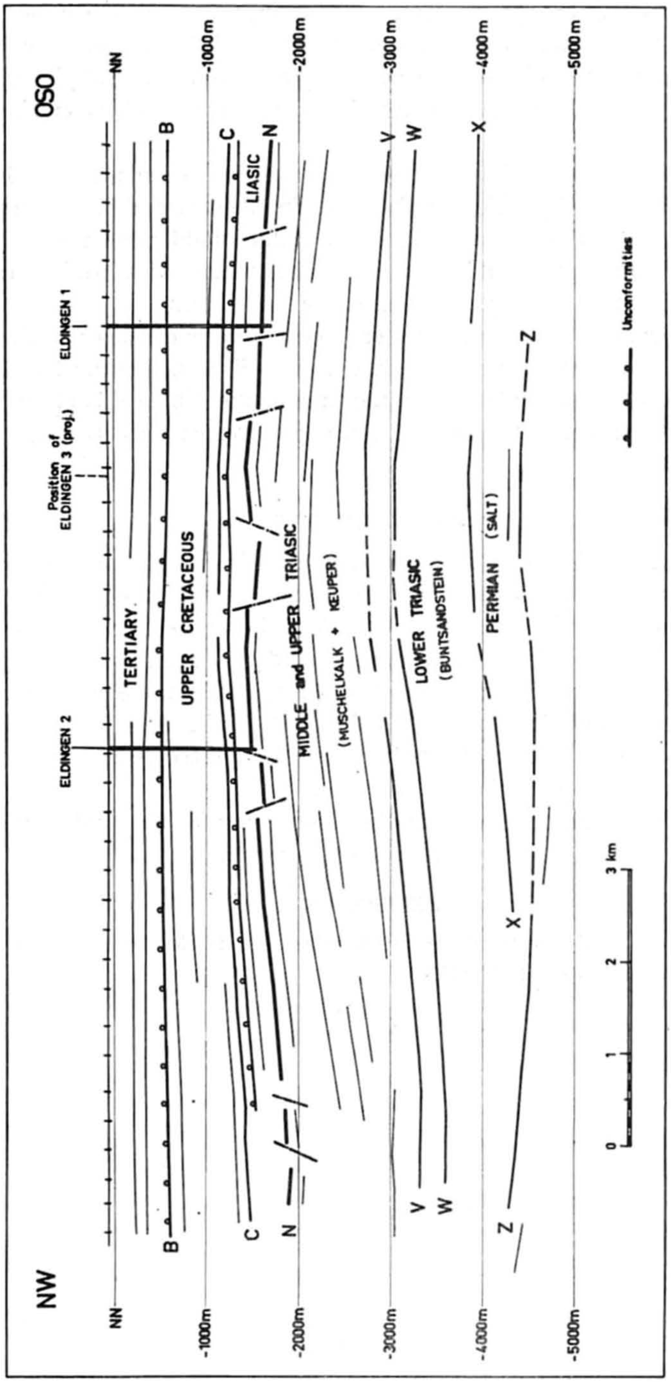

FIG. 9. Cross-section of Eldingen dome by R. Garber and H.-J. Trappe (geological names and designation of reflections are added by the authors).

The faults cutting through the structure and displayed on the contour map as well as on the cross-section seem to be confined to beds belonging in the neighbourhood of the reflection N. This might be caused by a levelling effect of plastic Keuper salt below these beds and by the presence of the unconformity above cutting off the faults.

The unconformity on the base of the Alb shows that the structure of Eldingen was formed before the deposition of the Alb. From bores and reflection surveys nearby it is known that also the Dogger and Malm (middle and upper Jurassic) and even higher strata like Wealden are present below the unconformity thus limiting the formation of the Eldingen dome between these times.

The unconformity by itself presents only very little updoming and the unconformity at the base of the Tertiary (reflection B) still less, showing that no great differential movements took place after the time of the Alb in this place, whereas not far away (Unterluess anticline), quite strong movements occurred up to Tertiary time.

ACKNOWLEDGEMENT

The writers are indebted to the Gewerkschaft Elwerath for the permission to publish the information represented in this paper. The field work of the three reflection seismic surveys and the geophysical calculations were carried out by seismic parties of the Seismos G.m.b.H., Hannover and the Prakla (Gesellschaft für praktische Lagerstättenforschung), Hannover. The leaders of these parties were Dipl. Berging. G. Teudesmann (Seismos), Dipl. Phys. R. Garber and Cand. Phys. H.-J. Trappe (Prakla). The reliable and accurate work of these gentlemen led to the very clear picture presented in the contour maps.

We also wish to thank the Amt für Bodenforschung for the kind permission to publish the gravity meter and the refraction seismic map.

REFERENCE

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