SEISMIC PROSPECTION FOR OIL IN POLAND
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Stanislaw M. Wyrobek

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SEISMIC PROSPECTION FOR OIL

IN POLAND

PART II.

P A R T III

SEISMIC EXPLORATION BY THE REFLECTION METHOD

from 1934 to 1939

and

THE ANALYSES OF ITS RESULTS

by S.M. Wyrobek

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CHAPTER IX.

Some notes on the Geology of the Explored Areas.

Seismic prospection carried out from 1934 to 1937 by the Pioneer Institute of Applied Geophysics with the use of the two reflection sets described in Chapters V and VI, as well as the prospection carried out by the Geotechnica Ex. Co. in 1938 and 1939 with the use of 12 geophone set, the short description of which is given in the Heiland's book "Geophysical exploration", are shown in the map Plate 1. Except for a small area in the north-western Poland (Inowroclaw, Barcin, Kruszwica), this map represents in a more or less detailed manner all the exploration done by reflection and refraction methods from 1934 to 1939.

As one can see, this prospection was mostly confined to the foreland area of the Carpathians, from the Roumanian border in the East to the vicinity of Cracow in the West, along a belt roughly 450 km (270 miles) long and 50 km (30 miles) wide.

A brief geological description along a cross section from the Carpathians to the Podolian Plateau was given on pages 87 to 90. On the map (Plate 1) this foreland area is shown as bordered on its South by the Carpathian Mountain Range and on its North by the Podolian Plateau, the Lublin Plateau, the St. Cross Mountains and the Cracow Plateau. The Podolian Plateau is of the Cretaceous age and like the Lublin Plateau of the same age plunges under the foreland area filled with Miocene sediments which in their turn submerge in the South beneath the Carpathians of the Mesozoic and Tertiary ages. These three almost parallel zones are topographically fairly evident in the terrain. The Podolian Plateau rises into hilly country along the Dniester river, which, in some places, cuts deep canyons in its Cretaceous and Devonian limestones. A similar structure exists in the Carpathians in the south with their outcrops of steeply dipping beds of the Tertiary age at the base. The foreland area between them, however, is in general flat, with a monotonous and uneven cover of Diluvial and Alluvial gravels, clays, peats, and sands with almost no exposures of the subsurface, the latter being composed of rocks of the Miocene age. By itself this area represented the ideal terrain for geophysical exploration promising interesting results as its structure was known the least.

A short review concerning the geology of the whole foreland area is worth giving, before approaching more detailed descriptions of the seismic prospection itself.

The foreland area has a surface of about 20,000 sq.km and in general belongs to the Neogene formation, namely, older and younger Miocene, which in parts has a thickness of 3000 metres. This area can be divided into two parts:

<u>1. The Western part</u> from Cracow to the river San, which consists of more or less horizontal layers of Younger Neogene (Upper Tortonian-Praesarmat), of which little is known except for the regions of Bochania and Wieliczka, with their very rich salt deposits. Some drillings were performed near the Carpathian

border and revealed gas deposits in the Tortonian formations.

2. The Eastern part, from the river San to the Roumanian frontier. This part, along its belt adjacent to the Carpathians, is composed of folded younger Miocene with its Precarpathian Salt formation from Dobromil to Kosow. According to Dr.Tolwinski before the Carpathians were finally formed, the rocks of the Salt formation (salt shales, gypsum beds, conglomerates) were deposited along its foreland. The approaching tectonic movement which pushed the Carpathian bow from the SW towards the NE, caused the overthrusting movements of the Carpathian cover over the plastic basement of the Salt formation, the Carpathian cover being split into separate slices (skibas) overthrusting each other and pressed into the plastic Salt formation. This slowly moving system of skibas pushed and disintegrated the Salt formation in the Lower Miocene period. These dislocated salt masses in their turn, during the Upper Miocene period were covered with deposits of so-called "Stebnik beds" composed of red shales, sands and sandstones, and conglomerates. Owing to the uninterrupted tectonic movement, the Stebnik beds are also folded and in their northern parts overthrust the Upper Miocene.

The reciprocal relation and disposition of the individual formations of the eastern foreland area were recognised most clearly on the segment of the Carpathian-Podolian culmination. The latter exists between Drohobycz and Kosow, where the longer axis of the foreland is lifted up together with the Podolian Plateau on the north and the Carpathians on the south.

Owing to extensive geological and geophysical surveys the Eastern foreland is fairly well known. Within this part three outstanding units can be clearly recognised (Plate 2):

a/ The Salt Formation adjacent to the Carpathians, in which drillings has shown the existence of a deep element of Flysh character, enveloped in the Salt Formation. The problem of the existence of this deep element along the border of the Carpathians was tackled during the years from 1930 to 1939 by several deep drillings, as well as by geophysical methods amongst which the seismic prospection played the most important part.

As is known, the productive parts of this element form transversal uplifts in Boryslaw, Bitkow, Rypne, and contain the most important oil fields in these areas. The rest of this fold along the eastern foot of the Carpathians, was tackled during these years very sporadically, and all the prospection both by geological and by geophysical means was confined to the region from Bitkow on the east to Nahujowice on the West. The seismical share in this area is shown in the map (Plate 1) and involved the following surveys carried out by the dip-shooting method and continous profiling with 6 or 12 geophone sets at different times from 1934 to 1939: (from E to W)

i/ a detailed reflection profile in the Bitkow and Maniawa areas (DSH 1, DSH 2, DSH 14),

ii/ a detailed reflection survey in the Niebylow area(DSH 3)

iii/ a detailed reflection survey in the Lubience area(DSH 15

iv / a dipshooting profile across the conglomerates uplift iv/ a dip-shooting profile across the comnglomerates uplift in Truskawiec (DSH 6),

v/ An experimental reflection survey on the Boryslaw - Tustanowice fold (DSH 5, DSH 8, DSH 9, DSH 16),

vi/ a detailed reflection profile on the deep element in the Nahujowice area (DSH 7).

In the last region (Nahujowice) one observes a sudden emergence of the deep element which probably extends towards the west but its course from Nahujowice to Chyrow and Dobromil is not known. Further to the west, in the region of Dobromil, the Carpathian bow changes its configuration and runs towards the north and therefore it is difficult to say what happens to the deep element. Not very much was done to investigate its location and course.

It is not the aim of the writer to stress the importance of this formation for the oil industry, but it may be of some interest to point out that this unit of the foreland area represents the greatest possibilities for encountering oil fields besides those known since 1910. Everywhere the shallow drillings met oil seepages, but there were very few deep drillings made and none deeper than 1900 m. Seismic prospection shows that the reflection method may be employed in a detailed way to locate the highest parts of this deep element, but it must be followed by deep drillings exceeding the depth of 2000 m, in order to gain knowledge about the Cretaceous rocks.

b/ The second unit of the Carpathian foreland, called also "anticlinorium"

"anticlinorium" or <u>the belt of the Stebnik beds</u>, covers the northern boundaries of the Salt Formation and forms a belt of about 20 km wide from Kosow to Przemysl. Very little was known about it in the years preceding 1932. Its northern boundaries were sporadically located between Kosow and Drohobycz and the Salt Formation was supposed to extend towards the north under the Stebnik beds. Tolwinski compared the significance of this unit with that in Roumania, where the Salt Formation in the shape of salt domes or diapires (Campigny) pierces the younger rocks, and on the flanks of these structures very rich oil desposits were found. Diapires of this kind are formed as a result of the intrusion of the plastic rocks through the less consolidated overburden. In the Polish part of the Stebnik beds and especially within the boundaries of the Podolian-Carpathian culmination one encounters the existence of salt-gypsum masses surrounded by the Stebnik beds and according to Tolwinski they cannot be anything else but the results of the intrusion of the Salt Formation through the Stebnik and younger beds. Numerous salt water sources occur in this area and may prove the correctness of Tolwinski's theory.

In addition to a carthographical geological survey within this unit, deep wells in Rachin, Gaje Nizne, and Kalusz did not give a positive answer. The thickness of this unit in Gaje Nizne (deep well) is about 1500 m, the section showing extensive foldings composed of a series salt, red shales, inter -

calated with sand and sandstones. Firstly the complete lack of hydrocarbons and secondly a very complicated and disturbed structure encountered here and there caused the exploration of this unit, both by deep drillings and by seismical prospecting to be postponed so that all efforts might be concentrated on the third unit of the foreland.

Apart from a detailed dip-shooting reflection profiles carried out here for the determination of the underground structure in Gaje Wyżne (DSH 4) and Łąka (DSH lo), all other prospection by seismical methods was confined to the determination and location of the rich Salt and Potassium beds in the areas of Stebnik (DSH 16), Lubience-Siemiginow (RFR 3) and Kalusz-Holyn (RFR 5). On p.p. 120-123 in this paper (Chapter IV) a description is given of the work carried out in the Dolina area (RFR 2) at the very contact zone of the first and second units and of the refraction survey in Medyka (RFR 4).

A special refraction survey to locate the salt structures in the western part of the foreland area, in the region of Bochania (RFR 9) and Brzesko (8), as well as in the region of Pilzno and Debica (RFR 7) were carried out in 1939 by the Geotechnika Ex.Co, using the 12 geophone set. p.124-128 (Ch.IV).

c/ The third unit of the Carpathian foreland, the so called <u>Tortonian unit</u>, bounded on the north by the Podolian Plateau and Lublin Plateau, consists of Upper Miocene series of shales, sands and sanstones, and conglomerates. On the east, the rocks

of this unit are almost adjacent to the Carpathians themselves, but further west they are separated from them by the two units of Salt formation and Stebnik beds, previously described.
In the southern part of this unit, at the contact of the Stebnik beds, there are the rich gas-fields of Daszawa and Opary, which as we know, do not possess heavy hydrocarbons (or at the most only 1,5%, whereas the Boryslaw gases have 37% of them). It would follow from this fact, that the Daszawa gas-field is a separate bituminous zone and forms a separate gas structure.
As has been shown by later prospecting, beds of the Daszawa type are confined to the contact of the Tortonian and Stebnik units and the exploration and further prospection of this contact confirmed the hypothesis by the location of an extensive belt of gas fields (Kosow, Kalusz, Balicze, Daszawa, Opary, Chodnowice).
The question of the exsistence within this contact of gas deposits only, was difficult to answer and this problem has not yet been solved. One can admit with Tolwinski, that if a given formation revealed a similar type of deposits, this type will occur as a steady phenomenon on a greater area. A very small content of heavy hydrocarbons may have some connection with the migration of oil either from the Carpathians or from the deeper bedrocks. In the detailed description of the seismical prospection within this contact in the Daszawa gas-area, the writer will endeavour to show the possibility of the existence here of deep stratigraphical deposits , this endeavour being based on an analysis of available material, as well as on the specific

behaviour of elastic waves in the deep bedrocks. The possibility of applying the seismic method for the location of those stratigraphical probabilities is also taken into account. This method when reasonably applied may form an important auxiliery instrument in the location of areas suspected of creating stratigraphical oil traps.

The geological and geophysical surveys were carried out along this contact in almost the whole area of the eastern foreland. The terrain north of this contact up to the Podolian Plateau was approached for the first time in 1930, when the first seismical prospection tied onto the Daszawa area was carried out from Daszawa towards the north. The description of this work is given on page 100-116 (Chapter IV). As was pointed out there, apart from the discovery of a second large gas field in the Opary area, no indication was received concerning the deep bedrock. Yet the reflection method applied in this area, showed that the bedrock consists of a hard rock, which has been proved by several deep drillings (Wownia, Uhersko, Kalusz, Chdowice, Kosow) to be composed of anhydrite, gypsum and salt layers of a total thickness not exceeding 40 m, which lies unconformably on sandstones, silicious shales or limestones of the Cretaceous age.

Considering the behaviour of seismic waves it was evident that this bedrock could not have been located by the refraction method. The beds underlying the gypsum bedrock are of lesser elasticity and so the bedrock itself being of small thickness could not create a condition sufficient for an impinging wave to be refracted to such an extent, as to cause the diffraction phenomena along the discontinuity. In other words, an elastic bed of this thickness, which is smaller than half the length of the refracted wave, is transparent for this wave, and so no refraction wave will be observed at the surface.

Almost the whole surface of this unit was covered by magnetic gravimetric, and seismic prospections and resulted in a countour seismic map of the deep bedrock, on the strength of which the Tortonian foreland was divided into a series of segments, the directions of which are parallel and transversal to the Carpathians These differ in their geological character. Beginning from the east we have within the Tortonian unit a large elevation of Pokucie and Stanislawow horst (see map Plate 1), then further west the depression of Dolina, followed by an elevation in the Stryj area, which in its turn passes into the great and deep depression of Przemysl-Medyka. The western boundary of the latter forms theoretically and structurally the western boundary of the eastern part of the foreland area. The western part of the foreland area was prospected only by geophysical methods, the research programme being interrupted by the War, and resulted also in the mapping of the same (?) deep horizon, which at the western boundary of Przemysl depression shows a sharp and strong elevation in Jaroslaw and Przeworsk areas, then a depression in Kolbuszowa, followed by slightly folded part in the SW-NE direction (foldings of the St. Cross Mountains?) in the Mielec area and again an elevation in Tarnow.

Seismic exploration within this unit was carried out on mainly a reconnaissance scale. The main purpose of this survey was the location and mapping of the basal gypsum bed by the correlation methods. This involved two related problems: i/ location of the subsurface outcrops of thse beds and thus the determination of the northern boundaries of the foreland and ii/ the determination of the southern contact with the second unit i.e. with the overthrusting Stebnik beds. The first problem was tackled by means of refraction prospecting, though shallow reflections from a depth as little as 180 metres were also observed. The second problem, involving the observation of the gradual disappearance of the gypsum correlation and of the gentle dipping of the latter under the rocks of the second unit, was executed by continous profiling across the line of contact. Separate correlation profiles to map the bedrock are marked on the map (Plate 1) by dotted lines in red and numbered COR 1 to COR 19, while the areas covered by reflection reconnaissance survey are marked by RFL R. Some parts of this Tortonian unit such as:

i/ the region north of Stryj to Mikolajow (COR 1, RFL.D.1),
ii/ the Wownia area (RFL D.1),
iii/ the Daszawa gas-field area (RFL D.1, RFL 4),
iv/ the Komarno Rudki area (RFL D.1),
v/ the region between Jaroslaw and Przeworsk (RFL D.3),
vi/ the Kosow area (COR 2 and RFL D.2.),
vii/ the Milec-Majdan area (RFL 5)

were explored in greater detail. These areas totalling about

700 sq.miles, were surveyed by correlation shooting and contionous profiling.

Some general remarks and final inferences.

To complete the geological picture of the foreland, it is worth noting that the whole tectonic phenomena, occurring in the foreland area of the Polish-Roumanian Carpathian Mountain Range, can be considered, as Tolwinski writes, as a gradual displacement of the tectonic movements in time and space from the NW towards the SE and S. Thus for instance, the Upper Miocene of the western foreland is deposited almost horizontally and begins to fold within the San river area, assuming a more disturbed character at the eastern end of the Polish foreland. In the Pliocene epoch the Polish foreland formed a land, whereas on the Roumanian foreland a large sea of the Pliocene deposited its sediments, which later were submitted to extensive folding. Within the boundaries of the Polish foreland, especially in the eastern part, there were large intervals and irregularizties in the process of the deposition of the sediments of the Miocene seas. Great differences in age and building up exist between the Salt formation and the adjacent belt of the Stebnik beds, the former belonging to the Aquitanian age, the latter perhaps to the Helvetian, though this has not been definitely proved. The same can be said of the Stebnik beds and the adjacent gas formation of Daszawa and the whole Tortonian belt. It is understood that these facts must have resulted, to a considerable extent, not only in the heterogenity of the sediments of the foreland. Within the same units when passing from west to east they must have produced various forms of the same layers and thus a variety of physical properties in the same deposits. By drilling it has been shown that the bedrock in the Stryj area consists of gypsum and anhydrite, and is underlaid by sandstone of the Upper Createceous age, whereas the same bedrock in the Kosow area consists of anhydrites and salts, and is underlaid by limestone of the Lower Cretaceous age.

Given the above facts one may foresee, that as far as seismic prospection was concerned one would have to deal with changeable elastic properties within the same unit, i.e. the character of the reflections must change, the average velocity must undergo a continous change and the dip gradient will vary. From Tolwinski's map (Plate 3) it is seen that, going from the west to the east through the area of the foreland, one can distinguish four meridianal belts dividing the foreland into western, central and eastern Polish parts, northern and southern Roumanian parts.

On account of the different lithological characteristics of the individual units of the foreland area, as well as on account of their different geological structure and age, the seismic prospection carried out in those areas differed regarding methods of examination. The Tortonian unit relatively horizontal and slightly folded or faulted, owing to a harder bedrock resulted in the introduction of the correlation method of reflection prospecting and required insignificant corrections of the averages velocities. The reflecting horizon prospected by the correlation method had the character of a bed slightly disturbed by small faults and was covered by beds almost homogeneous from the point of view of elasticity. Further to the south, within the contact of the Stebnik unit, the reflecting horizon was lomsing its distinct character so important for the correlation method, and there were more and more of the shallow reflections of unconformable slopes. The correlation method did not prove successful in this area and had to be combined x with the dip-shooting method. Within the area of the second unit there was nox possibility of applying the correlation method. The whole subsurface, to a considerable depth, seems to be extensively folded and disrupted and was composed of various folds and petrographically various beds, which in some places had a diapiric (vertical) or semi-diapiric (steeply sloping) character. Here only a very detailed dip-shooting method combined with the refraction method could have yielded some results concerning the structure. Finally within the area of the Salt formation, where the Carpathian deep element is pressed into it we have again under a relatively softer overburden strong foldings of the deep harder rocks. Here then again the combination of the correlation method with the dip-shooting method together with continous profiling seemed to be the most rational.

The geological map (plate 2) of a part of the eastern foreland from Dolina to Przemysl, was drawn with the aid of the available material. The research wells sunk in this area are shown by black circles and are numbered from 1 to 8, their corresponding logs being given in Plate 4.

The seismical prospection specified above, within the individual units of the foreland, has not been given in its chronological order. Some of it was repeated in the later years with the same or better equipment. Some areas were left over to be investigated by other methods. It therefore seems reasonable to consider this work in sections treating the same geological problem.

The next chapter will therefore deal with the prospection in the Carpathians, the Salt formation being included, on account of the deep Carpathian element part of which is in the depth of this unit.

The next four chapters (XI, XII, XIII, and XIV?) will refer to the seismical exploration of the Tortonian unit of the foreland. The prospection carried out here was the most successful operation of the whole exploration programme during the period from 1934 to 1937. The first experimental work was carried out in the region of the Daszawa gas-field, on account of the possibility of the correlation of reflections thereby obtained and the beds revealed by the existing wells. As the Daszawa area was also prospected at intervals during the following years before some final results were reached, it is given in chapter XIV, the first three being concerned with prospection along the Stryj-Mikolajow road, the contact zone, and the Kosow area respectively. The prospecting along the Stryj-Mikolajow road affords a typical example from the geophysical point of view, being carried out in an area almost unknown geologically and with little field experience. The Kosow example is characteristic result of a survey which was carried out in an area the geology of which was thoroughly prepared and investigated before. The Daszawa area may be called typical of showing the difficulties in the field prospecting and later interpretation of an area presumably known to be easy and simple, and shows how important is the knowledge of geology for the investigation of such an area.

R e f e r e n c e s:

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CHAPTER X.

Seismical exploration of the Carpathian structures.

An outline of part of the prospection in the zone of the Salt formation as well as in the Carpathians themselves, carried out on known structures for experimental purposes was given in "Geophysics" and in the Report of the World Petroleum Congress in Paris, by Dr. Mitera and Dr. Heiland.

The writer has no intention of repeating this in its previous form and will confine himself to a short description necessary for the consideration of the results in the light of the later investigations carried out there with the use of better equipment and with reference to present possibilities. At the same time the writer would like to add as far as his memory allows him a description of that part of prospections which were not published either because of secrecy or because of the outbreak of war.

The Carpathian geological problems and especially those of the deep folds of Boryslaw, Naujowice, and Bitkow, on which the main part of the oil industry in Eastern Poland depends, are very complicated and different in different areas even not far distant from each other and could be solved only by a detailed geophysical prospecting with the full knowledge and help of geology. Seismic prospecting, being the only one of the geophysical methods which may give results in such areas, was undertaken first of all on the well known subsurface structures in order to learn how much one could rely on this method and to what extend this method might be applied in some future investigation in the Carpathian area.

The application of the reflection method in the Carpathians met with both technical and methodical difficulties at the beginning. The first were caused by the irregularity of the topography, the second by the complexity of the geological structures.

The reflection method as compared with the refraction method requires much shorter traverses, but on the other hand an important role is played here by the weathering zone and by the irregularities of the ground under the traverse, on account of the time corrections which must be introduced in order to compute the depth and the dip with required accuracy. To apply the reflection method, it was important to know the elastic properties of the subsurface. These elastic properties could be learnt best by knowledge gained from the determination of the velocities of subsurface rocks.

The studies on the velocities of propagation of the seismic waves, show, that these depends not only on the petrographical characteristics of the rock, but also on many varied factors, of which the more important are: the stratification, the degree of consolidation, the presence of splittings and crackings, the size and shape of individual grains, the cementing material, the percentage of moisture, the effect of the pressure of the overburden and the effect of pressure to which the rock was subjected during the formation of a structure. All these factors cannot be dealt with separately and its total effect is clearly shown when comparing the velocities determined by samples in the laboratory with those obtained in the field. The former are always smaller (see p. 75., chapter III of this paper).

Among the mentioned factors, stratification is the most important. It has been proved (Mc Collum and F.A.Snell: "Assymetry of Sound Velocity in Stratified Formations", Physics, March 1932, p.174, also Roland F.Beers "Velocity stratification as an aid to correlation", Geophysics, 1940, Vol.V., Nr.1., p.15), that the velocity along the stratification of a bed is 10% to 40% higher than that across it. The experiment carried out by the writer in a limestone quarry in 1938, showed that the velocity along the stratification was of the order of 4500 m/sec, whereas across it amounted only to 4000 m/sec, which is more than a 10% decrease. This discrepancy decreases with the increasing depth, and is higher for less consolidated beds.

Moisture has, to some extent, a deteriorating effect on the velocity of rocks. This is explained by some authors (W.T. Born and J.E. Owen "Effect of Moisture upon the Velocity of Elastic Waves", Bulletin of A.A.P.G., Vol.19, Nr.1, 1935, p.9), as being the effect of the loosening of the rock particles under the influence of water. This influence is not uniform and the velocity decreases only to a certain limit with the increasing content of water, after which saturation point is reached and a further increase of moisture does not affect the velocity.

The effect of the pressure of the overburden differs for different rocks. N.Haskell ("The Relation between Depth, Lithology, and Seismic Waves in the Tertiary Sandstones and Shales", Geophysics, 1941, Vol.VI, Nr.4) shows, that the velocity increases with depth for the same formation and the rate of this increase is rapid for shallow depth, after which there is a slow lineal increase with depth. The sand formation shows a greater gradient of velocity with increasing depth than do the shales, which is due to the greater porousness of sanstones as compared with shales. Mr. Haskell also shows that, eliminating the effect of lithology, 75% of the increase of velocity is due to the effect of the pressure of the overburden, whereas the rest is caused by the cementation of the rock, which increases with the depth.

All these considerations show that, the velocities obtained for a rock in a given region, on account of different facial and structural conditions in which the rock is found, may be quite different for the same rock in another region.

The velocities of the longitudinal waves determined for the Carpathian regions in some of the experimental work done there, were collected in a table (Z.Mitera "Studies on seismic reflection methods in the Polish Carpathian Mountains" Report of the Geological Survey,Warsaw,1936,Vol.XII.page 21, and also Z.Mitera "Studies of seismic methods of prospecting and their application in exploration for oil in Poland",Petr.World Congr. in Paris, 1937, Vol.1). The values given in this table (shown on page 22) were observed on the reflection or refraction seismograms and refer to the beds under the weathering zone, on the corresponding traverses from 300 to 600 metres long. The thickness and the velocity of the weathering zone in the Carpathians were 10 to 50 ft and 350 to 900 m/sec respectively. Thus the velocities correspond to the depth of 100 to 200 metres.

The table shows that the highest velocity is that of sanstones of the Cretaceous age and that of Hieroglyphic Shales of the Eocene age, whereas the velocity of the Menilite shales is among the lowest, even when compared with the younger rocks of the Oligocene and Miocene ages. This is due perhaps to their low elasticity, due to which the Menilite shales suffered more from tectonic pressure than the other sediments.

As is known, in order that a reflection may take place at the boundary of two media, there must exist an actual discontinuity in the acoustic properties of both media, i.e. there has to be a sudden change in density and/or rigidity (See Chapter VIII). The coefficient of reflection (Chapter VIII) expressed in terms of velocity $r_{12} = (V_2-V_1):(V_2+V_1)$, may be assumed to represent the reflection power of the boundary surface. Applying this statement to the successive pairs of layers shown in the table, it will be evident, that the coefficient of reflection is fairly low, varying between 0,1 and 0,2; it has been computed for the most favourable instances, i.e. assuming for V_1 the lowest velocity in the upper bed, and for V_2 the highest volocity in the lower bed. One cannot then on

The Characteristic Velocities (longitudinal) of Wave Propagation in the typical Carpathian Beds.

Lithological character	Age	Velocity m/sec	Localities	r_{12}
Plastic clays with Salt and Gypsum	Salt formation Lower Miocene	2600 - 3100 2600 - 3060 2400 - 2800	Tustanowice Maniawa Niebylow	0,12
Polanica Beds (clays, shales and sanstones)	Oligocene	2100 - 3050	Nahujowice	0,19
Menilite Shales	Oligocene	2540 - 3100 2480 - 2700 2300 - 2500	Niebylow Bitkow Boryslaw	0,18
Red Shales Hieroglyphic Shales	Lower Eocene	2000 ÷ 2700 3280	Mraznica Bitkow	0,21
Jamna Sandstone	Lower Cretaceous	3040	Mraznica	0,09
Inoceramus Beds	Cretaceous	3080 - 3600 3020 - 3300	Orow Bitkow	

the basis of the table, expect to observe good reflections within the beds of the Carpathians. Furthermore, to apply successfully the reflection method, the velocity of the subsurface beds must show changes along with depth. The greater and the more rapid is this change the better are the results to be expected. It is not the fact in the Carpathians, as one can see in the table. Moreover, in the Carpathians, it very often occurrs, that the older rocks are overthrusting younger beds. This is not a favourable condition, since the seismic energy, passing on its way through the older rocks and thus more rigid beds, suffered scattering and dispersion, both causing a diminution of the original energy passing downwards to the actual discontinuity. The amount of the reflected energy is thus smaller. The same effect is achieved by more elastic thin beds or zones intercalated near the surface which camouflage or even obliterate the seismical reactions of the deeper parts and because of this some of the details of the geological structures are very often lost to investigation.

The changeable and comlicated geological features of the Carpathians thus required a series of experiments in order to establish technique for exploration in this terrain and to find a reasonable key for the interpretation of the results obtained. Therefore the seismic prospection carried out here in 1934 and 1935 had that experimental character in order not only to test the method and the apparatus, but also to get a knowledge of the wider possibility of application for purposes of further prospecting.

A series of these experiments was carried out on the well known structures of the deep element itself, which with its frontal parts is pressed into the Salt formation, with its trunk burxied under the overthrust of the Carpathians.

REFLECTION PROSPECTING OF THE NAHUJOWICE ELEMENT.

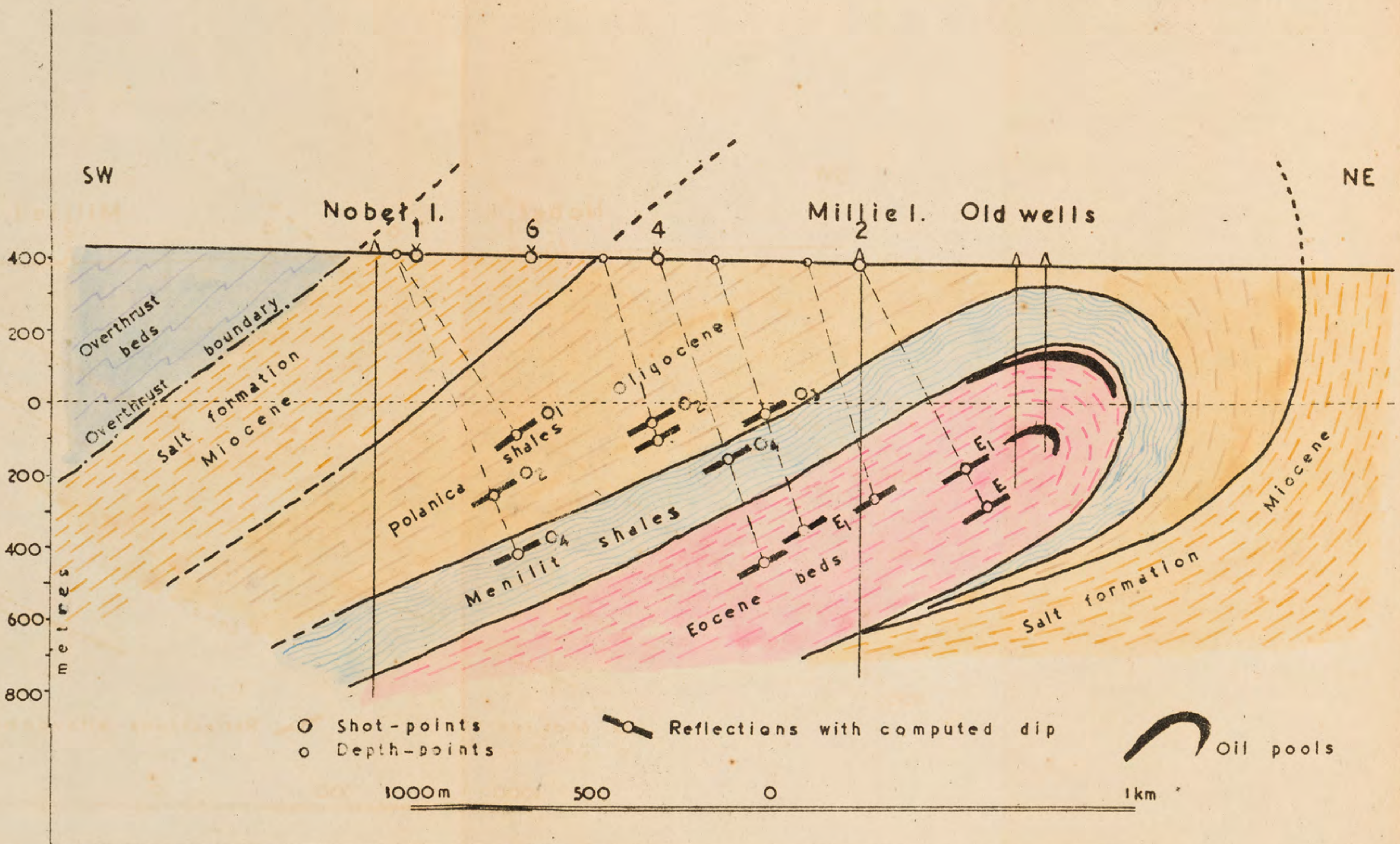

Fig. 1.

A series of these experiments was carried out on the well known structures of the deep element itself, which with its frontal parts is pressed into the Salt formation, with its trunk burried under the overthrust of the Carpathians.

Some of the examples given below also include prospecting carried out in 1938 and 1939 by the Geotechnica Ex.Co, with the use of a12 geophone set, since the results by these two apparatuses seem worthy of comparison.

A. The deep element in the Nahujowice area (DSH 7).

The deep element here is of rather a simple structure with outstanding petrographical discriminations between the successively enveloping themselves Limestone of the Eocene age Menilite Shales and Polanica Shales of the Oligocene age and Salt shales of the Miocene age (Fig.X-1). The frontal part of this element is very near the surface (850ft).

The prospection was carried out between two wells "Nobel 1" and"Millie 1". The reflection profile consisted of 6 shot-points, the depth ofwhich varied from 25 to 50 ft, and of a series of traverses shot in both directions along the profile.

This prospection revealed that, despite the outstanding petrographical ~~petrographical~~ discriminations between the subsurface rocks forming the element, there was small discrimination as far as the elastic properties were concerned. The seismic energy released from very small charges (up to ¼ lb) was rather large and, being of high frequency and large amplitude, was difficult to deal with.

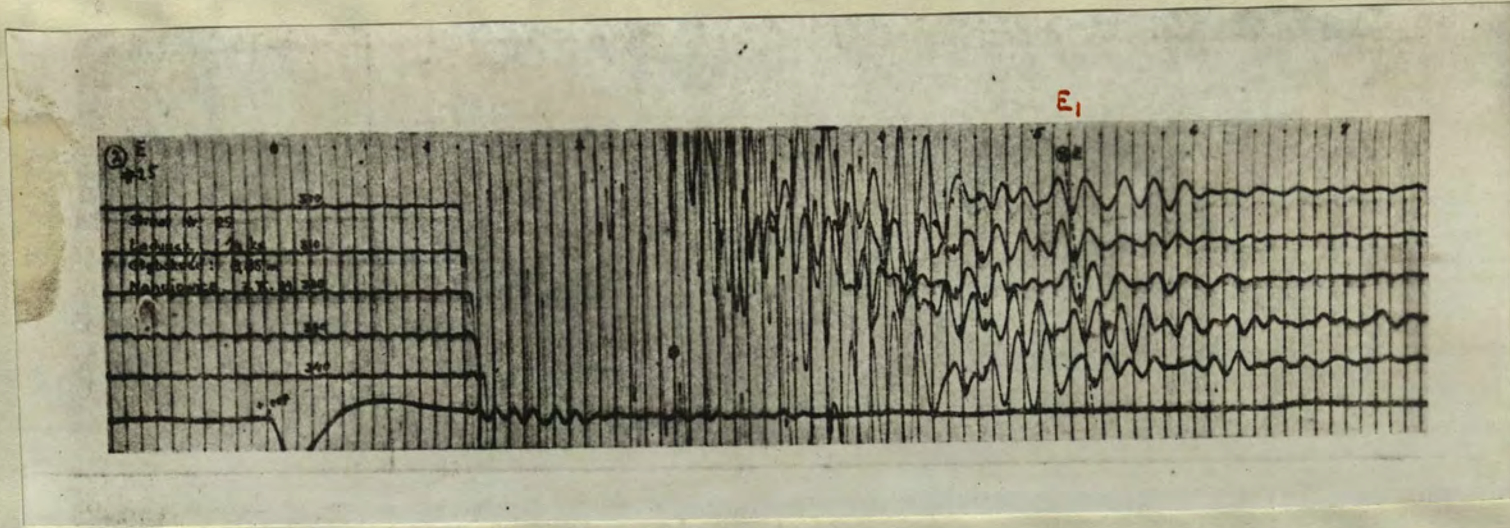

Fig.X - 2. A seismogram from the Nahujowice area.

Spread 300-340 m, Charge $\frac{1}{4}$ kg, depth of sh.h.9 m

The reflection "E_1" from limestones of the Eocene age

On the section (Fig.X-1), the reflections are shown by thick short lines. Most ofmthese reflections were from the Polanica beds (grey marly shales and limy sandstones), the elasticity of which was shown by their wave velocity varying here from 2100 to 3050 m/sec, which might reach value of 3500m/se(at the least, at the spots where reflections occurred.

The Menilite Shales give rise to weak reflections, which were confined mostly to the top where hornstones occur. The registered velocity within this formation was of the order of 2300 m/sec.

Fairly good reflections were observed from the Limestone of the Eocene age. A seismogram from S.P. 2 is shown in fig. X-2. The reflection corresponding to this bed is marked by the letter E_1. It occurred at a depth of about 2500 ft. The velocity of these beds was not registered on the reflection traverses. Beneath this limestone no reflections were obtained even with larger charges. This fact is clearly seen in the record on Fig. X-2. The initial energy is very strong down to the time of 0,5 sec and there is no reflection energy beyond the reflection E_1, which fact may prove that the limestone here form a kind of screen not transparent to seismic energy.

From the section fig.X-1, one can see that the reflections do not belong to any lithological discontinuity and are only confined to some harder intercalated layers within the formations described. They follow, however, the same dip, which implies that the correlation method being of no use, the method of deep shooting

shooting could only be applied, especially since the computed dips agreed in general with those given by geology.

The prospection carried out in the region of the frontal part was unsatisfactory, because the structure is too shallow for reflection prospecting.

The result in this area though not complete, was not discouraging to future investigation. It may be said, on the strength of the experience gained in later years, that with an equipment with 12-20 geophones, with an expander or overlap, the whole structure might be followed quite satisfactorily, as the direct wave and the high vibration which hampered the operation in this area would be sufficiently suppressed. Moreover, with an apparatus of this kind it would be easier to follow continually at least the hornstones in the Menilite Shales and some layers within the Eocene beds, if only by correlating the dips. Whether the frontal shallow part could be prospected is a matter for experiment. At least as was shown in 1938 on the Boryslaw deep element (see p.p.32-33) the dip could be followed far to the North, until it turns towards the south which would be a sufficient sign, that the culminating point has been passed, the latter being known as the most productive part of the fold. At the moment of passing the frontal part, opposite dips can be seen, due to which there may be a strong interference from impulses reflected at the frontal part and at the prolongation of Polanica beds or Miocene beds; this interference, however, may be a sign of trespassing on the fold.

From the geology of this area it is known that this fold plunges slightly towards the west, but there was no direct evidence of its prolongation. The purpose of the investigation was to discover if the method might be applied to carry out several profiles in a westerly direction, by which the existence of this fold might be proved. The investigation carried out in 1934 did not encourage the carrying out of this prospection , but as was mentioned above, it may be a worthwhile task when perfommed with modern equipment.

B. The prospection in the Boryslaw area.

The individual profiles carried out here by the reflection method are indicated on the map (Plate 5) and on the section (plate 6). The map shows the geology of the Boryslaw Oil field, the section is cut through the wells from the SW towards the NE. Both, the map and the section are copied from the originals drawn by Tolwinski, from the Geological Survey of the Eastern Carpathians.

a/ The reflection survey over the Tustanowice-Boryslaw deep element.

The summary survey over this part of the Boryslaw fold consisted of:

- Profiles DSH 8, DSH 8a, and DSH 8b, carried out in 1934 with the use of the Seiscor equipment (Pionier Co),

- Profile DSH 16 carried out in 1935 with the use of the Heiland equipment (Pioneer Co),

- Profile DSH 16 and DSH 8a carried out in 1938 with the use of 12 geophone set (Geotechnika Ex.Co.).

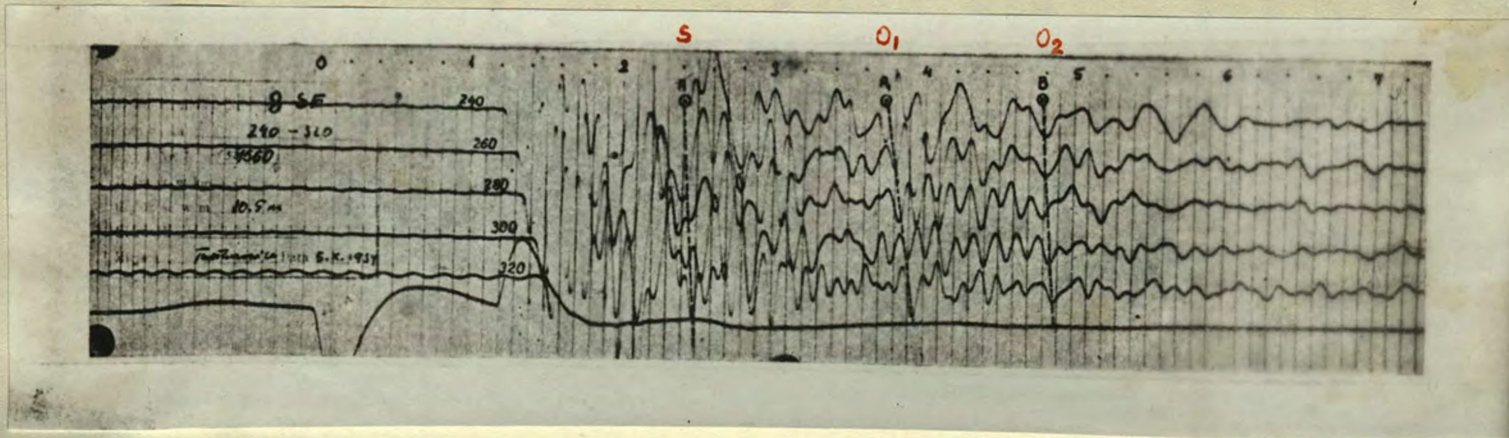

Fig.X - 3. A seismogram from the Tustanowice area.

Spread 240 - 320 m , Charge 1 kg , Depth of S.P. 10,5 m

Reflections S - Salt Formation
O_1 - Polanica beds (Oligocene)
O_2 - Hornstones of the Menilite Sh.(Oligocene)

Profiles DSH 8, DSH 8a, DSH 8b.

The profile DSH 8 ran along the strike of the dip element and consisted of 10 shot-holes spread uniformly along the wells Joseph, Wanda, Renata, and Dąbrowa 10. The depth of the shot-holes varied from 30 to 40 ft, the surface beds consisting of clay and gravels (watered or dry) which were drilled through. The charges were placed in the Miocene shales underneath.

The seismograms obtained from the traverses shot along the strike revealed the existence of several groups of reflections, similar to those given in the previous example, as they did not seem to belong to any persistent horizon but could be referred to some more rigid stratigraphical series within the formations exposed by the wells on the profile.

Shallow groups of these reflections are shown on a seismogram from that area (Fig.X - 3), from S.P. 8 on a spread from 240÷320 m towards the SE; while the correlation between them and thecorresponding geological section is given in fig.X - 4. From among these groups, that marked by "S" is the shallowest. According to the correlation it occurred at the boundary between the Salt formation of the Miocene age (salt clays with gypsum and conglomerates; grey shales with soft sandstones, about 400-500 m of thickness) and the Polanica beds (shales and sand stones, here about 600 m of thickness). Within the Polanica beds fairly good reflection is seen at the time of about 0,4 sec which corresponds to the depth, where the shales pass into sandstones. This reflection and its correlation are marked by "O_1".

REFLECTION PROSPECTING OF THE BORYSLAW ELEMENT.

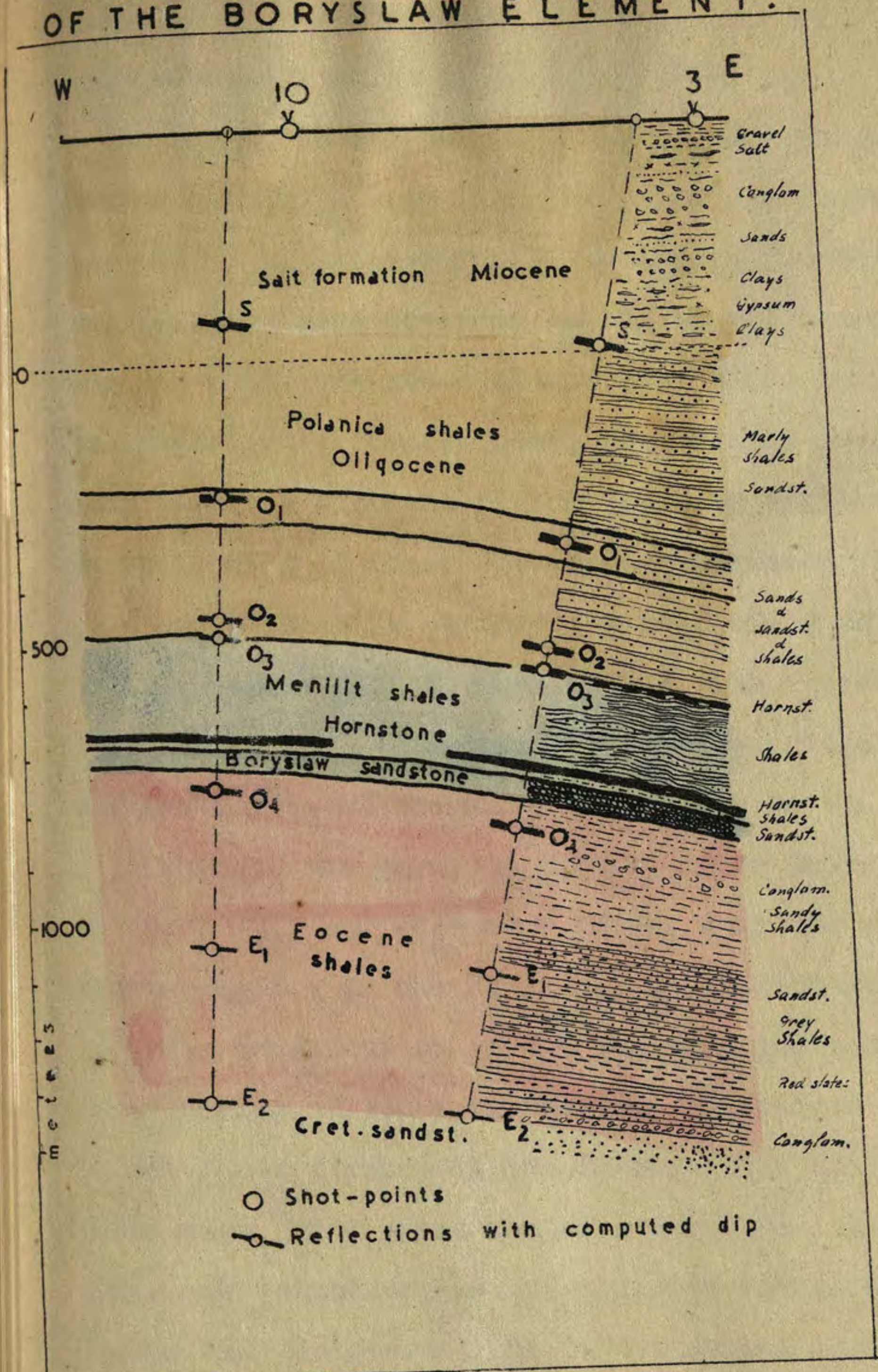

Fig. 4.

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Deeper groups were not so clearly observed. They formed impulses with semidefinite or indefinite initiation and could only be used for dip determinations. The group marked "O_2" O_3" might belong to the boundary between the Polanica and Menilite Shales , where a thin layer of hornstone occurs. From the lower bed of hornstones on the bottom of the Menilite Shales no reflections were observed on the traverses running along the strike, which may prove either that these hornstones are of insignificant thickness here, or, which is more probable, that they together with underlying Boryslaw sandstone are cracked so much within the frontal region, owing to their outstanding hardness, that they do not form any favourable surface for reflecting seismic energy. It is a physical fact, that a mirror with a cracked surface has very little reflecting power and causes rather the dispersion and scattering of the energy impinging on it.

Beneath the group "O_2","O_3", other deeper groups marked by "O_4", "E_1" and "E_2" were noted. They are shown on the seismogram fig.X.- 5. The first may be attributed to the zone of Boryslaw sandstone or to the top of Popiele Shales (marly and sandy shales of 100 m thickness). The second impulse occurred in the lower horizon of the Hieroglyphic Shales (grits and sandstones with green shales and red shales), whereas the third was correlated as belonging to the boundary between the Eocene and Cretaceous, the latter formed here from hard sandstones. The last two groups of reflections were obtained with large charges (about 25 lbs) and at long spreads.

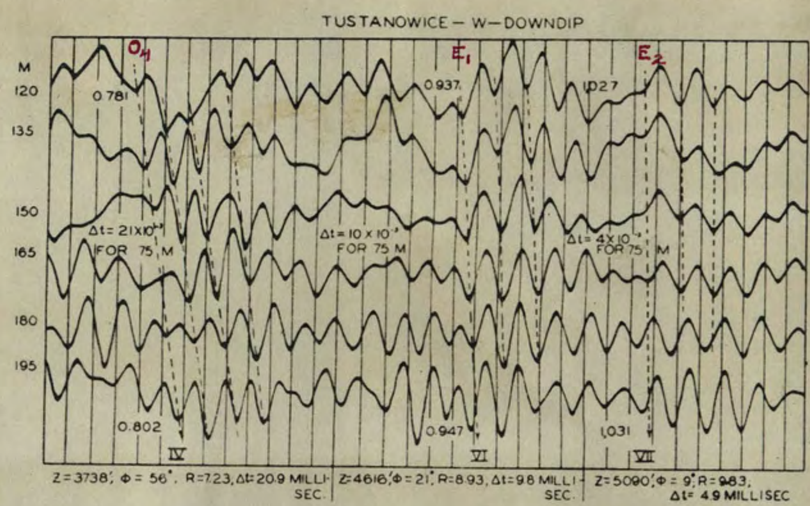


Fig. X-5. Record at Borysław-Tustanowice, showing three reflections with different time gradients

Fig. X. - 5. A seismogram from the Tustanowice

Spread 120 - 195 m

Reflections O_4 - Hornstones (Menil

E_1 - Hierogl. Sh. (Eoce

E_2 - Jamna Sandst. (Cret

Profile DSH 16.

Heiland, in his paper (Reflections from steeply dipping beds", Geophysics, 1936, Vol.1. Nr.2. pp.257-270), gives some results of the survey carried out in the Boryslaw9Tustanowice area in 1935 along the line DSH 16, from the well Opeg to the vicinity of Niagara, across the fold. The survey here, revealed the same goups of reflections as given above, of which the last, "O_4", "E_1" and "E_2" are shown in the seismogram fig. X - 5. The correlation carried out by Heiland is identical with that carried out by the earlmier survey. This survey showed that the hornstoned of the Menilit Shales gave rise to good reflections (mentioned by Heiland as predominant), which proves either that the first correlation was incorrect or that hornstones gave better reflections at right anglms to the strike, and that the bed along the profile was less broken than along the profile DSH 8, which as one can seen from the countours of the Boryslaw sandstone, ran along the biggest convexity of the fold. On the other hand, shallow reflections which were better observed along the strike, seemed to be less distinct when observed at right angles to it. This might be caused by the ground roll which influenced the dynamic type of Heiland geophones more than the electromagnetic type of Seiscor. This fact compelled the use of greater distances, which were not favourable to the shallow reflections. All these reflecting horizons are marked in red on the section (Plate 6), with figures corresponding to those marked on the seismograms.

Comparing the geological conditions and all three seismograms (fig.1 from Nahujowice and Fig.3, and 5, from Boryslaw) the following conclusion can be drawn:

i/ In Nahujowice, the deep element dips steeply more towards the south than in Tustanowice, and, being more shallow, the Polanica beds are at the surface. Therefore the shallow groups $0_1, 0_2, 0_3$ were more difficult to observe in Nahujowice than in Tustanowice, being mostly obliterated by a surface ground roll of higher frequency.

ii/ The reflections in the Naujowice area, owing to greater dip, could be observed when the geophones were closely spread (every 10 m).

iii/ Ground roll in the Nahujowic e area, though of higher frequency, was of short duration and did not affect deeper reflections, whereas in Tustanowice, ground roll of low frequency can be clearly seen on both seismograms.

iv/ The angularity correction for the average velocity was more prominent in Naujowice, as it was incorrect to apply the same velocity for a vertical shot and for longerspreads. Owing to this fact the dip computations for the Tustanowice area were more accurate than those in Nahujowice.

v/ As was shown in chapters VII and VIII of this paper, the distribution of seismic energy depends also among other things of the slope of the reflecting bed. If the highest amount of energy is reflected at the angle of total incidence, the spread on which this amount will be observed is very much shorter near the top of the fold, than further to the south. On the other hand according to the theory given in chapter VII, the greatest amount of reflecting energy is obtained near the shot-point, if one considers the most important factors reacting on the distribution of the energy. As the shortest distance from the shot-point to the reflecting bed grew greater, when passing from the top of the fold towards the south, the amount of impinging energy steadily diminishes and less and less of the reflected energy is picked up at the surface. A spread chosen for shooting towards the north, by avoiding ground roll and other surface disturbances, was not convenient when shooting towards the south, since the depth of the bed increased and the relation between the time of ground roll and reflection changed. Thus any standardised policy of shooting on a profile running accross such a structure will not yield satisfactory results. In the Tustanowice area, where the variations of the dip of the same beds are much smaller, a satisfactory method of almost standardised shooting was applied in a later survey given below.

As a whole, in the Boryslaw area interference and ground roll were very serious; long profile-traverses (400-500 m), deep holes (50-60 ft) and large charges (up to 25 lbs) were very necessary to register any deep indications; the latter could not be followed as continous, and seemed to be arriving from different zones of the same horizon from one shot-point to another. It was clear from both surveys that the cracked

DIP – SHOOTING CONTINUOUS PROFILING
applied in Tustanowice and Lubience .

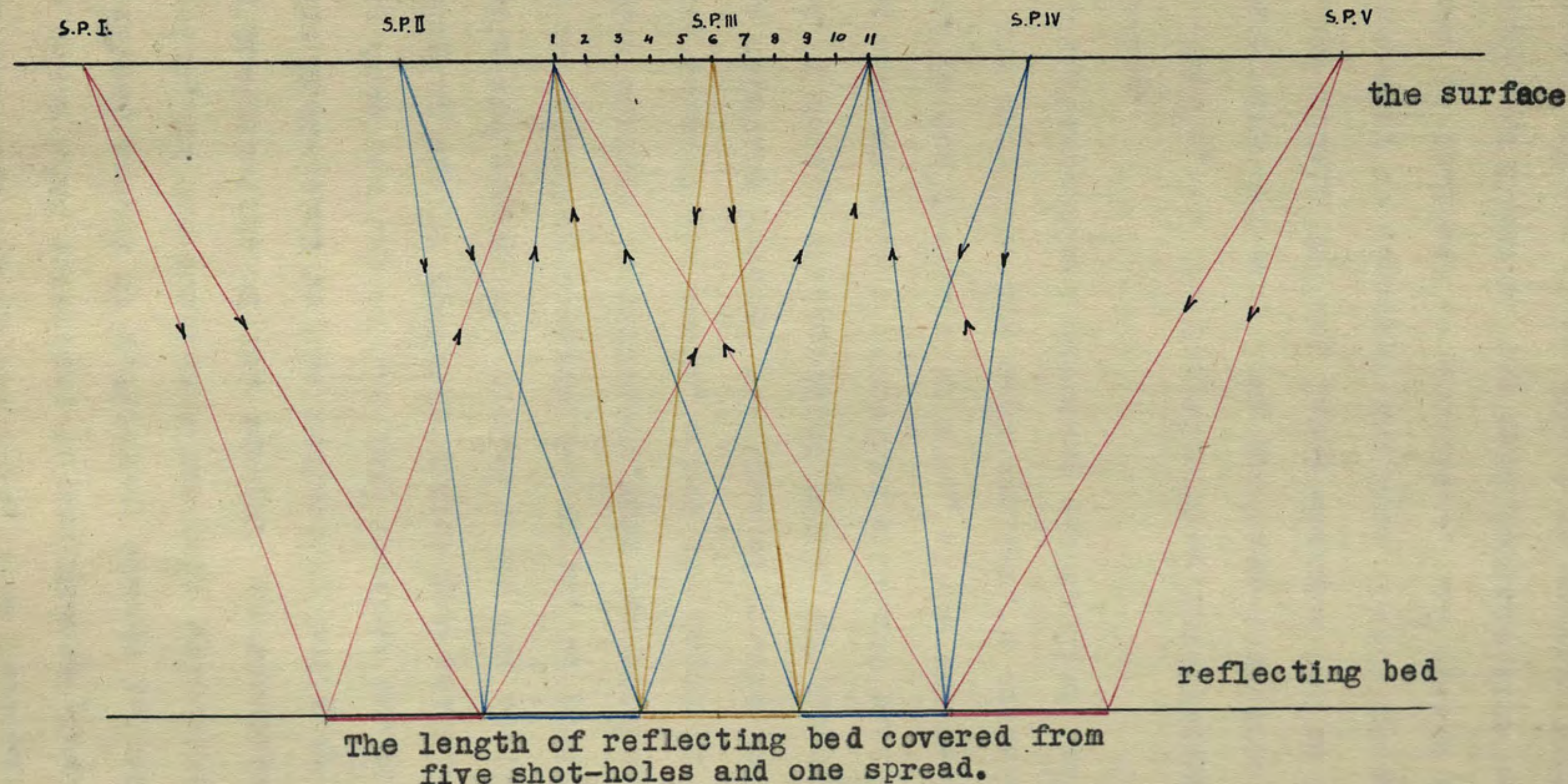


Fig.X. – 6.

frontal portion of the fold with its rapidly changing dips towards the norbh would render any correlation method rather impossible. Following the effects observed in the Nahujowice area, only by observing the slopes which gradually change direction from south to north, the culminating point of the fold may be located.

Profile DSH 16 (1938).

The further investigation of this problem was again tackled in 1938, using this time a 12 geophone set with overlap which suppressed to a considerable extent shallow interference and ground roll.

In an effort to carry out correlation and to test whether the cracked frontal portion of the fold would hinder reception, a line DSH 16, of continous profiling was started in the undisturbed part of the fold at the boundaries of the Marginal Skiba (in the vicinity of "Wagmann" well, see map Plate 5) section Plate 6), and carried out in the direction of the maximum dip. This line consisted of a successively shifted spread of eleven geophones spaced at 25 m intervals (Fig.X.-6). Each spread was shot out from five to seven shot-points spaced uniformly along the line, the depth of the shot-points varying from 36 ft to 60 ft. In this way it was possible to obtain reflections from the same strata with different angles of incidence and from different strata with the same angle of incidence. The successive spreads were linked by one or two geophone positions and this made possible the continuous investigation of individual reflections in each observed groups, using if possible the vertical times registered by geophones placed near the shot-holes. The effect of some rapidly changing dips and depth was thus avoided by this method of shooting.

In the previous investigation (1935) the average velocity for the area was obtained by correlating the observed reflections with the stratigraphical horizons encountered in the wells across which the traverses were shot. On account of this method the average velocity could not be computed with required accuracy the more so since the observed reflections had mostly semi, or indefinite initiations. Both these facts might be the cause of many errors committed when correlating the computed reflections with their lithological horizons.

In the 1938 prospection, depth and dip computations were based upon the average velocity determined by shooting in the "Dabrowa 10" well, situated as shown on the map (plate 5) near the top of the fold, and on the most prominent reflections,the phases of which were either definite or at least semi-definite and were observed at least at six traces.

Probably because of the cracked zone in addition to the superimposed dips (considered by Heiland in his paper) occurring in the frontal portion of the fold, the reflections were not continuous and their phases changed from one spread to another or even along the same record. With a six-geophone set, without the overlap arrangements it was really difficult to arrive at any definite conclusions concerning the prospection on this deep element. By using the modern equipment mentioned and the continuous method of shooting as shown on fig.X.-6, it was possibăe to follow almost the entire upper surface of the Polanica shales (reflection S and O_1) up to a point where the dip towards the north exceeded 60° (at the nose of the fold), the latter being observed much better at long spreads laid beyond the boundaries of the deep element. The shallow group which corresponded to the boundary between the Salt formation and Polanica beds was very strong, the short vertical spreads being here the most useful.

It is worth noting that because of the surface conditions, namely because of the overthrusting Menilite Shales, the reflections from the Polanica beds in the undisturbed portion of the fold (at the southern end of the line), did not seem to be any better than those from the presumably cracked zone (over the top of the fold). This proves that a greater part is played by the surface conditions, than by the physical conditions of the reflecting bed, and the latter can only be judged correctly either if the former remain constant or if their effect on the prospecting is accurately appreciated.

Besides the two prominent groups of shallow reflections mentioned, some deep indications were also observed. In general they belonged to the same groups described above. The group from the Boryslaw sandstone at the bottom of the Menilite shales was noted, but was either not continous or fairly weak.

Reflections belonging to the groups E_1 and E_2 were also registered, but as the exposed part of the beds suitable for seismic survey was too small, they could not be satisfactorily elaborated along a distance necessaru for final conlusions. These deep reflections were also observed where the line passed the fold, and it was difficult to point out any definite spot along the line, where the Cretaceous beds forming the 'marrow' of the fold, ceased to be present and where another deep bed-rock began.

Tests were made by the refraction method to determine whether the erratic conglomerates which outcrop before the front of the Boryslaw fold, form a continuous bed dipping steeply under the Polanica shales, or whether they belong to the lost 'tail' of the overthrust, the root of which is at the surface near the overthrusting Menilite Shales of the Marginal Skiba. These conglomerates form an outstanding hill before the fold (St. Anna Hill), which has escaped erosion owing to the extreme hardness of the conglomerates. The refraction technique consisted of a long spread of 12 geophones spaced at 50 m intervals, shot from two shot-points situated at its extremities. These shot-points were successively moved away from the fixed spread, in order to test whether any changes in high velocity could be observed. This failed, however, to produce satisfactory results.

Experiments, based upon the last method applied in the Boryslaw -Tustanowice area, were satisfactorily used in the

CROSS SECTION THROUGH THE SKOLE CARPATHIANS
after K. Tolwinski
(ref.12)

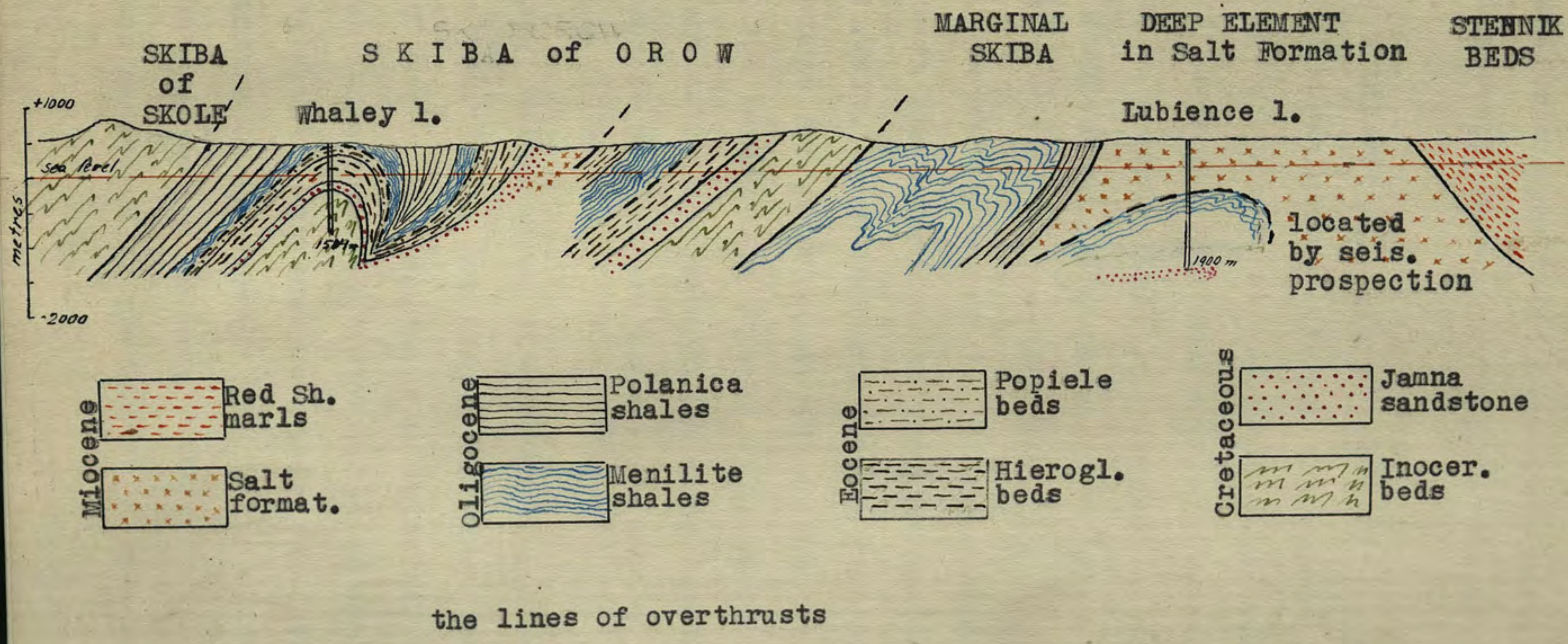


Fig.X-7.

Lubience area (DSH 15) in 1939, just before the outbreak of war. Here the northern limit of the Carpathian Mountain Range moves back towards the south from its normal boundary line, this fact for a long time being taken to indicate the existence of a subsurface structure similar to that of Tustanowice. The surface here is very flat, forming the alluvial valley of the river Stryj, and accordingly covered with clay and gravels of varying thickness over the whole area down to the foot of the Carpathians. The x latter is formed here of a Menilite and Polanica series overthrusting as in Tustanowice, the beds of Salt formation of the Miocene age (see fig. X - 7). The subsurface was a virgin area, the nearest wells to the west being in Truskawiec, to the east in Dolina.

A standardised dip-shooting method of continuous profiling was carried out along three parallel profiles 2 miles long and 1,5 miles apart running away from the foot of the Carpathians towards the NE. These three profiles outlined and interesting deep structure which in the behaviour of the observed dips resembled that of Tustanowice. An additional profile which ran across over the culminating points, which were located on the previous profiles, outlined the transversal culminations. At the most favourable spot of the southern end of the structure a well was sunk in July 1939. This well reached in 1941 the Menilite Shales at a depth of about 500 m and some seepages of oil were noted. It reached in 1943 the Limestone beds of the Cretaceous age at a depth of 1900 m (6340 ft) and was liquidated. As far as is known several more wells were sunk there.

As far as the reflection prospecting was concerned, the reflections observed were numerous and many of them quite prominent. These were not continuous and only correlation by using the computed dips could be applied. It was characteristic that all three sections obtained from the three parallel profiles were very similar with regard to the shape of the structure and the appearance of the reflections. The shallowest were those undoubtedly corresponding to the Polanica upper surface, the deepest belonging to the Cretaceous beds.

The structure discovered was due entirely to the reflection survey.

b/ The reflection survey of the deep element in the region of the overthrust in Orow and Mraznica.(DSH 5

The experimental work was carried out in connection with the well "Pionier Orow I" sunk to investigate the deep part of the southern end of the Boryslaw fold as shown on the section (Plate 6). As is evident from the section, the well passing through the overthrust entered into the Cretaceous formation at a depth of about 1400 m, and at the time of seismic investigation had reached the depth of 2100 m (in 1934).

Near the well two shot-holes, 12 m deep, were drilled in the surface sandstone. The results of a traverse from one S.P. are shown on the seismogram (Fig.X. - 8). One can see here several reflection groups, the most outstanding of which is that

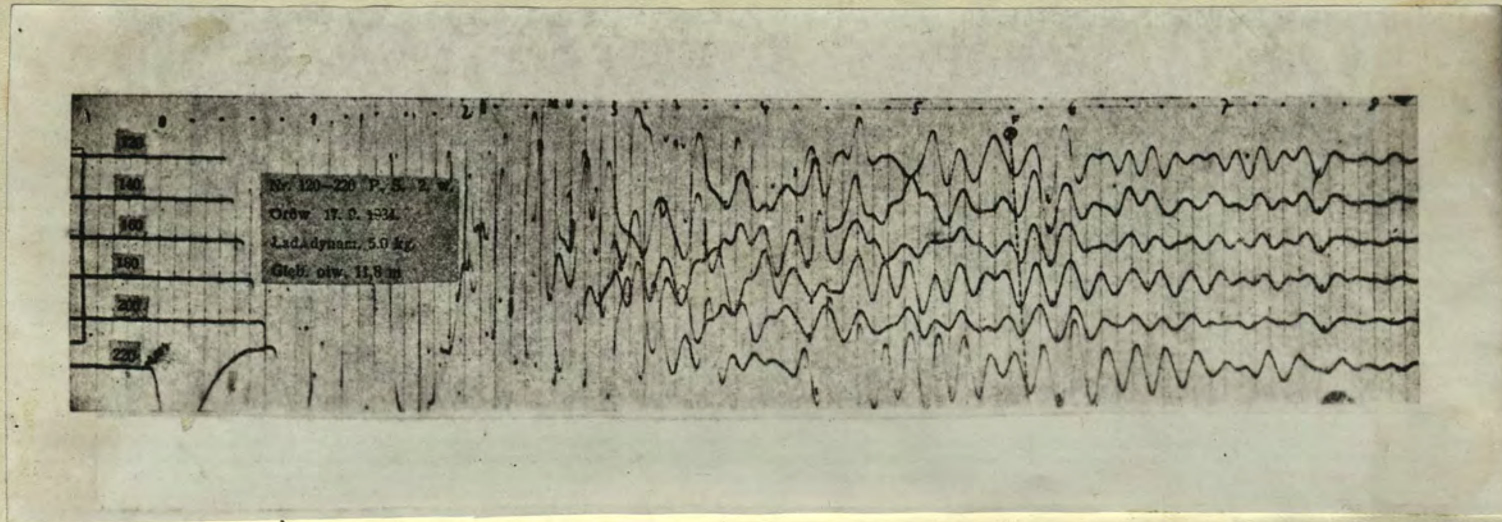


Fig.X - 8. A seismogram from the vicinity of the "Orow" well.

Spread 120 - 220 m, Charge 5 kg, Depth of S.P. 11,8 m

Reflection "F" from the Inoceramus beds - 810 m.

appearing at 0,56 sec, which corresponds to the Inoceramus Beds (green shales and limy sandstones) of the Cretaceous age, occurring in the well at a depth of 810 m. The corresponding refl. horizon is marked by "A" on the section. The boundary of the overthrust at a depth of about 1400 m, was characterised on the seismical record by a multiple group of very regular reflections of rather large amplitude which gradually petered out. The corresponding reflection horizon is marked by "B" on the section. Using large charges of about 40 lbs very deep impulses of small amplitude were observed from a depth of about 2500 to 2670 m (8200 to 8760 ft), which as was later shown, corresponded to the reflection horizon marked by "C" on the section. In order to find a means for interpretating the above mentioned reflections (particularly the deepest ones) a test shooting was carried out in the vicinity of the well "Stateland South" in Mraznica, situated as shown on the map (Plate 5). On the traverse (DSH 5a), the overthrust boundary (refl.hor."B") being at the depth of 1021 m was accentuated on the seismograms by a group reflection similar to that observed near the Orow well. Below this latter group the next group of reflections was observed from a depth of from 1820 to 1860 m, which by their character could be correlated with those observed in Orow (refl.hor."C"). These reflections could be referred to the Menilite Shales occurring in the Stateland well at a depth of 1821 m. Comparing the results obtained from the shooting in the vicinity of both wells, the Menilite Shales in the Orow well should be at the depth of 2500 to 2670 m and should occur beneath the Polanica beds, the latter in this area not being discriminated by any reflections as at the frontal portion of the fold. The depp reflections observed in the Orow well showed by their dipping and depth unfavourable structure, since according to the geological inferences the Menilite Shales here should be much shallower and rather in the form of a second digitation of the Boryslaw deep element. On the basis of the seismical, results the well at Orow having reached the depth of 2240 m (7350 ft) was indicated as dry and liquidated.

The shooting in these two areas revealed some interesting phenomena as far as the elasticity of rocks was concerned. A shot of two pounds revealed reflections down to 0,6 sec. The second shot of 10 lbs revealed good reflections at 0,56 sec (as shown in fig.8) and traces of reflections belonging to the overthrust boundary as well as those belonging to the Menilite Shales. A third shot of 30 lbs resulted in some improvement of the reflections from the overthrust boundary, but did not improved the very deep traces. A charge of the same size, fired from a second new hole situated about 20 m away from the first, revealed these traces with an amplitude about twice as large as before. In the first case the bottom of the hole must have been cracked and covered with pulverised rock which hampered the effect of the next charge. In order to obtain good reflections a charge must be at least 50 lbs and be placed in a much deeper hole and fired without any preparatory charge. In the experiment the geophones were placed on a hard rock and so the acoustic resistance being fairly high, had a decreasing effect on the size of the amplitude of the reflected wave arriving at the geophone. It has been proved by experiments carried out there, that, when the geophone was placed on the turf which covered the rock, the shallow reflections had greater amplitude (see chapter VIII)

Analogous survey was carried out in the vicinity of wells "Bitumen 1" and"Petain 1 " (DSH 9) in order to disclose the seismical behaviour of the overthrust boundary (refl.hor."B") known in both wells and to transfer the observation to the vicinity of the well "Kwiatkowski" in which this boundary was not yet reached. These experiments showed that there existed no reflection which could have been considered as a persistent horizon (marker horizon) for the boundary between the Cretaceous Inoceramus beds overthrusting the Salt formation and Polanica beds, on the strength of which, the condition in "Kwiatkowski" well might well have been disclosed. There was no criterion reached concerning this boundary, except a statement that the vibrations within the zone of the overthrust were of higher frequency than those within the underlying undisturbed zone. Some better reflections were observed from the Inoceramus beds (refl.hor."A") and Jamna sanstones, both shallow and within the overthrust zone. The reflection groups which were observed at the top of Boryslaw fold were fairly scattered here and no correlation was possible.

REFLECTION PROSPECTINC OF THE BITKOW ELEMENT

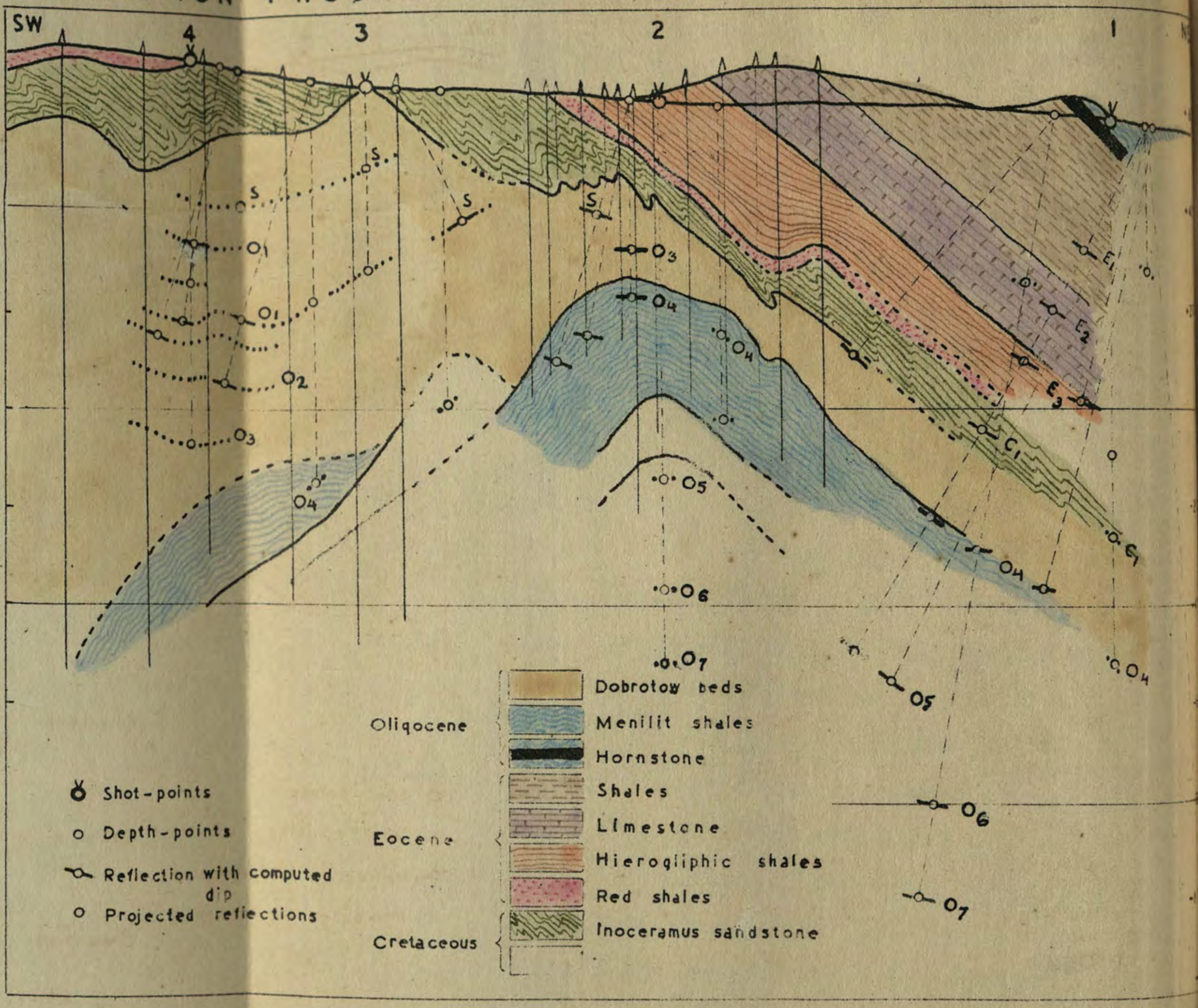


Fig. 8.

C. The deep element in the Bitkow area. (DSH 1,2,14)

In the geological structure of Bitkow one recognises two different tectonic units: that of the deep element pressed into the Dobrotow beds (corresp.Polanica Beds) of the Oligocene age and that of the overthrust element, part of which lies on the Dobrotow beds and in this way covers the deep element (Fig. X.- 8).

Seismical research work, similar to that carried out in the Boryslaw area, was of an experimental character in order to disclose the seismic character of the rocks in both elements. A profile of four shot-holes was run across the structure from SW to NE as shown in fig. All shot-points were drilled in the overthrust rocks, so that Nr. 1 was in the Menilite Shales, Nr.2 in the Eocene Hieroglyphic Shales, Nr.3 and 4. in the Inoceramus beds of the Createceous age. From each shot-point at least four traverses were shot, the length and the directions of which depended mainly on the transport condition and also on the technical conditions of observation. The length of the spreads varied from 30 m to 400 m with 20 m interval between the geophones (5-6 geophones). The profile ran along a brook, the sides of which were covered with gravels or clays of the alluvial age of varied thickness. These were largely the cause of all surface disturbances and, being of low frequency, caused the reflections to appear on the typical ground roll, difficult to eliminate at short distances. The irregularity of the topography and of the weathering zone caused the greatest difficulty in computing the reflections. As the geological section was well known, the interpretation was based on a combination of the correlation method with that of dip-shooting, that is by correlating the beds of the same dip. No marker reflections were observed, this being due partly to the structure itself and partly to the character of beds.

The average velocity was computed on the strength of the refraction profiles correlated with the corresponding beds. Several average velocities had to be used on account of fairly big differences in the thickness of the overthrust and the deep element. It was impossible to obtain this velocity by shooting in the neighbouring wells, as all of them were under exploitation

Fig. X,- 9, shows the computed reflections correlated with the geological structure. The groups of reflections observed were marked to correspond with the age of the beds in structure. The first group registered from the S.P.1 were those marked by "E" (E_1, E_2, E_3) and could be referred to the Eocene beds, of which the first was from the middle of the Eocene shales, the next two probably from the top and the bottom of the Eocene limestone. The "C_1" reflection could be referred to some of the more elastic zones within the Inoceramus beds of the Cretaceous age, and occurred within the overthrust boundary. The deeper groups marked by "O" were supposed to belong to the

Oligocene Menilite Shales (hornstones), or to the Dobrotow series when shooting from S.P. 3 and 4. Within the upper part of the Dobrotow beds in the Oligocene series some reflections were observed more outstanding than those within the Oligocene series of the deep element.

Relatively better reflections were registered from the S.P. 1., than from the remainder. It was due to the smaller velocity of the Menilite shales in comparison with that of the Cretaceous age beds underlying the S.P. 3 and 4. Owing to this fact, the seismic energy from S.P.1 penetrated the deeper parts more easily, whereas when shooting was done from S.P.3 and 4, this energy encountering the hard rocks on the surface was scattered and dispersed, and even large charges did not improve the value of the reflections.

As a whole, the prospecting was difficult. Surface conditions, variable dips of the structure itself, different older rocks underlying the weathering zone will never favour seismic prospecting. As is shown in the section, the computed dips in general, agreed with those from the geology, though on the steepest parts there was not such a great gradient as should follow from the actual dip. It was due on the one hand to the inability of securing a right phase of the reflection, registered only by five or less traces; and on the other, the close displacement of geophones which was necessary, caused a short segment of the beds to be prospected from one shot. Moreover, the same reflection observed on the next spread, appeared very much deeper and with a different gradient, influenced more or less by a variable frequency of the ground roll. The observation was also rendered difficult by the fact that a shot-hole conditions changed rapidly from one spread to another, anda new shot-hole in the vicinity but ~~already~~ in different surroundings would have to be used.

In 1939, along the road from Maniawa to Markowa a continous profiling /DSH 14/ was carried out with the use of a 12 geophone set, applying the same method of shooting as in the case of Lubience prospection (fig.X.-6) The surface conditions here were more favourable as the terrain was flat and regular, with softer rocks at the surface. The explored profile was extended towards the north, so that the overthrust zone was passed, beyond which, the Miocene formation was the first encountered under the weathering zone of gravels and clays. The ground roll and interference from the higher frequency Salt formation was successfully eliminated or minimised by use of the overlap arrangement. The reflections were very much better than on the previous profile. They were not sufficiently continuous to be correlated from one point to another. They were, however, well correlated with the aid of their dips, which varied uniformly from 2^{0} to 25^{0}. This profile was parallel to the previous one and ran from it at a distance of about 1,5 miles away. The structure did not show very much resemblance to that described above, and there could be no correlation between the character of the reflections, their relative separation and the corresponding beds. It is very typical of the structure along the zone from Dolina to Bitkow that the building up of the subsurface deep element is not uniform in this area, and the geological conditions on one profile are very different from another not more than a mile away.

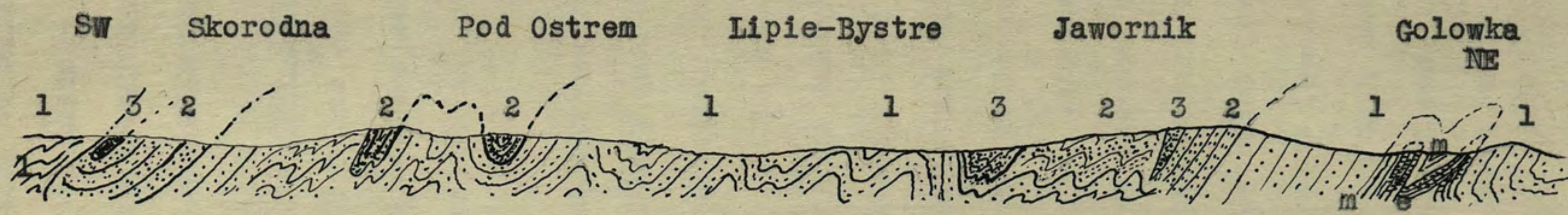
D. Other examples from the Carpathians.

To conclude the reflection prospecting within the Carpathians two reflection surveys are worth mentioning, on account of their failure, as far as the outlining of the subsurface was concerned.

The first was carried out in the Niebylow area (DSH 3) still on the deep element in the Salt formation, the second in the Central Depression of the Carpathians (DSH 12 and DSH 13).

The purpose of the first survey was to locate some features of the subsurface deep element, which might be pressed into the Miocene Salt formation, in the same way as in the Tustanowice area. The survey in the Niebyłow area consisted of four reflection profiles, with 4 to 6 shot-points strung along them at 1 km intervals. The dip-shooting method was applied with two or three successive spreads on each traverse shot in the direction of the maximum dip from the SW towards the NE. Though some good deep reflections were observed, neither they nor the shallow impulses, could be correlated along the profile, on account of the great changes in the dips. A later geological survey, with some shallow research holes, outlined a structure of multiple short overthrusts the relative behaviour of which

CROSS SECTION THROUGH THE CENTRAL DEPRESSION
OF THE CARPATHIANS
After L.Horwitz.P.I.G.XII.1936



1 - Lower Krosno beds
2 - Medium " " Upper Oligocene
3 - Upper " "

m - Menilite Shales Lower Oligocene
e - Sandstone & Shales Eocene

0 1 2 3 4 5 km

Fig. X - 10.

very much resembled a pack of cards, or piles of books on a shelf, when one or more are taken away. The dip was very changeable, and varied from 20^{o} to 70^{o} for different layers. It is difficult to say if the deep parts have the same behaviour, since the deep reflections in one shot-hole being clear and distinct, were so much affected by secondary vibrations in another hole, that it was impossible to follow the same phase of the reflection, even along three or four traces on the seismograms. The survey took about one month of field work.

The survey in the Central Depression of the Carpathians carried out in 1937 with the same six geophone set, had here rather an experimental value, in order to discover it the reflection method, partially successful in the Marginal zone, would be able to give some indication of the structure in the area, where some new oil deposits had recently been found. The prospection consisted of two profiles, namely that of N.Zagorz-Rzepec (DSH 12) about 25 km long, on which 16 shot-points were distributed, and that of Ustrzyki-Lutowiska (DSH 13) about the same length, on which only four shot-points were carried out. The survey took about a month of field work. The shot-points as well as the traverses were located along the uneven, ragged valleys in which the main roads cross the parallel brooks several times. A geological section through this part of the Carpathians is shown in the sketch in fig.X-10. The surface conditions consisted of hard sandstones of extremely varying dips, and the drilling of shot-holes was very tiring.

The effects of shooting were very much the same as observed in the Crow or the Stateland areas. The first few charges, as a rule affected the bottom of the holes so much, that for another spread or traverse from the same shot-point, another shot-hole had to be drilled, otherwise the greatest part of the energy was already lost in the surrondings of the shot-hole. Moreover, hard rocks on which the geophones were placed had their diminishing effect upon the amplitude of the reflections. Some effective experiments were carried out with the geophones placed on a block of clay, artificially collected as a support for the geophone. It had the effect of increasing the amplitude of the reflections. Simultaneously, however, the amplitude of the surface high interference wave was also enlarged. Another experiment, dealing with the latter fact, was to join two or three geophones together on one amplifier. The geophones in a single group were at 10 to 15 ft intervals from each other, the groups being spaced uniformly along the line at intervals of 80 to 100 ft. This method of the multiple geophones is that now universally used in prospecting. Its effect was to cancel the surface interference wave, as it travelled along the surface and at the same time to multiply the energy of the same reflection which came from below. It proved successful, though on account of too few groups of geophones being available, it was too tiresome, and the correlation between the successive seismograms was very uncertain.

From the geological section of this area, it is evident that, owing to the steeply dipping beds over the whole area, the seismic method yield may some results only when applied on a very detailed scale, involving a considerable amount of corrections due not only to the varying weathering zone condition but also to changes in elevation, velocity and dips.

Both these surveys were classified as unsuccessful.

General possibilities for the application of the reflection method in mountainous areas, especially in the Carpathians.

On the basis of the examples previously described several conclusions can be drawn:

1. Within the formations of the Carpathians, it was not possible to discriminate reflections which might serve as "markers" of some characteristic beds. Thus the correlation method of investigation cannot be applied in the Carpathians.

2. In most of the cases, instead of distinct and free reflections which could be separated definitely from the remaining impulses, groups of reflections or their phases could be observed. These may be referred to a series of layers of higher elasticity, which are present in almost all Carpathian formations. The computed dips of these reflections (impulses) conforming with the existing geological slopes of the formation made it possible to investigate structures by means of the dip-shooting method.

3. Existence of surface secondary vibrations could easily be removed with the use of modern equipment, with overlaps or expanders, and with multiple geophones.

4. Surface and subsurface conditions being very changeable the observed reflections were very much affected by the number of shots and by the size of the charge. An optimum of direction of the traverse and an optimum of spread on each traverse could be found, but requires much experimentation. Thus to speed the operation an equipment with large number of individual geophones would be of use, indeed essential.

5. The investigation of the deep Carpathian structure within the Salt formation is possible, but the too complicated structures as in the Niebylow area have to be left.

6. Within the overthrust areas where the surface rocks are older than underlying them, prospection is more difficult and great attention must be paid to changes of average velocities due to variation of the stratification within small segments.

7. In comparison with other geophysical methods, the reflection method seems to be the only one which might yield results in this area.

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C H A P T E R XI.

Seismic reflection survey along the Stryj-Lwow road.

The profile described below (shown in the plan in Plate 7 and in section in Plate 8) runs from the town of Stryj (south) along the main Lwow-road up to the station Bilcze in the direction SSW-NNE and thence towards Rozdol in the direction SW-NE, the total length being about 16 miles. The first experimental work was carried out using 19 shot-holes, of an average depth of 27 m(90 ft), the bottom of each reaching the shaly clays of the Tortonian age, underlying the Diluvial water-gravel beds. These shot-points are marked by the Nos 4 to 20, the average distance between them being about 1 mile.

As the work proceeded and the experience grew, 40 more shallower holes were drilled either beside the original shot-holes or between them at appropriate distances, so that the work could become more detailed. The following figures, some of them taken from the writer's article in the Polish Oil Industry (Przemysl Naftowy, XIII, 9,1938.p.221-223) give data concerning the period of work, the number and type of shot-holes, the number of shots and the expenditure of explosive.

The whole work within the profile is divided (as shown in table,page 52) into three different phases which were characterised by improved methods of work, resulting in increasing efficiency in dealing with the given problem.

Phase of work	Dates of field-work	Number of work days	Shot-points: Type and Nos	Shot-points: Number	Shot-points: Aver. depth	Number of shots	Explosive expen. in lbs: total	Explosive expen. in lbs per hole	Explosive expen. in lbs per shot
I	1.8 - 25. 8.34	20	deep Nos. 4 - 20	19	20	376	1360	72,o	3,6
II	26.8 - 1. 9.34 20.9 - 2.10.34 8.3 - 3. 4.35	30	shallow Nos. intermed	30	14,7	269	421	14,o	1,6
II	17.10.1935	1	shallow N.831-2-5-6-7	5	13,o	21	18	3,6	o,9
III	16.1 - 18.1.36	2	shallow N.930-1-2-3-4	5	32,o	41	37	7,4	o,9

The first phase of work.

Basing the field work on American experience which favoured deep shot-holes it was decided to apply them in the prospecting. Along the whole profile the surface beds consisted of a thin cover of clay (4 - 15 ft) underlain by Diluvial water-gravels of the rivers Stryj and Dniester. These varied in size from very coarse to very fine and were 40-60 ft thick. They are deposited on the more or less impervious clays of the Tortonian age. In order not to hinder the work of the observing party a set of 19 deep shot-holes was prepared and cased in advance by a detached drilling party. The reflection field party was assisted by an auxiliary drilling set, the work of which was to keep the shot-holes in good condition.

The preparation in advance of a set of shot-holes of the same depth for the whole profile almost predetermined the result, by depriving the observer of the most important parameter which he should be able to control during his work, i.e. the depth of the shot-holes. Moreover, the probable depth of the bedrock to be prospected was, according to the geologists about 2000 to 2500 m (6500-8500 ft) in that area, so the original intention was to observe reflections from that depth more or less neglecting all shalow indications.

It must be stated,also, that the reflection set used at that time was not equipped with a compounder or with automatic volume control. These have since made it possible to fire 2 or 3 shots at one depth and then to move on to the next shot-hole.

With the set actually used, each reflection or a group of reflections had to be elaborated separately by the observer and as it was necessary to register reflections from a considerable depth, the expenditure of dynamite was considerable.

The results were not encouraging, although the subsurface was supposed to be of the type most convenient for obtaining good reflections. All parameters, which the observer could control in order to influence the quality and character of the record, were examined. Various displacements between the shot-point and the first seismograph, varying from 20 to 700 m (60 - 2100 ft) were tried, the length of the spread for six geophones usually being 100 m (300 ft). The effect of the direction of the traverse was checked in all its bearings from the shot-hole. The geophones were placed on the surface, or dug in the meadows, ditches, or hard road material, in order to test the effect of surface material. Finally the overall frequency response of the recording system was adjusted by changing in turn the springs weights and the amount and kind of oil-damping in the geophones, by changing the range of frequency discrepancy in the entire amplifier system and finally by changing the damping in the galvanometers. All this, however, though giving more or less satisfactory records, could not be standardised so as to make the method efficient for the required survey. The only remaining parameter, namely, the depth, was also examined. The depth was increased so as to place a new charge in new surroundings, but the effect of a decrease in depth was not tested, since such a decrease was believed to have a deteriorating effect on the results. Besides, the casing and the gravelsm did not supply good conditions for repeated shooting.

The records showed that the reflection energy was combined with another useless seismic energy of high frequency, which made it difficult or even impossible to isolate.

Previous experience with shallow holes in the Daszawa area and in the Boryslaw area favoured rather deep holes, as was also the case in America. As there was no other parameter possible, however, a shot-hole only 12 ft deep and not penetrating the gravels was used. The results were at once very much improved and from this point onwards the second phase of the work was opened.

The second phase of work.

The experiment carried out with the use of shallow holes, the average depth of which did not exceed 12 feet, and which terminated at the upper level of the gravel beds, proved the existence of a very distinct reflection, which, owing to its steady appearance along the whole prospected profile, was called the "guide" or "correlation" reflection and its reflecting bed the "marker horizon". Three typical examples of this reflection are shown in Fig. XI - 1.a.b.c. These seismograms were recorded at points

a/ Nr. 9 Derzow - (Heiland paper)

b/ Nr.204 - Bilcze wood - (Mitera paper)

c/ Nr. 18 - Dobrzany - (Mitera paper)

Seismograms from the profile Stryj-Rozdol
"Marker" reflection from the gypsum
bedrock .

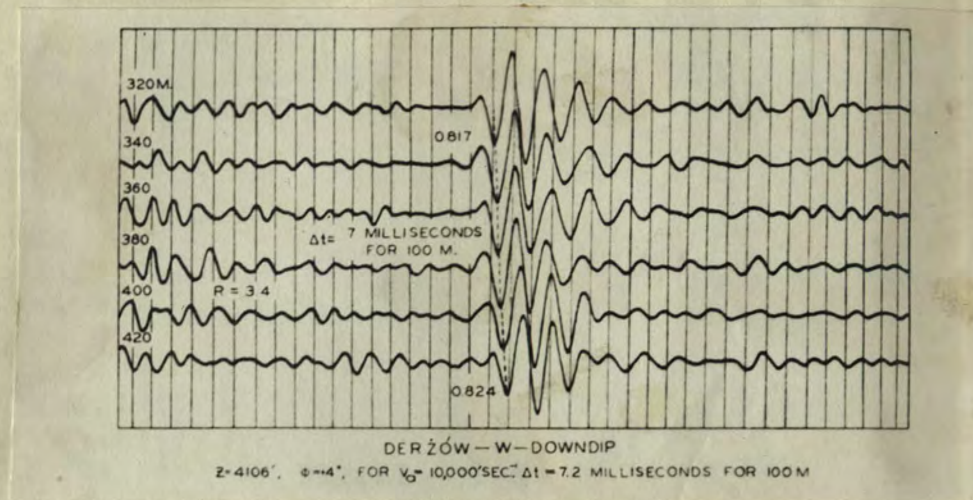


Fig.XI.- 1 a

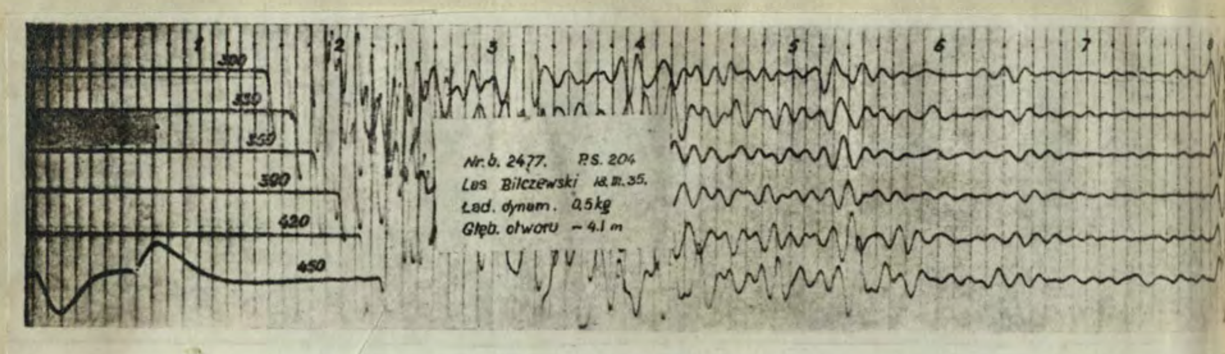


Fig.XI - 1 b

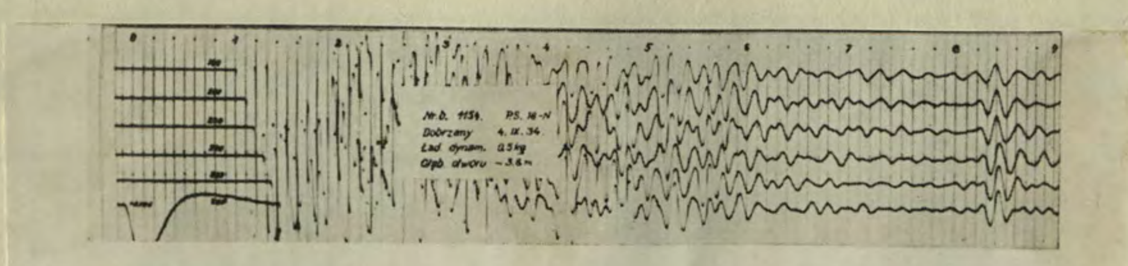


Fig.XI - 1 c

these being marked on plate 7, by the letter a,b,c respectively.

The distinct character of this reflection was first of all marked by its occurrence in sharp, strong impulses after an almost dead interval (picture a and b) or after the relative extingushing of secondary vibrations (picture c) The perfect agreement in the phase and the decided strong increase in amplitude of the vibrations across the record, these vibrations arriving at the individual geophones with very great apparent velocity, formed a definite proof of the arrival of a seismic energy reflected from a bedrock much harder than the series of the overburden.

Comparing these three seismograms which were taken at different points along the profile it may be shown that the character of the correlation reflection varies slightly and depends on the surface conditions, on the angle of incidence of the seismic wave at the reflecting horizon, and on the thickness of the reflecting bed.

According to the previous considerations on the seismogram the character of a reflection may be defined by its first impulse, its frequency, its highest amplitude and the number of cycles.

<u>The first impulse</u> in all seismograms is directed upwards. Let us explain the cause of it. The coefficient of reflection $r_{12} = (d_2V_2 - d_1V_1) : (d_2V_2 + d_1V_1)$, where <u>d</u> is the density of the media, V velocity of waves in the media 1 and 2, at the boundary of which the reflection occurs.

When $d_2V_2 > d_1V_1$, the compressive wave impinging on the boundary is reflected as a compression without a change in phase and so the first movement of the ground under the geophone will be upwards. Reversing the consideration, if the movement of the ground is upwards then the compressive wave is reflected as a compression and so $d_2V_2 > d_1V_1$ and thus one is dealing with a reflection horizon whose acoustic resistance is greater than that of the overburden. This phenomenon has been studied in greater detail by S.S.West ("The effect of density on seismic reflections", Geophysics N.1.Vol.VI.1941) who, introducing the relation $V = k\sqrt{\mu/d}$, considers μ (the rigidity of medium) instead of velocity in his formula

$$r_{12} = (\sqrt{d_2\mu_2} - \sqrt{d_1\mu_1}):(\sqrt{d_2\mu_2} + \sqrt{d_1\mu_1})$$

Introducing the values from the example given in chapter VI, $d_2/d_1 = 1,3$; $V_1/V_2 \doteq 2$, the value $\mu_2/\mu_1 = 5,2$ is obtained which does not enter into the considerations of S.S.West. It may fall in, however, with his types 1 and 4, in which there exists a real discontinuity of density and velocity, thus giving a high difference in rigidity, in which case the first impulse will always be upwards without a change in the phase.

Turning again to the seismograms, the depth and the dip computations for the purpose of correlation were based on the first trough, the impulse towards it being strong and its time easily read, as is the case in all three instances (a,b,c). In cases, however, where the first trough was not so distinct, the condition that the first impulse must be upwards as proved by good records, was of great assistance to the computer in selecting the first phase for the correlation.

The frequency of the considered reflection for the same distance of 300 m from the shot-point, read from the given seismograms is 67 to 72 cycles per second.

The amplitude of the second peak is in all seismograms the greatest of all the amplitudes of the remaining peaks.

The number of cycles, beginning from the first peak is 2 lining up in the first and second trmough.

All these parameters are brought together with the corresponding values regarding spread, direction, time depth and dip and shot-hole characteristics, in the following table:

Rec. No.	Direction	Spread	Time depth for 300m	Time dip for 100m	Shot characteristics			Character reflection		
					Depth	Bottom	Charg. lbs	first imp.	fr.	cy.
a	9-W	320-420	.817	.oo7	17'	gravel	1,1	cl.	72	3
b	204-NE	300-450	.816	.oo7	14'	"	1,1	cl	67	2
c	18-N	180-280	.838	.oo7	12'	"	1,1	cl	68	2

The surface conditions computed from those seismorgmams show at all points they are almost identical. The weathering zone avergge velocity is 1000 m/sec down to the depth of 15 m then 2000-2100 m/sec down to 51 m, below which the Miocene clays have a velocity of 2700 m/sec. The average weathering zone velocity contains a surface velocity of ab.650 m/sec and a deeper velocity of about 1800 m/sec.

From these data, as well as from the writer's experience in that area, the conclusions concerning the character of the guide reflection may be as follows:

Reflections of small duration (a small number of cycles), high frequency (65-70) and of strong impulses occurred, assuming the same surface conditions, where the prospected traverses crossed the bed at right angles to its strike, or where there was a horizontal reflecting horizon. Where the slope of the reflecting horizon was more than 3° and the prospected traverses run obliquely to the strike (instance a) the impulse received had more than two cycles.

As has been shown in Chapter VIII, where there is more than one cycle, the existence of changes in the thickness of the reflecting bed itself may be indicated. In the area dealt with there were, however, too few instances of deep wells which might definitely prove this fact.

The distinctness and sharpness of the "guide" reflection, was, as has been said, a proof of the existence of a sharp and definite discontinuity between the overburden and the bedrock. In instances where this sharpness of the boundary was obliterated on account of some disturbances of tectonic origin in the bedrock itself, or within the beds overlying it, there would exist an obliteration in the sharpness of the reflected impulse, with a simultaneous change of character. This phenomenon was very often observed by the writer, and occurred in the disturbed zone of the fault area, where the impulses disappeared suddenly and appeared again at a different depth, ashort distance further away.

A decrease in the distinctness of these impulses or their almost complete obliteration is, figuratively speaking, a "reflection" of discontinuity or of variations in elasticity of the reflecting surfaces. On the other hand it may be the result of variations and changes in the lithological and tectonical characteristics of the beds in the overburden, and finally the effect of the surface beds, as has been proved more than once when prospecting the area adjacent to the profile under consideration. Knowing from a number of experiences the surface conditions and their seismical effect, it was possible to arrive at some more definite conlusions concerning the lithological and physical characteristics of the reflecting bed itself.

Before going any further, let us consider those phenomena which occurred when shooting from deep and shallow shot-holes. A series of experiments along the whole profile showed that when the explosive charge was placed beneath the gravel bed in a deep hole, it produced such strong vibrations of the whole gravel bed, that, owing to their long duration and relatively high frequency, they interfered not only with the shallow but also with the deep reflections. On the other hand, when a charge was placed in a shot-hole above the gravels at a depth of 6-12 ft, or at a depth equal to one third of their thickness where they occurred at the surface (approx. the ground water-level) it not only failed to produce vibrations inthe water gravels but the gravels themselves acted as a kind of filter for all secondary tremors. An explanation of this may be given in two ways either by considering the phenomena of vibrations of thin plates (membranes) or by considering the normal propagation of waves within the bodies, (solid).

Consider a water-gravel bed of a thickness varying from 40 to 80 ft and velocity higher than 1500 m/sec; it lies above a bed of impervious clays of velocity 2700 m/sec, and is overlain by an inelastic thin cover of clay or soil. The bed of this kind can be compared to a plate, the thickness of which is very small with regard to its surface dimentions, this plate being laid on a massive block of material more elastic than the plate itself. When this plate is knocked by a special device from below, it will vibrate independently of the block below in a way which resembles the vibrations of membranes. These vibrations may create different interference patterns along the surface of the plate. The latter may serve as an explanation of the fact observed in the terrain, that in some directions or at some spreads nearer the shot-point, the vibrations of the gravel-bed were more attenuated than in other directions or at spreads further away.

Consider now the propagation of waves within a solid body. The whole water-grawel bed adheres tightly to the impervious clays below, but a shot produced at their boundary would cause two vibrations of different velocity on account of the difference in elasticity. They will differ also in the direction of propagation, i.e. in gravels they would spread upwards and along the boundary, whereas in bottom clays they would spread downwards and along the boundary. Assume now for a moment, that geophones are placed on the surface of this boundary, the gravel bed extending infinitely upwards and consider only longitudinal waves. We shall be dealing with an example in which the wave travelling along the surface of the boundary in bottom clays is a direct wave propagated along the surface of the ground on which the geophones are placed, whereas the wave propagated along the surface in gravels would correspond to the air wave spreading in the air from the shot-point to the geophone, its character and speed being different. The direct wave in gravels, being spread in a material of relatively high elasticity, will produce vibrations of higher frequency and may cause secondary vibrations within the gravel bed itself, but these arrive at the geophones later than the direct wave in bottom clays, causing the "surface wave" produced within the gravel bed, and thus prolonging the duration of the whole phenomenon.

If we now place the geophones on the surface of the ground we shall be dealing with the finite thickness of the gravels and with that part of the wave which spreads upwards in the gravels. This wave, reaching the surface of the ground or the bottom of the weathering zone, is reflected downwards to the bottom clays and again reflected upwards to the surface and we shall have repeated reflections travelling between the

the surface of the ground and that of the boundary. Simultaneously the direct wave within the bottom clays suffers diffraction along this boundary and produces a refraction wave which may interfere with the vibrations of repeated reflections within the gravels. It may ~~ix~~ in a way be a kind of stationary wave, as the diffractions and part of the repeated reflections travel in almost apposite directions. This assumption may explain the long duration and high amplitude of the whole disturbance. As has been shown in practice it was impossible to deal with this even, as was proved by the later survey, when using very modern sets with overlaps or automatic volume control.

In our practice we arrived at a very reasonable and perhaps known conclusion,"If one cannot take advantage of a phenomenon produced accidently, and cannot find anything reasonable to deal with it or to suppress it, the best way is to avoid producing it".

Where there was shooting at the top of the gravel bed, the production of a strong direct wave in the bottom clays was avoided in any case. The repeatedly reflected wave within the gravel bed was reduced to a minimum ~~x~~ if only by the fact that the size of the charge was reduced considerably and the wave was confined to the area of the weathering zone itself, a zone of small velocity and high absorption.

If we consider the vibrations of a plate, the latter being struck from the top, they may be transferred in the direction of the stroke, i.e. towards the underlying massive block. In this case the energy produced will spread through the block to its base, from which, being reflected, it will return to the surface only as useful energy.

The writer does not think that the mechanism of this phenomenon has been sufficiently explained. It would be useful to carry out several experiments with the purpose of arriving at a definite solution to these complicated vibrations, especially since they have been confined so far only to areas where the gravels were watered and the wave speed within them exceeded 1500/sec. In other parts of the same foreland belt where the characteristics of the bedrock and the overburden remained the same, but where the gravels were dry or where their thickness did not exceed 6 ft, better results were obtained with charges placed beneath the gravels, or as a rule beneath the top of the ground water level.

Shallow shot-holes in that area, giving good results not obtainable from the deep holes, necessitated the introduction of a new and simple technique of drilling and shooting. A hand auger was used for drilling holes down to the top of the gravels and a small drilling set was necessary where the gravels were nearer the surface. In the latter instance the whole was entirely cased with a short pipe. Shooting was carried out by lifting up the casing after the charge was loaded. This was an easy procedure and very often after the shot, the pipe returned to its original position, preserving the hole for the next charge. Besides this, the recording was much simplified. Two shots, one preparatory and small;and the second decisive,(or very occasionally three shots), were all that was required for a hole to stand when shooting in one direction.

Owing to the speed of drilling the shallow holes (15' in clay, by 2 men with a geophone auger in 20-30 minutes, or in case of coarse gravel, 1 hour per each 3 ft of gravel with a drilling set) and the simplication of the observation process, the whole profile was prospected again. 40 new shot-holes with a displacement of 750 m (2200 ft) required three times less explosive than the first phase of work. The average output was one shot-point per day, the highest being 5 per day. The low average output was due to the shooting of at least two spreads on one traverse, the number of traverses being not less than two in two opposite directions, and also due to the weathering shots carried out for each spread. Some of the traverses were shot on a continous spread from 0-800 m for the determining of the average velocity, as there was no well available at that time for this purpose.

The third phase of the work almost two years later in the region of Stryj was concerned with the location of the boundary between the Tortonian belt and the overthrusting Stebnik beds. The method of the field procedure did not differ much from that established before, as is seen from the number of shots fired and the expenditure of dynamite.

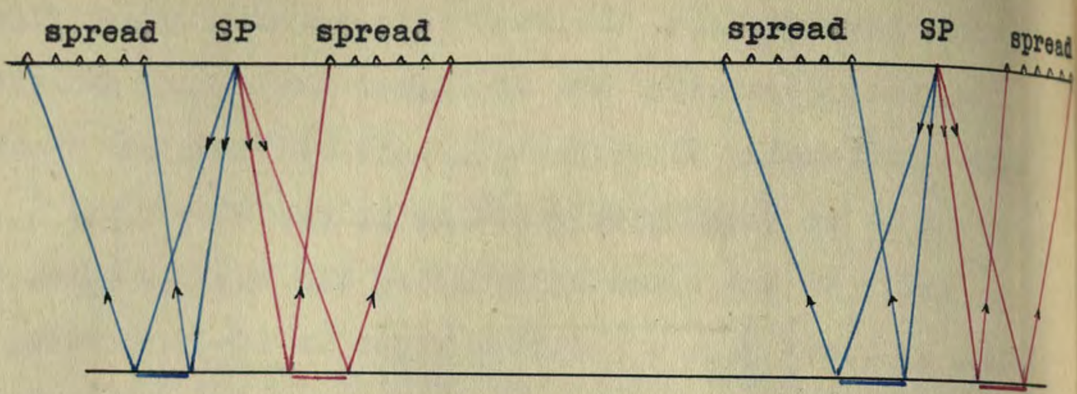


Fig. XI - 2. Reflection paths for a shot-hole with two-way geophone spread

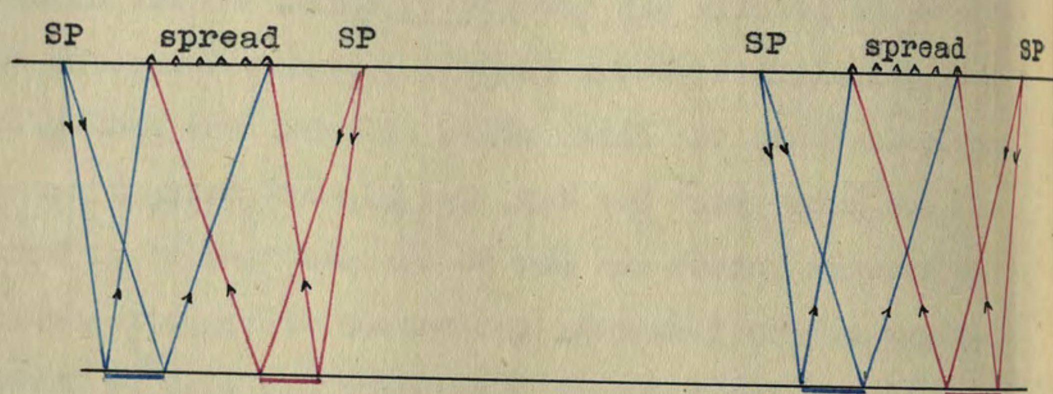


Fig. XI - 3, Reflection paths for a single geophone spread with two shot-holes

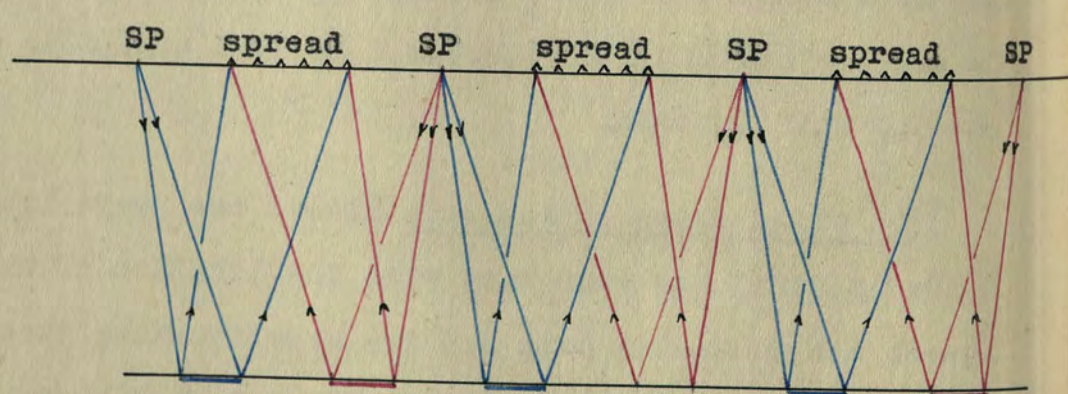


Fig. XI - 4, Reflection paths for continuous spread

To conclude the part of the field work procedure with regard to method, here are the types of reflection traverses used during the above three phases of field work:

Fig.XI-2 shows the reflection paths for a ~~single~~ shot-hole with a two-way geophone spread used mainly in the first phase of work, when the deep holes were explored, the displacement of which being about 1 mile, did not allow any other alternative to be applied.

Fig.XI-3 shows the reflection paths for a single geophone spread with two shot-points. It was used during the second phase of the work, where the drilling of a new hole was done in a shorter time than the change of a traverse, which was more convenient for correlation purposes than the former. Very often the space between two adjacent pairs of shot-points permitted a spread to be placed between them, so that a continous profiling was obtained, which, being the combination of fig.2 and 3 is shown in fig.XI-4. and was as a rule applied in the location of the southern boundaries of the Tortonian belt.

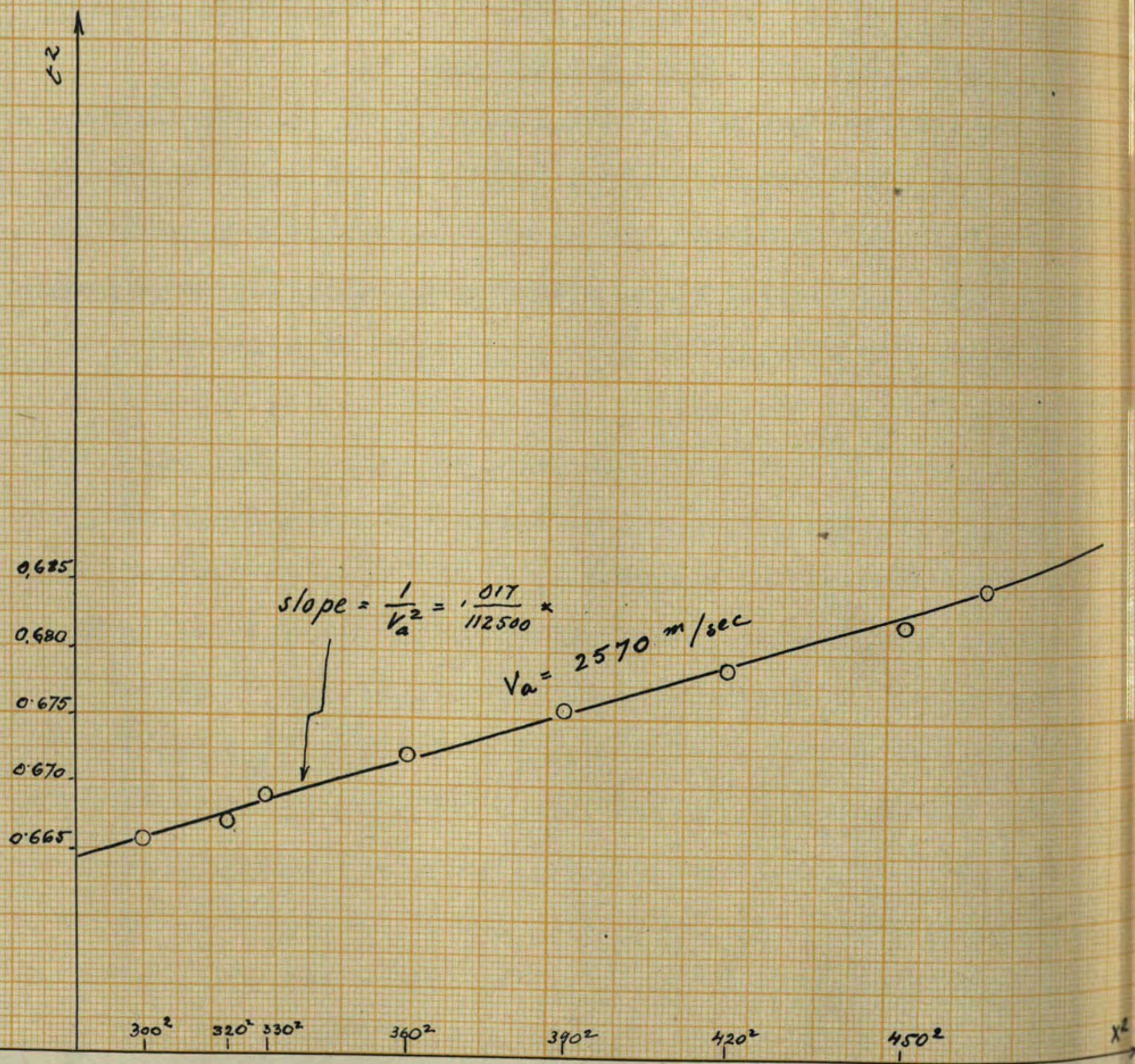
From the experience gained on that profile, the best spread proved to be that from 300-450 m with 6 geophones every 30 m. This standardised spread was later applied over the remaining area (see seismogram Fig.XI-1,b). The choice of this spread was based on various factors, of which the most important was that when shooting from a shallow hole, one had to deal with the air-wave, which at a distance of 300 m from the shot-point did not affect the reflection, its time of appearance on the record being (300 to 450): 330 = o,9 to 1,3 seconds, whereas the "marker" reflection usually occurred between o,8 and o,9 sec. Moreover, the ground roll at that distance usually ceased to affect the reflection (see the detail in chapter VIII). Vertical spreads were avoided on account of too shallow holes and secondary explosion phenomena.

The final results of the prospection.

The distinct and undisputed character of the "marker" reflection permitted the interpretation to be based on the so-called correlation method, in which the separate segments of the prospected horizon shown as"reflections"can be unequivocally and definitely indentified as belonging to the same bed or to the same part of the bed.

The deep reflections which occurred more or less distinctly below the "marker", were rather helpful in correlation across faults or in parts of attenuation of the main correlation. The less distinct was the latter, the more developed were the deeper reflections, this fact being very characteristic throughout the area. Moreover, their time-distance from each other was fairly constant. The first deeper reflection occurred 150-200m below the "marker", and the second about 400-500 m below. The latter seemed to be more distinct at the southern end of the profile and proved to be very useful in the location of the southern boundaries of the Tortonian belt.

Fig. XI - 5 , Average Velocity Determination from a reflection time-distance curve



Above the "marker" horizon , the shallow reflections occurred on the profile more or less clearly, but could not, however, be definitely explored and correlated from one shot-point to another and were not considered in the interpretation.

In 1935, two research wells "Premier I" in Wownia and "Polmin I" in Uhersko (see the map Plate 7) reached the bottom of the Tortonian soft series, at a depth of 1175 m and 1147 m respectively, revealing the existence of a hard rock composed of anhydrites and gypsum . In both wells this bed has a thickness of 12 m and 11 m respectively underlaid by softer sandstones , probably of the Upper Cretaceous age. On the basis of seismic measurements carried out in both these wells the average velocity of the area was obtained and the exact depth of the "marker" horizon was determined, the latter being thus identified as the top of the gypsum bed. This identification was also carried out by a direct connection of both the wells with the profile itself.

The average velocity of the overburden down to the gypsum bed was about 2560 m/sec, which may easily be checked in the seismograms Fig.XI-1,a,b, using the Dermott's method. The result is shown in the diagram Fig.XI-5. The agreement between the two values of the average velocity shown there with the value obtained by well shooting is a proof of the very monotonoeus character of the whole Tortonian overburden within the profile discussed. Assuming the velocity of the gypsum bed to be about 5000 m/sec we obtain the refraction factor n = 2, which was the basis for our considerations in Chapter VII.

The cross section along the profile prospected is given in Plate 8. It has been enlarged and redrawn by the writer from the original print, assuming the length of the individual segments of the reflecting horizons to be roughly 100 m, i.e. half the length of the sum of two spreads.

This cross section shows in as true a way as possible the picture of the behaviour of the stratigraphical beds of gypsum and anhydrite, from the point where they occur in their suboutcrops (Rozdol) to the point where they dip beneath the Stebnik beds (Stryj). In order to discriminate the distinctness of the impulses registered, a special classification of the reflections was introduced, namely:

Weight 1 (marked on the section by a single short-line) belongs to a reflection with indefinite initiation, i.e. it defines a trace of the reflection, the first phase of which it was not possible to determine. It consisted usually of one cycle of small amplitude.

Weight 2 (marked by a double thin line) belongs to a reflection with a semidefinite initiation and defines an impulse more distinct than before, but there was no certainty as far as the first phase was concerned, the latter being the basis for the depth calculation.

Weight 3 (marked by a thick short line) belongs to a reflection with definite initiation, i.e. it defines entirely a distinct and full valid impulse, the first phase of which could be determined without doubt.

As for the basis of the correlation of the "marker" reflection only impulses with weight 2 and 3 were considered. Those with weight 1 had their value only for comparison and orientation.

With reference to the character of the "marker" and that of the deeper reflections, the seismic profile considered can be divided into five following zones. This division was very useful in the interpretation of the remaining area:

The north border zone: The gypsum correlation occurs here near the surface. At the depth of 20 to 100 m, determined by the refraction method, a high-velocity over 5000 m/sec was located. Deeper reflections were also observed, and might be attributed to the deeper parts of the bedrock, detected along the profile. This zone forms the southern area of the Podolian Plateau which emerges at the surface further north. It is worth noting here, that three additional shot-points (1,2,3) were explored on the Podolian Plateau itself and a short prospection was carried out in the Park area of Lwow, in connection with an old shallow drilling sunk there. Some shallow reflections were observed here and an attempt was made to correlate them with those registered at points 1,2,and 3, and through them with those appearing below the gypsum correlation on the profile. However, the time spacing as well as their character was much too different, and further investigation was postponed.

2. The faulted zone. On the profile it is 2½ miles wide. At the southern end the gypsum correlation is fairly good but

not continuous. Near the middle, the horizon falls to its greatest depth of 1300 m, forming a tectonic ditch, which was later observed along the whole northern boundary of the foreland area. The gypsum bed seems to have smaller consolidation, on account of which the deeper reflections occur more distinctly. The northern part consists of stepping uplifts of the "marker" horizon, and the reflections, retaining their distinct character, are difficult for correlation, the latter being greatly helped by the deeper reflection groups.

Within the area of dislocation, the seismograms had the appearance of being "chopped" by some roll of high frequency and small amplitude, which very often influenced the peaks and troughs of the gypsum correlation and deeper reflections, even when the charges applied were very small. This "chopped" character of the records was typical of this area when prospecting had passed the deep ditch and was approaching the northern zone. Therefore it was taken as an indication for the observer to change his shooting tactics. It has been proved experimentally that charges had to be greater than in other parts of the profile that better initiation of reflections was obtained when shooting parallel to the strike, and that shorter spreads were more favourable than those standardised. The mentioned "roll" was perhaps the effect of that part of the seismic energy which was reflected from the broken parts of the bedrock as well as from the flanks of the faults, this energy being of smaller frequency than the normal reflections. It is also worth noting that after

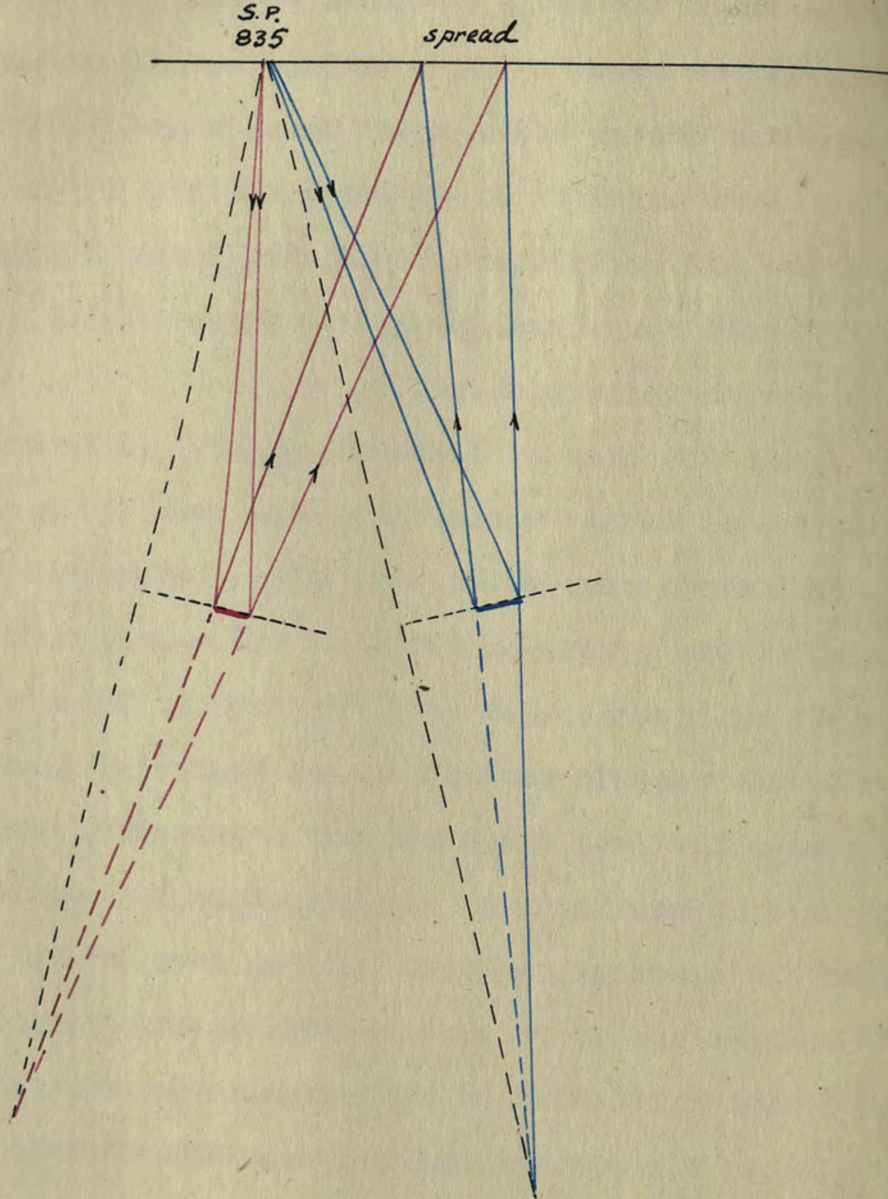


Fig. XI - 6

a traverse was shot along the strike, another traverse at right angles to the strike was carried out in order to prove that the observed reflections did not originate at the sides of the faults If so, they could not be obtained in any form when shooting across the strike.

3. The middle zone is here 7½ miles wide. It is characterised by very good gypsum correlations(such as shown in fg.X-1a), which were easily obtained on each direction and spread. This fact is a proof that the gypsum bedrock is very well consolidated is fairly horizontal and is of constant and greater thickness than in the remaining zones. Owing to the compactness of the gypsum bed, the deeper reflections were not very apparent, and showed mainly an indefinite initiation. A greater part of the seismic energy was reflected at the gypsum bed itself, with only a very small part penetrating deeper. All but very few of those deeper reflections have been given the smallest weight as may be seen from the section.

There are three interesting examples worth noting:

a) Shooting a traverse between the points 837 and 835 two "marker" reflections of different time-gradient were registered on the same record. The calculation showed that they belonged to the same horizon, but were reflected from the left and right sideof a small uplift under shot-point 11. Fig.XI-6 explains it graphically.

b) Interesting records were obtained when shooting from S.P.14 towards NNE. After the gypsum correlation registered

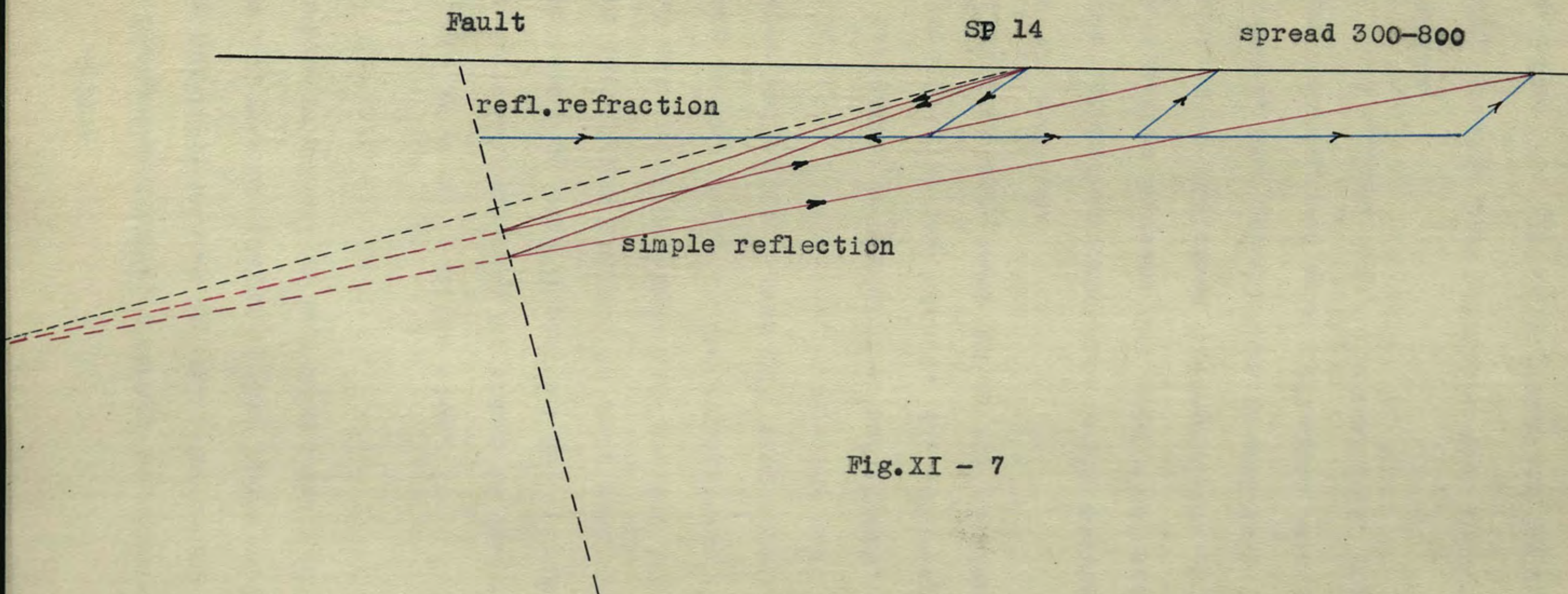

Fault
SP 14
spread 300-800
refl.refraction
simple reflection

Fig.XI - 7

here at 0,85 sec, a deeper and stronger impulse was observed at about 1 sec, the time-gradient of which was greater than that of the first arrivals and could be attributed neither to any direct wave nor to the air wave, its frequency being smaller than that of the reflections or air wave. It was observed at several spreads from 300 to 800 m and did not change either in character or in time-gradient. This might prove that it originated at a persistent discontinuity of a very steep if not vertical slope. The computation of this impulse showed that it was the effect of an almost vertical surface located under S.P.15 (see the section). Fig.X07 indicates that a very small segment of the reflecting surface corresponds with the explored geophone spread 300-800 m. R.Lindsay ("Reflected refraction", Geophysics Vol.VII,Nr.1.1942) describes a similar case considering it as a reflected refraction and as a simple reflection from a steep wall. Either of these cases could be assumed possible in our example. In the case of a simple reflection it proves that in the neighbourhood of S.P.15, there exists an almost vertical plane, part of which was accidentally located by the observation In the case of a reflected refraction it proves that even near the surface under S.P.15 there exists a strong vertical discontinuity within the shallow beds as the refraction wave impinging on it could not be reflected from a small segment of a fault the latter existing only in the deeper parts of the section. One has here to deal either with a strong vertical discontinuity within the shallow beds only, or with an uplift of the whole

section

section from the bedrock up to the surface, so as to create conditions for steep reflection. The latter is more probable, and the steep reflecting surface is perhaps the northern limit of the Wownia horst (see below). Too little was done at the time of prospection,-apart from computing the distance and the dip, on the assumption that the average velocity is to correspond with a shallow depth,-in order to arrive at more definite conclusions. The problem might easily have been solved by one or two detailed refraction traverses running across the supposed fault, which would locate the discontinuity in a horizontal direction (lateral) when passing from the area south of S.P.15 to the north of it.

c) In the southern part of this zone, 50 m below the gypsum correlation another weaker impulse was recorded which on the record was almost following the former and used to be called a double gypsum correlation. This is likely to be the interference effect of two waves, one reflected from the top and the other from the bottom of the gypsum bed. This fact may prove that the gypsum bed in this zone has a thickness greater than half the wavelength.

4. The Wownia zone, is here two mile wide. The character of the gypsum correlation is not good and the reflections were very difficult to obtain. They were discontinued and attenuated even on short segments, and this fact compelled the observer to place the geophones at very short distances from each other (often 10 m).

Exept for the northern part of this zone where the computed dip is towards the south, all the segments of the reflection horizon, as is evident from the section, dip towards the N. Better reflections were obtained on traverses shot along the strike, which proved the discontinuity at right angles to the strike, and led to the assumption of several faults, concluded also from the dip-shooting. In its highest part the gypsum bed seems to be lifted up 150 m as compared with the adjacent zones.

S.P.16 was the first to be shot on the whole profile. Because of little experience at the beginning of the work, this point was explored for 2 days, on traverses and spreads in all four main azimuths, from a shot-hole 90' deep. Without a knowledge of the character of the zone in which S.P.16 was situated, the results seemed to be very discouraging. The existence of this zone was revealed only after the whole profile on both sides of the zone was explored.

This zone was an object of detailed seismic prospection carried out in 1935 in connection with the two deep research wells mentioned earlier. The Wownia well was located on the strength of geological inferences in the prolongation of the line passing through Dąszawa gas area, Uhersko well and Opary gas area, (see Plate 7) and it was a matter of interest to locate the position of the faulted zone with regard to both wells. For the basis of this survey shot-points 18, 19 and 14 of the profile described were chosen. From P.S. 18 a correlation shooting profile was carried out towards the "Wownia" well and the gypsum bed encountered in this well was identified as the "marker" horizon. No changes in the character and depth of the gypsum correlation were observed along this line. This was not the case when turning from S.P.18 towards the "Uhersko" well. Here a discontinuity of the gypsum correlation was noted, though when shooting across the well a good character of the reflection was again observed. Across the "Wownia" well a perpendicular profile was then carried out, composed of several standardised traverses-spreads. It revealed the existence of the faulted zone near the well towards the NE. When entering this zone the character of the reflection was changed or the reflection was obliterated by scattered energy. Somewhere in the middle of this zone on the line mentioned, some new reflections were observed at a shorter time on the records. Once the zone was passed, good gypsum correlation appeared and connected by a shooting line with S.P.14. This perpendicular line when compared with that made along the main road (S.P.15, 16,17), permitted the approximate boundary of the faulted zone to be drawn. Several additional lines, parallel to and between the two previously mentioned, determined with a certain amount of accuracy the boundaries and the direction of the "Wownia horst", as marked on the map Plate 7. Its southern extention was not prospected. It may be of some interest to note that this horst had its highest point near Wownia village from which the top, gradually or by steps, fell towards the NW , as well as towards the SE. Seismic prospection has not attempted to prove whether or not this horst suffers complete obliteration in these two directions. The writer feels that if the seismic prospection had been done before the location of both wells, that location would have been more favourable in disclosing some interesting deep structure. But at that time the companies concerned with both wells had no confidence in seismical results.

5. The south border zone. It is about 2 miles wide on the profile with a good character in the gypsum correlation. To the south this character deteriorates and deeper reflections improve. The noticeable attentuation of the main correlation begins at S.P.931, which is also as was later proved the northern limit of the overthrusting Stebnik beds, where as may be seen from the section, the shallow reflections dip steeply towards the south. A detailed descrption of this zone is given in the next chapter.

Further south at the western corner of the town of Stryj (about 3 miles from S.P.20 towards the SW) rather good reflections were observed at an approximate depth of 2700 m. It was not possible, however, to correlate them with those on the profile since they occurred too deeply and were different in character, while their time space did not correspond with that noted in the north. Besides, many shallow reflections were observed, probably belonging to the horizons in the overthrust of the Stebnik beds. The connection could have been obtained only by a continuous dip-shooting profiling ,beginning from S.P.20.

Combining the seismical results along the profile Stryj Rozdol, with the data known from the Stebnik beds unit and with the cross section through the Boryslaw fold, a geological section across the Carpathian Foreland was obtained. It is shown in Plate 9. This cross section corresponds with the scale 1: 100,000 and is cut along the lines A - B and B - C traced on Plate 7.

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loc. cit. p.16 ref. 1, 2,
loc. cit. p.50 ref. 6.

13. S.M.Wyrobek (S.M.Wir), " Geophysical Exploration in Poland" Geophysics, Vol.IX. No.2. April 1944.

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14. S.M.Wyrobek , " Profil Seismiczny Stryj - Bilcze-Rozdol" Przemysl Naftowy XIII. 9, 1938. p.221-223.
15. K.Tolwinski , "Problemat rezerw gazu ziemnego w Polsce Pol.Tow.Geol. Tom XII. 1936 p.412 Resume in french: Le probleme de reserves de gas naturel en Pologne.

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16. S.S.West, loc.cit p.57.

CHAPTER XII.

THE REFLECTION SURVEY WITHIN THE CONTACT ZONE OF THE TORTONIAN AND THE STEBNIK BEDS.

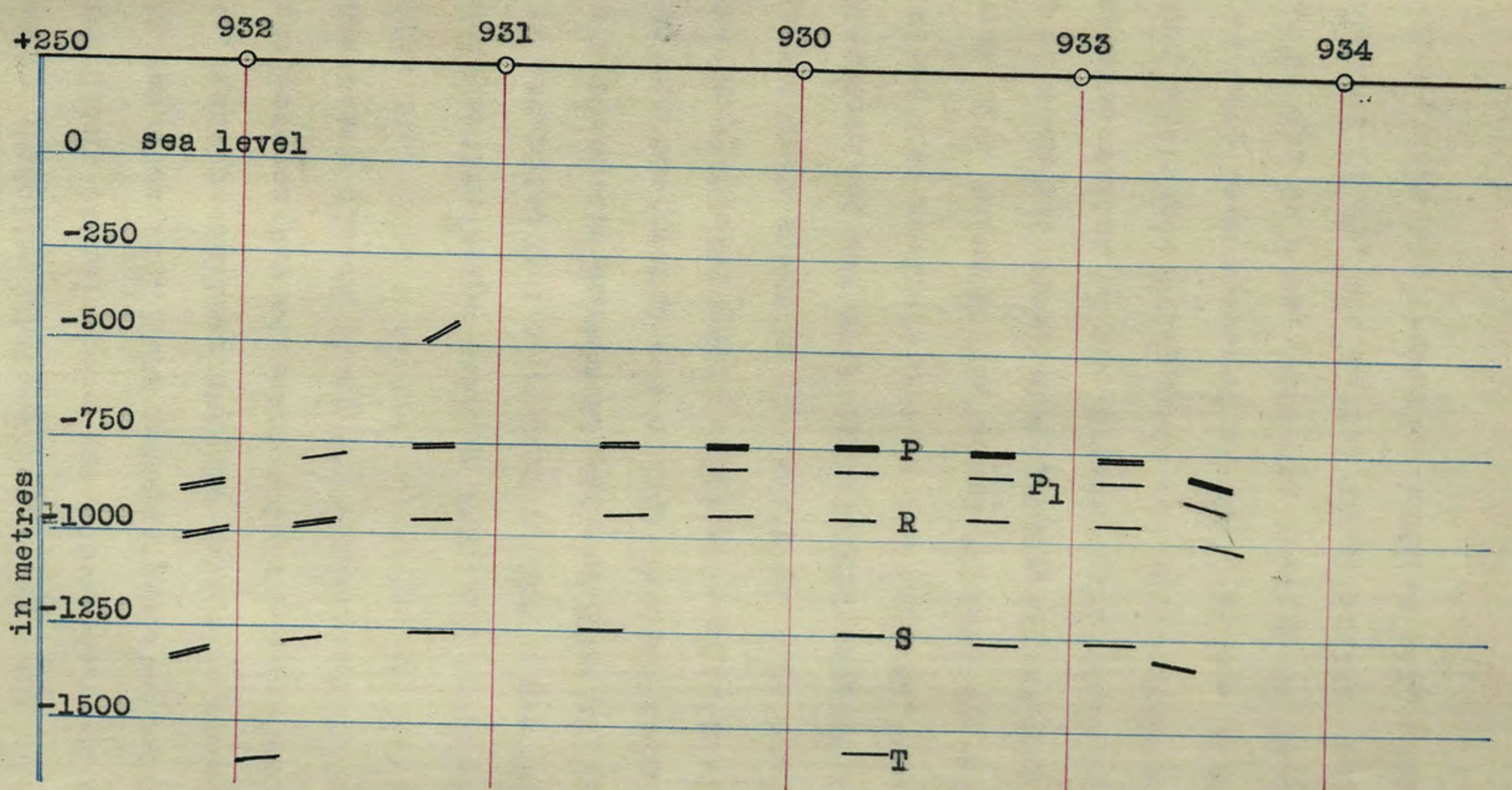
As a consequence of the refraction prospecting carried out in 1932 in the Daszawa gas -field and the Opary gas-field (the latter discovered in 1933) there has resulted a hypothesis that the accumulation of hydrocarbons is associated with the Tortonian sediments at the contact with the overthrusting Stebnik formation in the south. This hypothesis has been proved by borings in three firther instances, namely in Koningsau and Kalusz, and later on in the Kosow area.

Within the region of the "Wownia" and "South border" zones described in previous pages, Pionieer Co, carried out in the yearx 1935 a series of shallow research borings down about 150 m, which resulted in the definite location of the contact between these two foramtions on the Stryj - Lwow road, this contact lying in the vicinity of S.P. 931 (Plate 8). This research was followed immediately by seismic prospection in order to establish if there existed any definite relationship between the attenuation of the gypsum correlation and the overthrustibg cover of the Stebnik beds.

It seems necessary to mention here, that the field work on the profizle Stryj-Rozdol being finished, a reconnaissance and detailed work was carried out on both sides of this profile reaching the town of Rudki in the NW (30 miles to the NW) and Zorawno in the SE (12 miles to the SE), from the southern boundary of the Podolian Plateau (northern zone) down to the south to the point (line) where the attenuation of the gypsum correlation was observed. This survey consisted of a net of shot-points, mostly shallow, drilled with the geophone auger, the distance between two adjacent points being about 1 km, and most of them being placed along the communication roads in the area.

This prospecting being done, a detailed prospection followed, in order to establish the existence of the above mentioned relationship between the ~~[illegible]~~ attentuation of the gypsum correlation and the overthrust of the Stebnik beds. This prospection on the Stryj-Rozdol profile falls in with the third period (phase) of the work shown in the table on page 52. As has been said, a standardised set of 5 shot-points (SP.930-1-2-3-4) was explored along the southern end of the profile, the distance between each pair of S.P. being 750 m, which allowed for a spread of 300-450 m between two shot-points, (Fig.XII-1) Exploration included the observation of the gypsum correlation and the deeper reflections, allowance being made for those shallow reflections which might have been obtained at that spread. From the table on page 52 it can be seen, that the average depth of the shot-holes was about 32 ft, the latter being drilled and cased in gravels. There were ten traverses carried out, each on a spread

Fig. XII-2


+250
932
931
930
933
934
0 sea level
-250
-500
-750
-1000
-1250
-1500
in metres
P
P1
R
S
T

300 - 450, the number of shots per traverse being 4. The fact that the length of the traverses and the depth of the shot-holes remained constant along the explored set of 5 shot-points, led to the assumption that, for the same amount of explosive, and the same value of amplification, the gypsum correlation registered, would be influenced only by the presence of the Stebnik beds, provided that the weathering zone condition remained fairly constant.

The results of this survey can be summarised as follows: (see fig.XII-2, redrawn from Plate 8):

a/ On the section of the profile free from the Stebnik beds (S.P.930, 933, 934), the gypsum correlation (marked by "P") was very good (as shown in fig. XI-1c) and had a weight 3. About 40 m below the gypsum correlation a double correlation ("P_1") was observed, under which a group of three deeper reflections was noted. The first marked by "R" occurred 200 m below "P", the second "S" 500 m below, the third "T" 800 m below "P".

b/ On the section in which the overthrust exists (S.P.931 and 932), the gypsum correlation "P" deteriorated, having semi-definite initiation (weight 2) under S.P.931 and indefinite initiation (weight 1) under S.P. 932. The double correlation "P_1" was absent. The deeper reflections appeared to be better initiated and the whole group dipped slightly towards the south.

c/ Shallow reflections, not shown on the section, were almost horizontal on the part free from the overthrust (as may

Pioneer Co.

GEOLOGICAL MAP OF THE RUDKI-KOMARNO AREA

Scale

1000M 0 1 2 3 4 5 6 7 8 9 10KM

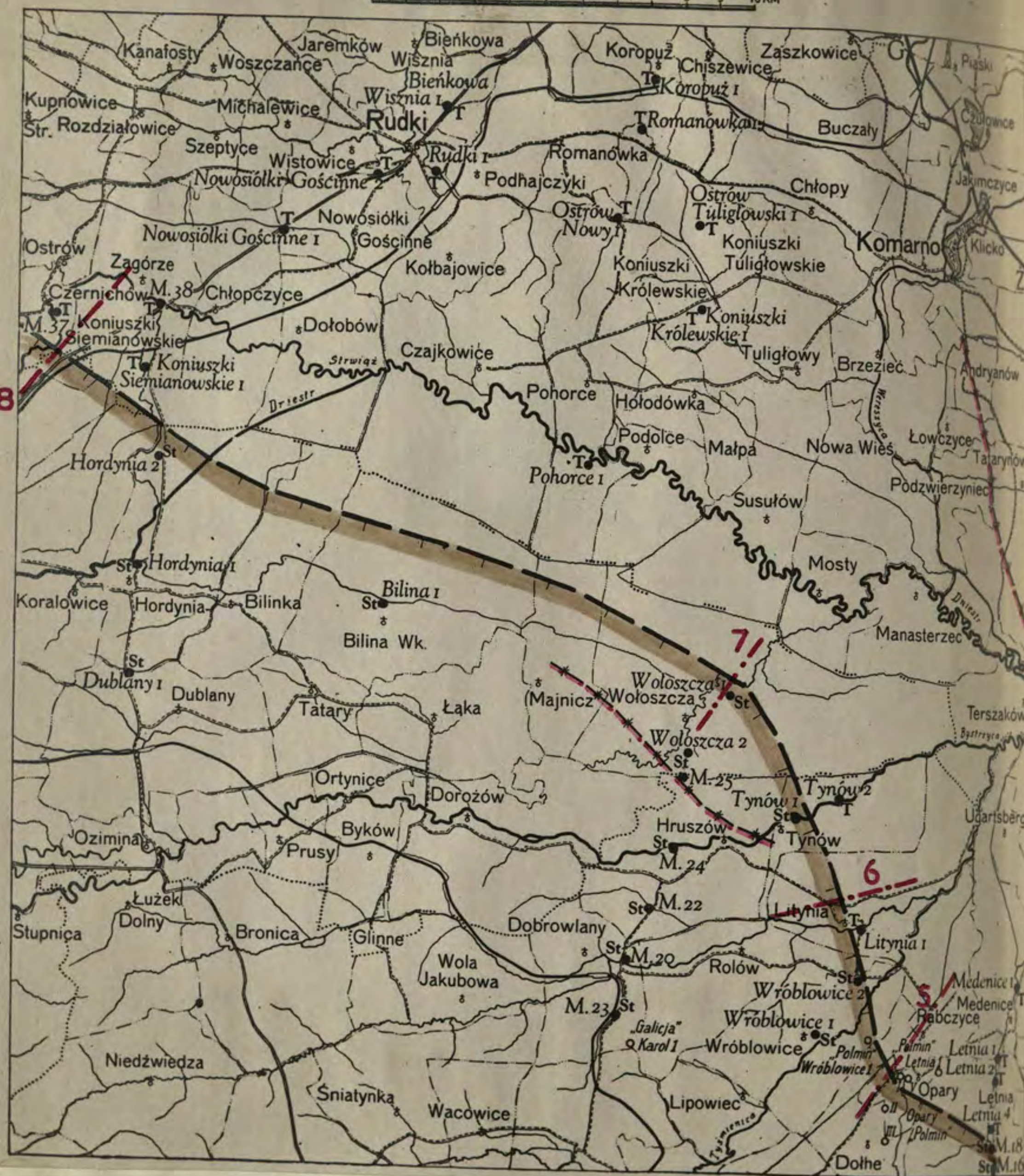


Fig. XII-3.

•T - Bore-hole in the Tortonian formation
•St - " " " " Stebnik "

Seismic dislocation Gródek-Zurawno

Synclinal axes of the marker gypsum correlation

Reflection profiles

The overthrust of the Stebnik Beds

be seen from the records fig.XI-1 b,c.)

d/ Beginning from S.P. 931 shallow reflections if observed dipped fairly steeply towards the south.

From the above the following conclusion may be drawn:

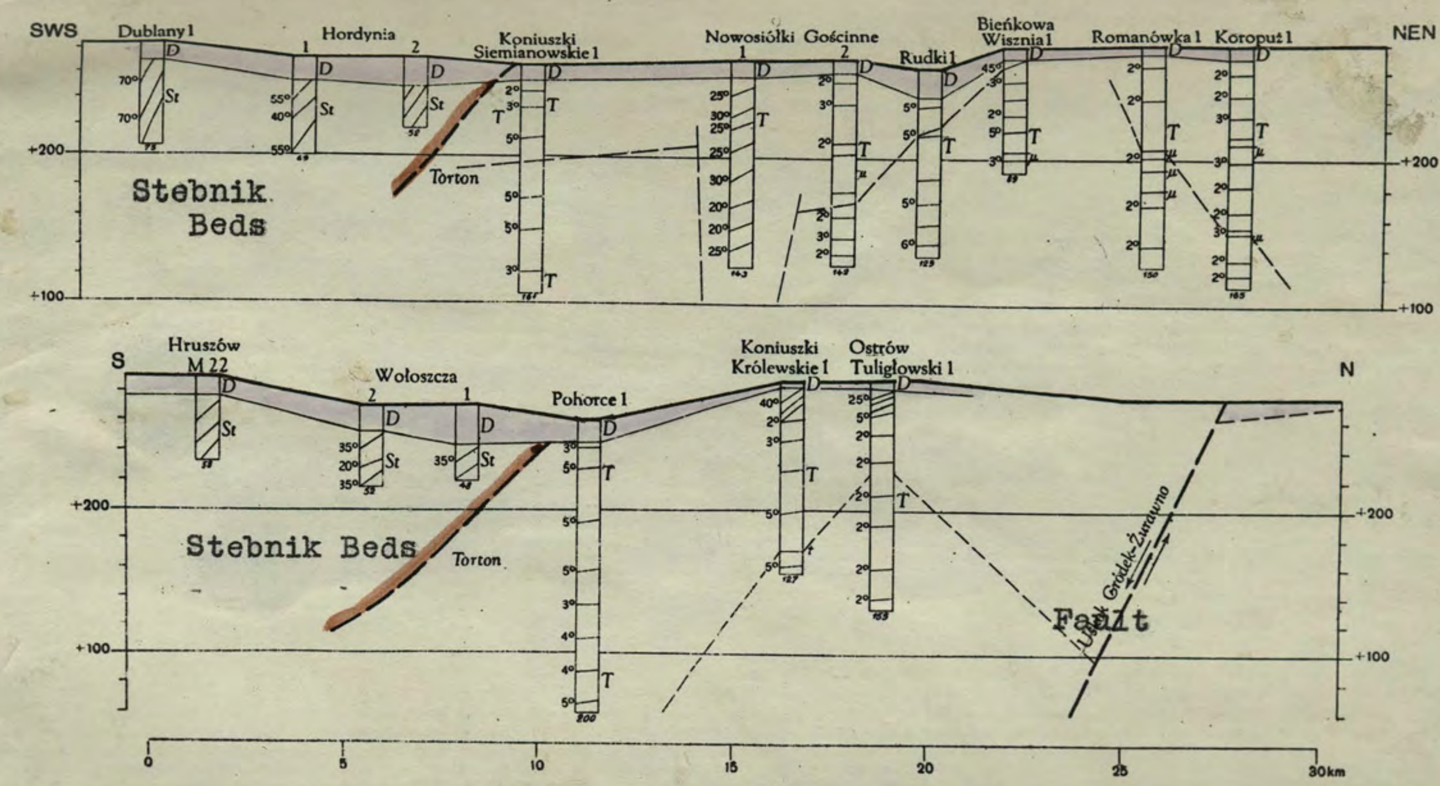
- The overthrust of the Stebnik beds had its effect in the deterioration of the gypsum correlation, so much so that it was imperative to observe the whole group of deep reflections in order to carry out the correlation in a definite way, and the shallow reflections played their part in the location of the presence of the Stebnik beds.

Backed by these results, the survey proceeded along towards the north, where identical sets of 5 shot-points (or more if necessary) were laid as shown on plate 7, and fig.XII-3, being marked from 1 to 8. Each of these short profiles had its beginning at the spot where good gypsum correlation was registered and proceeded towards the SW until the same results were reached as those described above.

This survey was carried out in winter (January 1936) on account of the necessity of crossing moors and the lower country of the River Dniester. Even so, it was impossible to carry out the survey over the area from Majnicz to Hordynia, which forms the region of submersion of the River Dniester.

In the summer of 1936, the seismical survey was verified by shallow research drillings, the results of which are shown in fig.XII-3. (O.V.Wyszynski "Materialy geologiczne z wiercen poszukiwawczych na przedg.okolic Rudek" Przem.Naft XIII.Zesz.18).

Fig. XII-4.



D - Dilluvium, T - Tortonian formation St - Stebnik Beds

The geology of this area is as follows:

Diluvium: the whole area is covered by a thick mantle of Diluvial clays, underlain on the north of the River Dniester by sands and on the south by gravels and sandstones about 25 m thick.

The Tortonian formation consists of monotonous shales and clays, analogous to those encountered in the Stryj region.

The Stebnik formation consists of strongly folded and pressed red marly shales laminated with thin beds of sandstones.

Fig.XII-3 shows the boundary between the beds of Stebnik formation and the Tortonian formation, drawn on the basis of the shallow drillings and seismic prospection.

Reflection profiles Nos. 5, 6, 7, and 8 shown in this figure were thus checked by geological results. Two correlation sections of the latter survey are shown in fig.XII-4. From them it is evident that the Tortonian beds are in comparison with the Stebnik beds, fairly horizontal and being of different petrography and lithology might have had different effects on the prospected deep horizons, in the way given on page 82.

From fig. XII-3 one detail is seen to be characteristic, namely the interception of the two lines which mark the boundary of the Stebnik overthrust marks the elevation of the Opary gas field, already discovered by a seismical refraction survey which located here in 1933 an uplift of a horizon of 3200 m/sec analogous to that in the Daszawa gas field.

The reflection field work on profile 7 was hampered by the surface condition of the weathering zone,which consisted of peat and muds and the only possible results were obtained by using deep long wooden posts sunk down through the peat cover to the clays. It was observed that it improved the seismograms to a considerable degree, when the posts were sunk down only to the top of clays, whereas where the peats were shallower and the wooden posts were driven into the clay, the results were no better. This is the cause of change in the acoustic resistance of the conducting media, described in chapter VIII.

Within the area of Woloszcza a detailed dip-shooting was carried out in the summer of 1936 (DSH 10, Plate 1 and 7). It revealed, as shown in fig.XII-3, a syncline of the bedrock the axle of which runs from Majnicz to Tynow in the SE-NW direction. That the dip-shooting was necessary confirms the previous remarks, that beyond the southern boundary of the Tortonian belt no correllation method can be used, not only on account of the steeply and unconformably dipping shallow beds, but also on account of changes in the character of the gypsum correlation and the deeper reflections. The presence of a syncline in the bedrock, about 2 km away to the south of the boundary, is a proof that there also the bedrock is affected by the overthrust of the Stebnik beds, and it is the only proof which we possess from that area.

Resuming the above it can be stated:

a) The gypsum correlation at the boundary of the Stebnik overthrust, deteriorates, and about 1 to 2 km further away to the south even shows structural changes.

b) The deeper reflections, fairly weak before the overthrust, at the boundary are more distinct and further away are conformable in structure with the gypsum correlation.

c) The shallow reflections, horizontal within the Tortonian belt, slightly change their dip towards the boundary, and within the contact zone show steep slopes towards the south, which is in agreement with the geology, revealed by shallow drillings.

It has not been proved, by any deep drilling within the contact zone, whether the gypsum bed retains its previous compactness. From the above considerations, it could follow that the obliteration of the gypsum correlation cannot be due directly to the overthrusting beds, since an overthrust acting as an opaque screen for the reflection energy, so that the gypsum correlation loses its previous distinct character, would also affect the deeper reflections, whereas as was shown by the seismic results, these deep reflections improve as the gypsum correlation deteriorates. Then one has to assume that within the contact zone, the gypsum bed itself is getting either thinner or is passing into another lithologically different and less compact bed. Assuming the latter, the underlying deeper beds, in this case sandstones, may yield better reflections since more energy is impinging on them. However, as has been evident from the log of the well "Premier I" in Wownia these sandstones are of too small a thickness to produce good reflections, whereas as was shown by the seismical survey the deeper reflections very often had the weight 3, when the gypsum had the weight 1. It leads to a further assumption that within the contact zone, the thin sandstones become thicker at the cost perhaps of shales imbedding them. Thus one may have to deal here with stratigraphical changes in the lateral direction within the same beds.

Before arriving at any further conclusions, two more examples are to be discussed in the two following chapters.

R e f e r e n c e s:

in Polish:

17. O.V.Wyszynski loc.cit. p.82 (Geological data from the shallow drillings in the Rudki foreland) Polish Oil Industry 1938.XIII.18.

in English

loc.cit. ref. 13. p.78.

C H A P T E R XIII.

REFLECTION PROSPECTION IN THE KOSOW AREA.

The Capathian foreland in the Kosow area was thoroughly prepared geologically and seismic prospection was presented with a problem selected after the geological data had been obtained and corresponding conclusions were drawn.

A regional geological survey carried out here in 1931 covered the eastern parts of the Tortonian unit from Kolomyja to Kuty /see the map Plate 1/ over a surface of about 1000 sq.km. Applying the elimination method, the more interesting part was revealed from that survey and was submitted to a detailed geological prospection in 1934 over a surface of 246 sq.km, followed by nine shallow core drillings, 5 of which resulted in rich gas eruptions. Simultaneously with these drillings a seismical survey was carried out in 1936 to investigate the deep bedrock of the Tortonian sediments. A deep research well "HUCUŁ" was sunk in 1937 in the part thought to be most suitable according to conlusions drawn from all these preparatory surveys.

Geological data.

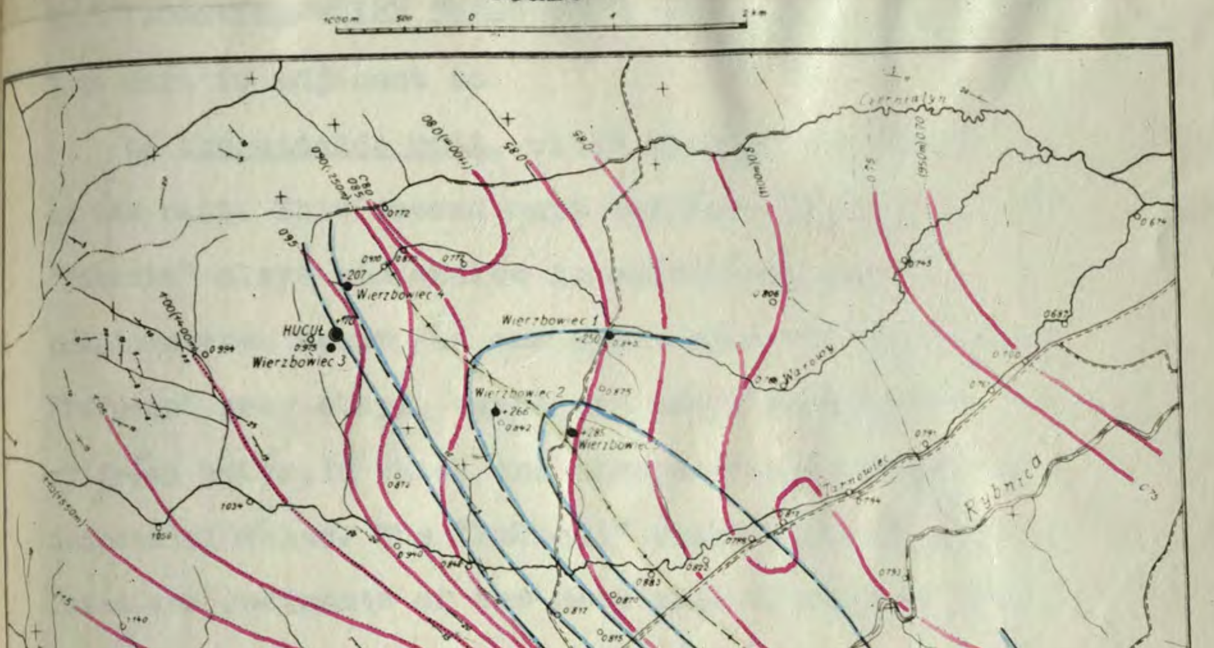
The preliminary survey permitted two structurally and stratigraphically distinct units to be outlined in the foreland of this region of the Carpathians. They are:

a/ the Słoboda unit adjacent to the Carpathians and partially forming the structural part of their border. It consists of

Fig. XIII-1.

GEOLOGICAL MAP OF THE KOSOW AREA

Scale



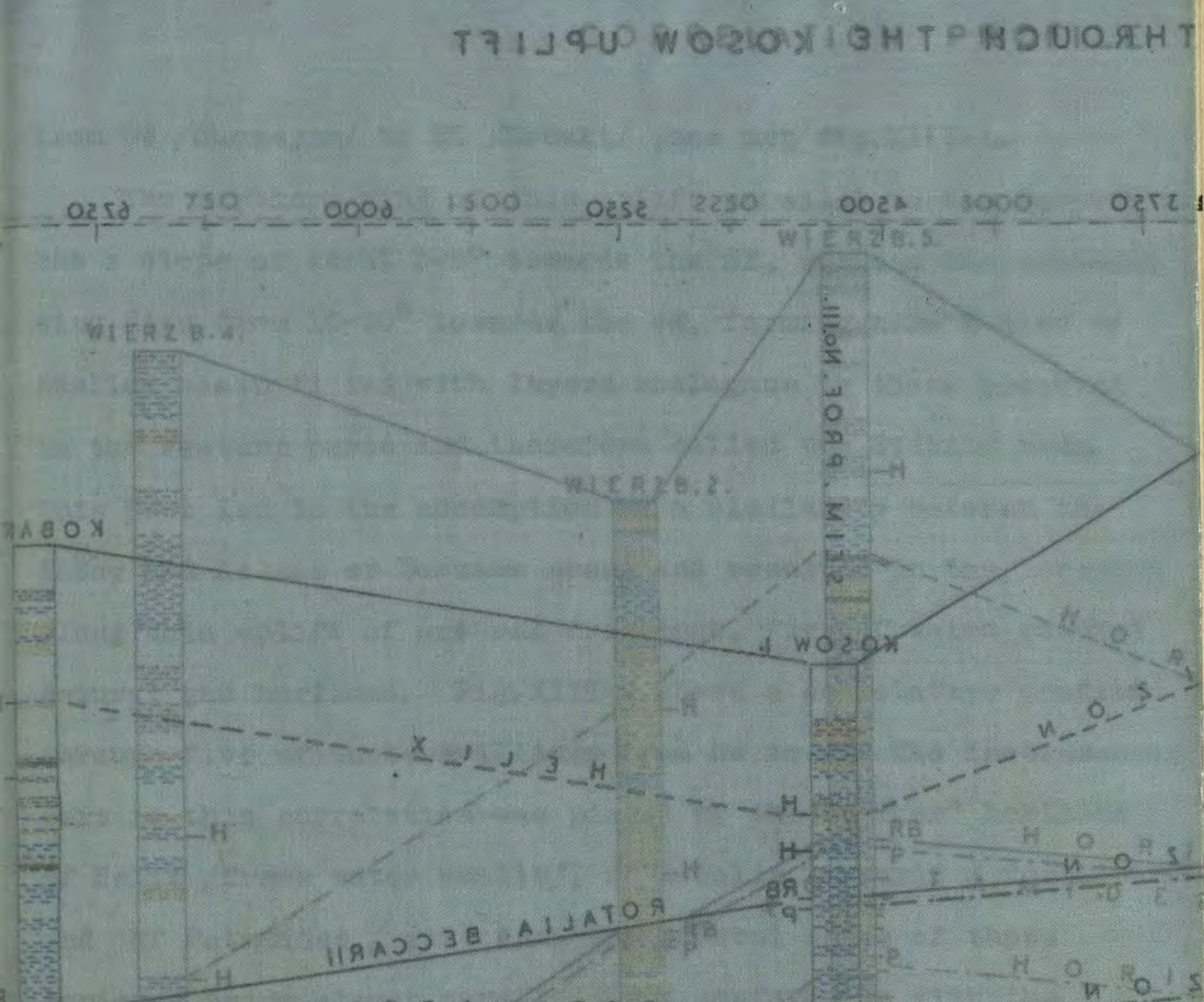
Tort. clays
" sand a. sandst.
Salt Formation
Red Shales
Dobrotow beds
Conglomerates
Menilite Sh.

• Shallow research bore-holes
• Deep research well 'HUCUŁ'
Countours of the horizon with Rotalia Beccarii
Time-countours of the reflection marker horizon.

conglomerates, Dobrotow beds and red shales overthrusting the Salt formation which forms vertical folds across the Kosow town. This unit is adjacent to

b/ the outside unit, which spreads to the Podolian Plateau on the east. This second unit consists chiefly of the so called "Pokucie" clays and shales in which more and more sand and comglomerates occur as one approached the Carpathians. The "Pokucie" grey clays, sands and conglomerates are the sediments of fresh water, in which one also encounters coal seams of industrial value. The "Pokucie" clays without sand and conglomerates are sediments of the deep sea. After many fossils had been discovered the age of this unit was ascribed to the Tortonian. /W.Friedberg " Polish Miocene", Annuals of the Geol. Society 1936/

In the Kosow area the foreland and the Podolian Plateau form a transversal uplift in the SW-NE direction. This uplift means that in the Carpathians the Skiba of Skole is moved back towards the SW, and the Carpathian border consists of rocks which in the Birkow or Boryslaw regions form the deep elements described before. In the Podolian Plateau, owing to this uplift, the Devonian rocks can be observed in the canyons of the River Dniester. The "Pokucie" clays are deposited horizontally between the Słoboda unit of the Lower Miocene age and the Podolia Plateau of the Cretaceous age. The detailed geological survey detected in the northern region of Kosow a longitudinal uplift within these Tortonian clays, the axis of this uplift running


THROUGH THE KOSOW UPLIFT
6250
6000
5250
4500
3750
WIERZ B.4
WIERZ B.5
WIERZ B.3
KOBARI
KOSOW 1
SEIM. PROF. No. III
HELIX
HORIZON
ROTALIA BECCARII
POTAMIDES
HORIZON
SEIM. PROF. No. IV.
SEIM. PROF. No. I.
SEIM. PROF. No. II.
H Helix (snail)
RB Rotalia Beccarii (foram)
P Potamides (mus)
no core
clay
shale
sandy clay
sandy shale
sand a. sandst.
coal
173
273
FIG. 2.

CORRELATION PROFILE THROUGH THE KOSOW UPLIFT

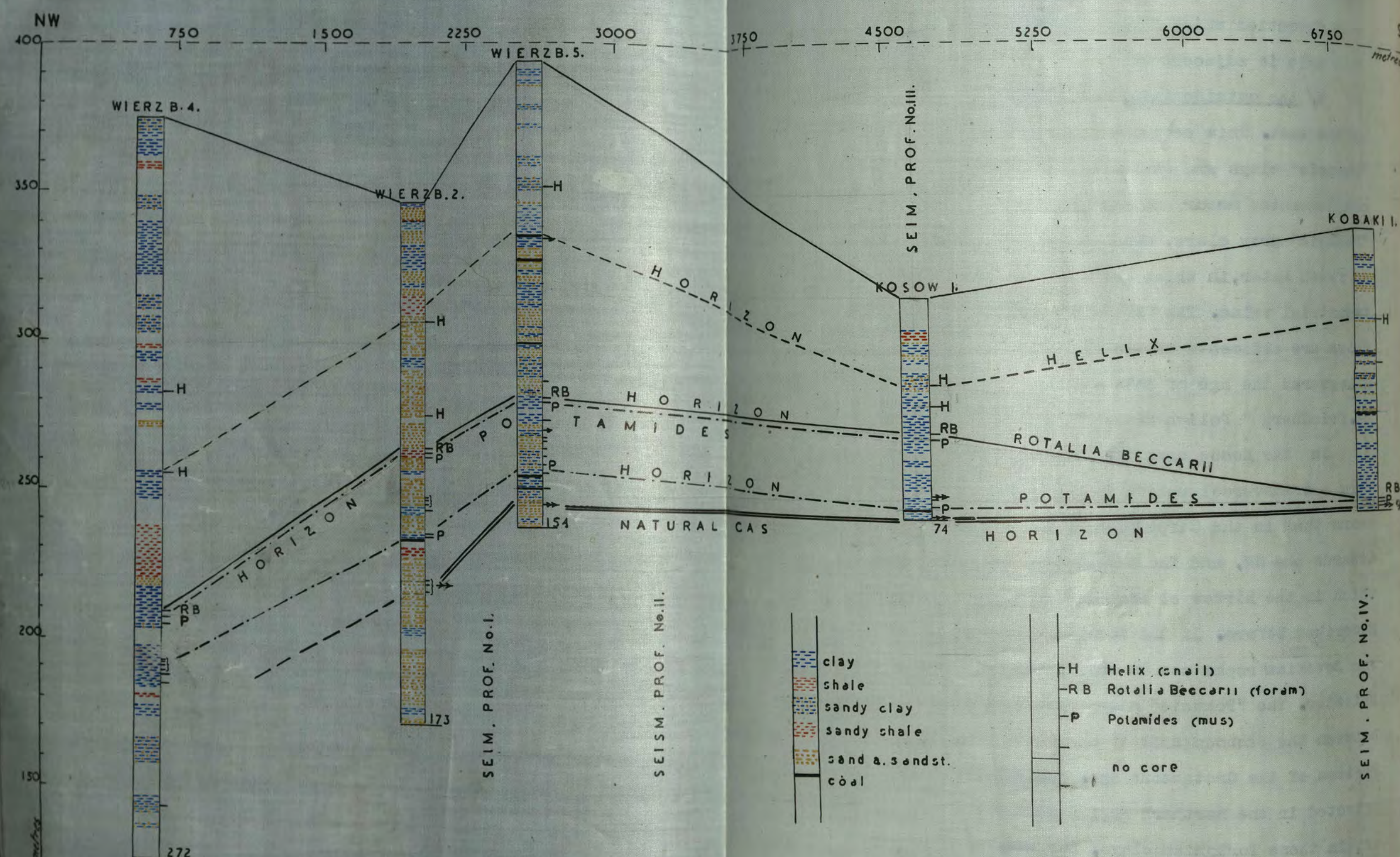


FIG. 2.

from NW /Chomcyzn/ to SE /Kobaki/ ,see map fig.XIII-1.

The norhhern wing of this uplift parallel to the Carpathians has a slope of about 3-5° towards the NE, whereas the southern wing dips from 10-30° towards the SW, forming here a kind of shallow basin filled with layers analogous to those observed in the western parts and therefore called the Stebnik beds. This fact led to the assumption of a similarity between the Kosow and Kałusz or Daszawa areas and resulted in the location along this uplift of several drillings, five of which reached natural gas horizons. Fig.XIII-2 shows a correlative profile through five of these drillings from NW to SE. The instrumental part in this correlation was played by the "marker" horizons of Helix /fresh water snails/, of Rotalia Beccarii / foraminif/ and of Potamides / gastropod/ the general shape of these horizons being almost parallel and conformable with the horizon of natural gas occurring at a depth of from 50 to 150 m.

Thus three interesting factors were present:

i/ A transversal uplift in a SW-NE direction,

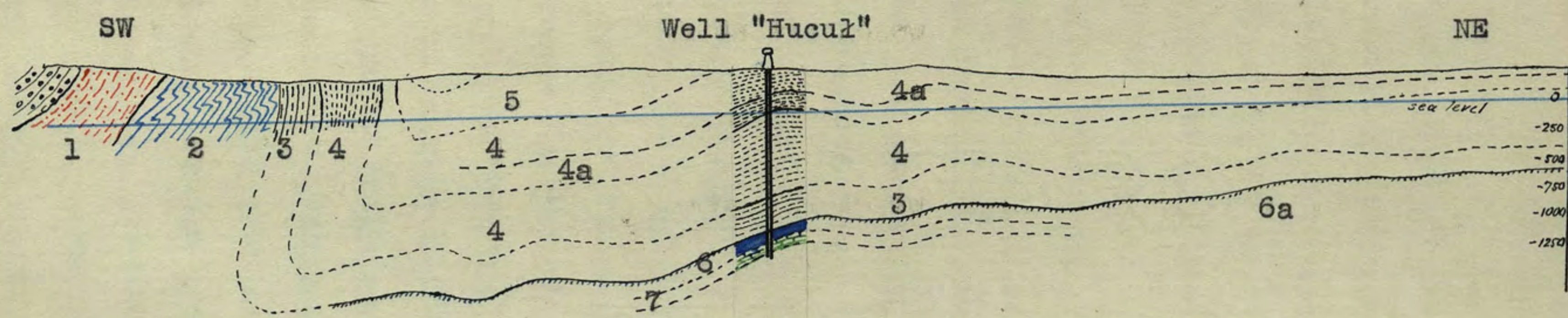
ii/ A longitudinal uplift in a NW-SE direction proved by drillings,

iii/ The existence of natural gas deposits within the zone of contact of the Tortonian unit with the Stebnik beds.

These three factors necessitated the investigation of the deep structure by a deep bore-hole, particularly within this area, since the subtortonian sediments might have been

Fig. XIII-3.

GEOLOGICAL AND SEISMICAL CROSS SECTION
THROUGH THE KOSOW AREA



1 - Red Shales
2 - Salt Formation
3 - Sand Series } Tortonian
4 - Clay Series
5 - Stebnik Beds
6 - Salt and gypsum of the Bedrock
7 - Limestone Cretaceous

4a "Marker" horizon with Rotalia Beccarii
6a "Marker" reflection horizon

0 1 2 km

reached at their shallowest part within the important zone of the contact of the overthrust of the Stebnik beds with the Tortonian sediments.

Before this could be achieved, however, a seismic survey was carried out with the direct object of investigating, if and to what extent, the shallow subsurface uplift is a "reflection" of the deep bedrock. This prospection proved the conformity of this assumption and showed that the bedrock, consisting of a very elastic and hard material, was slightly folded at a depth of from 1100 m in the Rożniów area to 1900 m in the Kosow area, the sharpest fold occurring underneath the shallow uplift mentioned. / See fig.XIII-1 and the section fig.XIII-3/.

On the southern wing of the deep plunging structure the "Hucuł" well was sunk in January 1937, reaching in June 1937 the depth of 1237 m and in August 1938 its final depth of 1558 m. The stratigraphical section, through this well is shown in fig. XIII-4. It can be seen that from the surface down to 1060 m one has to deal with a series of clays and shales with two horizons of coarse sandstone, one at about 350 m and the second at 600 and 700 m, the thicknesses of which do not exceed 10 m; from 1060 to 1360 m one notes a series of clays and shales with a higher amount of sands and fine grained sandstone. Down to 1360 m the sediments proved to be of the Lower Tortonian age.

The bedrock, interesting from the seismical point of view, consist of:

1360 - 1375 m /50 ft/ ,anhydrite white and grey,compact,

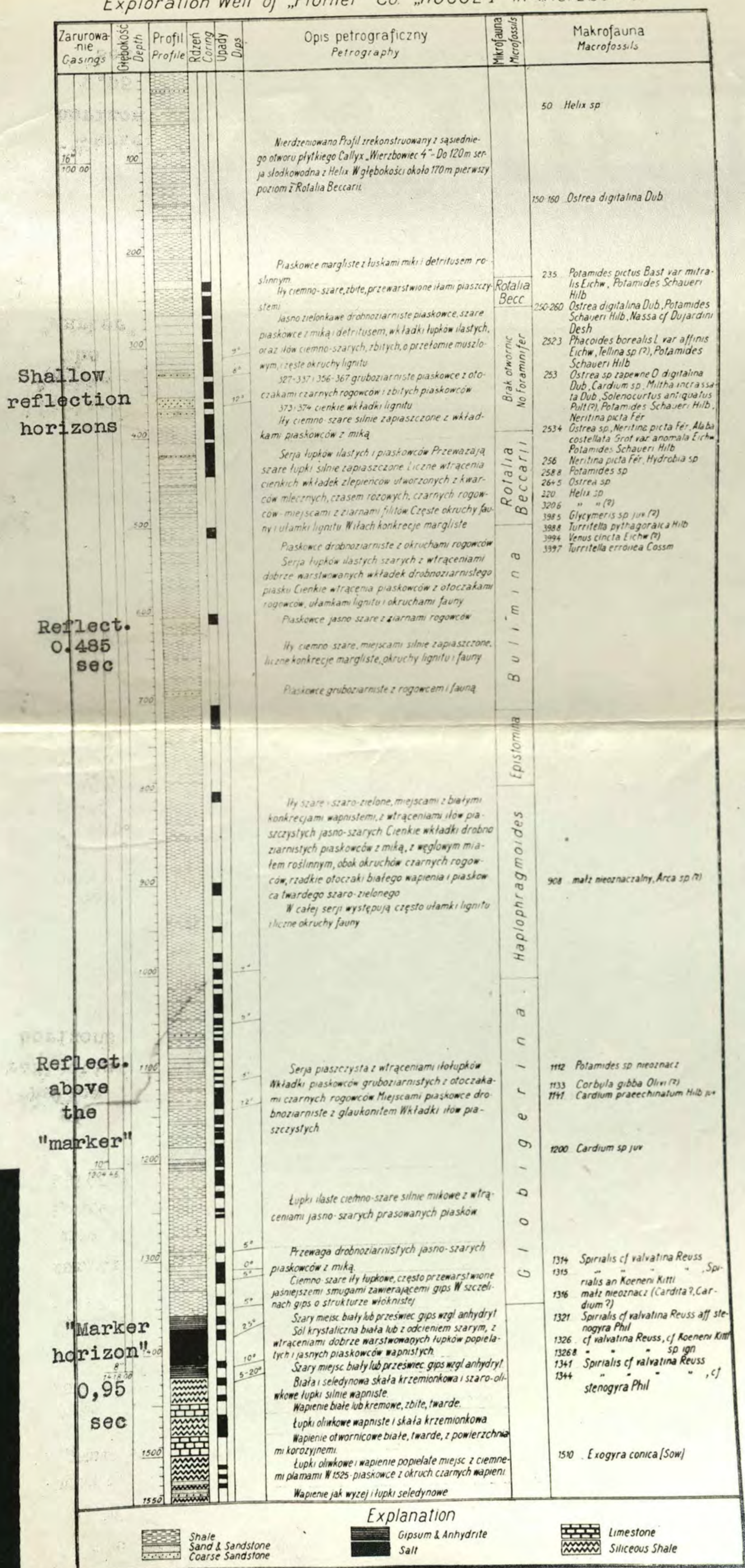
1375 - 1410 m /116 "/ , crystallic salt, slightly intercalated with shales and limy sandstones,

1410 - 1425 m /50 "/ , gypsum and anhydrite, compact.

Fig. XIII-4.

Otwór poszukiwawczy S.A. „Pionier" „HUCUŁ I" w Wierzbowcu

Exploration Well of „Pionier" Co. „HUCUŁ I" in Wierzbowiec



1360 - 1375 m /50 ft/ ,anhydrite white and grey,compact,

1375 - 1410 m /116 "/ , crystallic salt, slightly intercalated with shales and limy sandstones,

1410 - 1425 m /50 "/ , gypsum and anhydrite, compact.

65 m /216 ft/ , total thickness of the anhydrite-salt series.

The complex of rocks underlying the above consists of:

1425 - 1450 m siliceous shale

1450 - 1460 m compact white limestone

1460 - 1480 m siliceous shale

1480 - 1500 m compact white limestone

1500 - 1535 m siliceous shale, limestone, sandstone,

1535 - 1550 m compact white limestone,underlain by silic.shale.

The comparison and correlation between this stratigraphical section and the seismical results are both given at the end of this chapter.

Seismical research over the area.

This research was carried out with the use of the six-geophone set of Seiscor over a surface of about 50 sq.km. The number of shot-points amounted to 65. They are plotted on the map fig.XIII-6, the numeration of these corresponding to the alternation of the seismical work in the field. Shot-points ran along four profiles of general direction from SW to NE. The latter are marked on the map by the Nos I to IV and formed the basis for the interpretation of the seismograms obtained.

The number of work-days in the field amounted to 46, githe average output 1,35 shot-point per day, which in comparison with the other areas is rather small. There were, however, many difficulties in technique and method which hampered the efficiency of the field party.

The technical difficulties were caused by the unfavourable irregularity of the ground, which rendered the chóice of suitable traverse / length and elevation/ rather tiresome if not impossible. The difficulties in method arose when finding an optimum spread and azimuth, an optimum in the size of the char-ges and in the displacements of the seismographs. With regard to both these difficulties, better conditions were encountered along profile II, which ran along the communication road almost horizontally. The surface beds here consisted of clays from 2 to 5 m thick, underlaid by gravels from 5 to 10 m thick, with the Tortonian clays underneath. On the northern part of the profile the charges were placed in shallow holes at the top of the gravels, otherwise the shot-holes would have had to be drilled down to the Tortonian clays. Profile III ran along the River Rybnica and had gravels from the surface down to 10 or 15 metres. The irregularity of the surface of the gravels, owing to the numerous bends of the river which flows in shallow canyons, were not favourable for the prospecting. Shot-points of profiles I and IV were situated on the slopes or in the valleys of the hills which form the banks of the Rybnica-River valley. Shot-holes here had a depth of from 5 to 15 m in the Tortonian clays and shales and their being mainly dry resulted in bigger charges and longer traverses on account of the lack of energy and big ground roll. These varieties in the topography and surface conditions are well evident from fig.XIII-2.

In general the depth of the shot-points varied from 4 to 22 m, that most often used having a depth of from 8 to 12 m. The number of metres drilled amounted to 675, by hand augers or auxiliary drills.

The size of the charge varied from 0,10 to 5 kg . The necessity of the choice of an o-ptimum in the spread, in the length of the traverse and in its direction compelled the o bserver to use a series of repeated charges in the same shot-hole, which very often resulted in the drilling of a new hole.

The total expenditure of dynamite was 545 kg. The number of seismograms received was 1229, the number of traverses 147, and the amount of seismograms per one shot-hole 19. The last figure gives evidence of the difficulties encountered in the area. /The above figures are taken from the writer's report in Polish Oil Industry,Przemysł Naftowy 1938,Vol.6/.

The Kosow area was a new one from the seismical point of view. The nearest point of the foreland prospected up to that time was situated in the area of Stryj-Zurawno and thus about 90 miles away. The transversal uplift of about 3000 ft in the Carpathians might suggest ~~a different~~ a different depth of the ~~bedrock, a different character , and different average velocity~~

bedrock, a different character and a different average velocity of the area in comparison with the Stryj area. Therefore , at the beginning of the field work in the Kosow area, it was absolutely necessary to carry out a series of methodical tests in order to determine what kind of impulses could be registered in the prospected region, if there was any marker horizon suitable for the correlation method /which is more accurate and economical than the dip-shooting method/, and finally what were the characteristic velocities of propagation of seismic waves in the individual sediments and thus the average velocity down to the eventual reflecting beds.

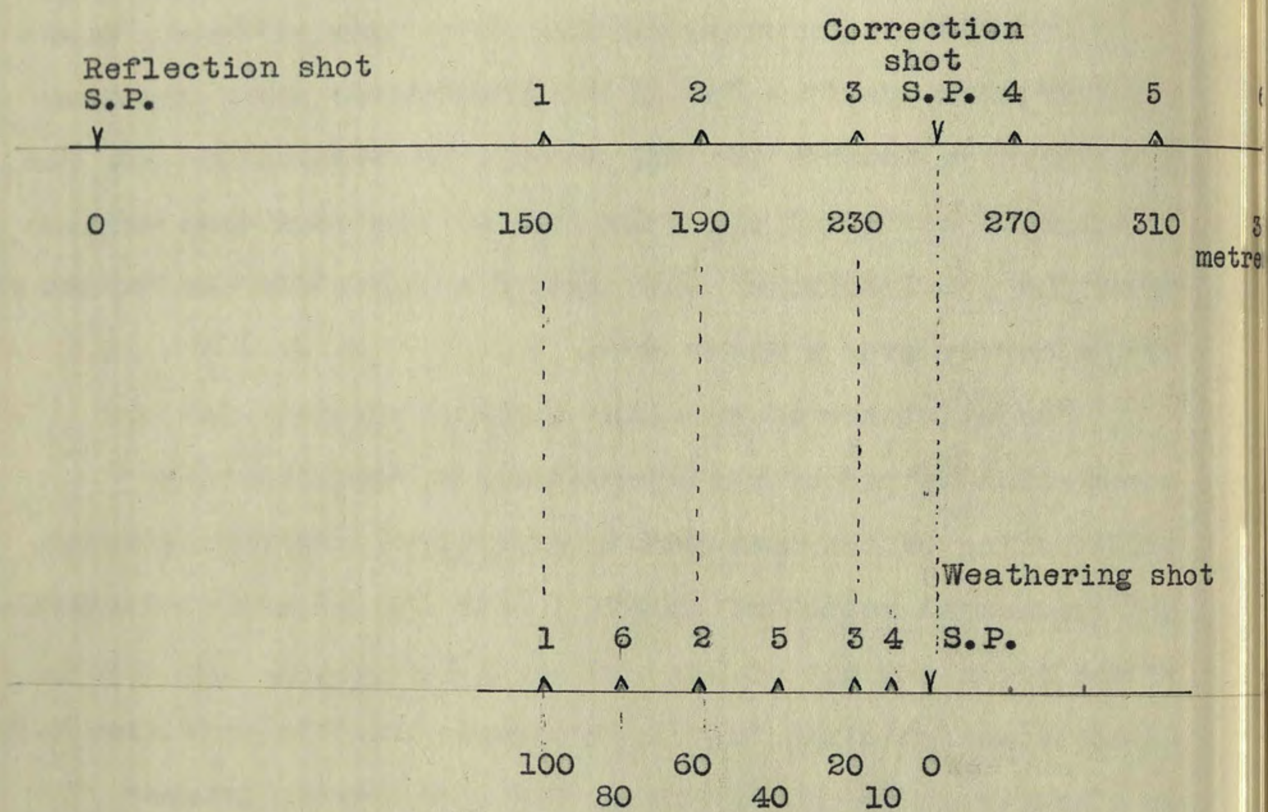
Since the region of parallel uplift seemed to be the most interesting for the geologists, these tests were carried out in shot-points 4 and 5 /see the map fig.XIII-6/. They did not result in the definition of any marker horizon , but did give some indication of shallow reflections which might serve for the dip determination and thus might favour the use of the dip-shooting method. The same happened with shot-point 3. Only when the prospection was carried out at the shot-points 2 and 1 i.e. nearer the Carpathians, it resulted in the determination of a definite group of deep reflections which could be used for correlation purposes. The character of this group was reminiscent of that registered in the Stryj area, though it was not so outstanding as a single reflection but consisted of several phases of which the third had always the highest amplitude. It could not be considered as a single reflection and therefore was called a correlation group or "marker" group and proved to belong to a rigid and hard series of rocks which under a considerable depth /about 1900 m/ underlay the less solid and compact overburden.

In order to investigate this deep "marker" group over a larger area, profile No.II was protracted along the road Kosow-Rozniow towards the NE, as well as towards the SW. The seismograms confirmed the existence of the same deep horizon along the profile, which thus formed a basis for the expansion of the survey over a wider area.

The existence of a marker horizon suitable for the correlation method of interpretation, necessitated the establishing of the most probable vertical average velocity and the actual method of shooting for the accurate calculation of the depth and dip of the reflecting horizons. The average velocity was obtained from a continuous profile shot from S.P.4 on a length of from 0 to 700 m, the reciprocal distance between the individual geophones being 40 m. A shallow refraction shooting for each spread of six geophones was thoroughly carried out yielding the data for the weathering zone corrections. Applying the least square methods the best approximation obtained for this profile was:

- the depth of the reflecting horizon Z = 1150 m

Fig.XIII-5


Correction shot
Reflection shot S.P.
1 2 3 S.P. 4 5
0 150 190 230 270 310
metre
Weathering shot
1 6 2 5 3 4 S.P.
100 60 20 0
80 40 10

- the vertical average velocity down to this horizon V_a = 2850 m/sec, with the mean error ± 5%.

In order to deal with the second necessity, i.e. the facilities in reaching a sufficient accuracy in the calculations the following precautions in the field work seemed of primary importance: /fig.XIII-5/:

a/ the length of the spread should be 150 - 350 m for six geophones, with a reciprocal distance between them of 40 m. This spread was chosen on account of the ground roll, the amount of useful seismic energy, and the sound wave. The distance of 40 m. between the individual geophones permitted the time-gradient necessary for the dip calculation to be established with sufficient accuracy.

b/ To determine the actual relative time difference between the extreme geophones or so called "step-out" time, correction shots were introduced, fired at the middle of each spread.

c/ To determine the oscillation of the weathering zone and to compute its thickness, a short refraction shot was used as shown in fig.

d/ On account of relatively great changes in the topography the knowledge of the elevation of the individual geophones with respect to the shot-point, and the elevation of the latter with respect to the datum line were important. It was stated that the difference in the elevations of the extreme geophones being 2 ft caused a difference in step-out time exceeding 0,001 secs.

From the long continuous profile carried out for the average velocity determination /P.S.4/ as well as from the first arrivals registered on allothers seismograms from the whole area, it was possible to establish to a certain depth the characteristic vellocities of propagation of the seismic waves withinmthe shallow formations encountered. Excluding the places situated on the hills, where sand and clay sediments prevailed, characterised by small velocities, the following data could be averaged within the area of Kosow:

- The weathering zone was of a thickness varying from 1.5 m to 8 m., with a velocity of from 320 m/sec to 600 m/sec. The thickness of this zone at each spread was computed from the short refraction shots; the charge /from a cap to 1/10 of kg/ used to be placed on the surface of the ground and tamped by a heavy iron block /of 50 kg/.

- The underlying beds of sands, clays and gravels down to the surface of the Tortonian clays and shales were characterised by a velocity of from 1350 m/sec to 1900/sec.

- The series of the Tortonian clays and shales had a velocity of from 2000m/sec to 2800m/sec, the lower values being confined to pure clays, whereas the highers values were attributed to the more sandy clays.

It should be mentioned that the computed depth at which the changes of these velocities occur do not coincide with the surface of the contact of the layers mentioned. This fact was very often observed particularly when computing the weathering zone depth and showed that the magnitude of this was affected not only by the lithological character of the rocks but by their compactness, relative content of moisture, the structure etc /as has been discussed in chapter X/. From this reason therefore the seismical layer computed from the velocities obtained does not coincide with the weathering layer geologically.

<u>The determination of the velocity curve.</u>

Using the least square method one point (A) of this curve was determined, from the continuous profiling carried out at S.P.14. It was then received Z = 1150 m, V_a - 2850 m/sec. Plotting depth against velocity /diagram fig.XIII-8/ and tracing through it a curve parallel to that computed from the well shooting in the "Premier" at Wownia, the depth velocity curve for the Kosow area was obtained. This procedure was justified, on account of the following reasons:

- The computed value of the average velocity for 1150 m was hardly 10% higher than that from the Wownia area, where V_a = 2590 m/sec for the same depth. As the deviation of this velocity is rather small it was assumed that its increase with depth might be of the same order as in the Wownia area. This assumption was proved lately by comparison of the logs from the "Premier" and "Hucuł" wells. The lithological composition was almost the same and followed the same scheme, the only difference being that in the "Hucuł" well the layers had more sandy clays than those in the "Premier" well. This should result~~s~~ in a higher velocity, which was the case.

- An additional point for a shallow reflection was calculated by the least square method and the data obtained were as follows: $Z = 483$ m, $V_a = 2750$ m/sec. From the extrapolation of the new curve traced by the point $Z = 1150$ m, $V_a = 2850$ m/se the value of velocity obtained for the depth of 483 m was 2690 m/sec, (B) and thus only 2,2% less, which proved that assuming this kind of slope for the velocity curve would not cause any considerable deviation in the calculations.

One year later, when the "Hucuł" well reached the bedrock at a depth of 1360 m, an additional survey was carried out in the vicinity to check the average velocity. Two traverses from two shot-points /59 and 59a/ were carried out. One of these traverses gave satisfactory positive results. On account of the topographical situation of the well itself, this traverse ran away from the well 200 m towards the south. This traverse allowed a new point of the velocity curve to be computed. The data obtained were $Z = 1430$ m, $V_a = 2870$ m/sec. (C) It has to be noted here that the depth of the reflecting horizon in the well was 1360 m. From the well log the slope towards the W being about 20°, gave the depth under the traverse 200 m away at 1430 m. The time of the reflection was 0,981 sec, after the necessary corrections were allowed for.

From the formula $V_a = 2Z/T \cdot \sqrt{1 + [X/2Z]^2}$, where X the mean distance /length/ of the spread, the average velocity V_a was computed. Plotting it on the same diagram /fig.XIII-8/ it will not fall on the same line traced before. If one traces a new curve through this point parallel to the former, the depth computed by its aid will be 2% lower than the former depth based on the first curve. Considering, however, that the former average velocity determination was based on the point 14, in which the marker horizon occurred at 0,817 sec, while this time it is based on S.P.59a, where this horizon appears at 0,981 sec, it will be evident that here the reflection horizon being 0,164 se deeper, the average velocity must be higher, as is the case.

As there was no other data available to determine this velocity more strictly, it was necessary to assume a curve which runs to the point A , according to the previous computations, and from this point slightly bends and passes through the point C, obtained from the S.P.59 a. Prolongation of the curve under the new slope, slightly different from the former, seems to be justified as the reflection horizon plunges in the direction of the Carpathians and thus the velocity curve in this direction should more and more deviate from the theoretical value.

Considering the accuracy of the average depth determination for the Kosow area and the extrapolation of the velocity curve, it was estimated that the maximum absolute error in the depth calculation for the reflections with a definite initiation

/weight 3/ should not exceed ± 10%. More outstanding errors could have been expected where one had to deal with reflections of semi- or indefinite initiation /weight 2 and 1/, and further where considerable changes in the weathering zone were present and where the reflecting horizon was occurring at a rapidly changing depth.

The "marker" reflection group along the profile II, occurred at the time 0,6 sec. at Rozniow, 0,9 sec. at "Hucuł" and at 1.3 sec. at Kosow town. The distance between the first and third places was about 5 miles. The variation in depth of this horizon was thus fairly considerable, and the assumption of one velocity curve might result in errors higher than 10%. An additional continuous profile should have been carried out for the determination of the average velocity in the Rozniow area, i.e. at the shallowest point, and a third one in the Kosow-town area, near the Carpathians, where the reflection horizon is at its deepest spot. These three values might result in a curve which should show the changes of the average velocities with the changing depth of the reflection-horizon. On the other hand, the profiles I and IV carried out across a very irregular countryside with hills and valleys even on the same shooting traverses showed that the velocities determined in this way could not have been applied with sufficient accuracy to the whole area. On the strength of this consideration it seemed more reasonable to the writer to base his interpretation on the times of the reflections, the interpreœtation based on the depth determination being left for the exclusive interest of the Company.

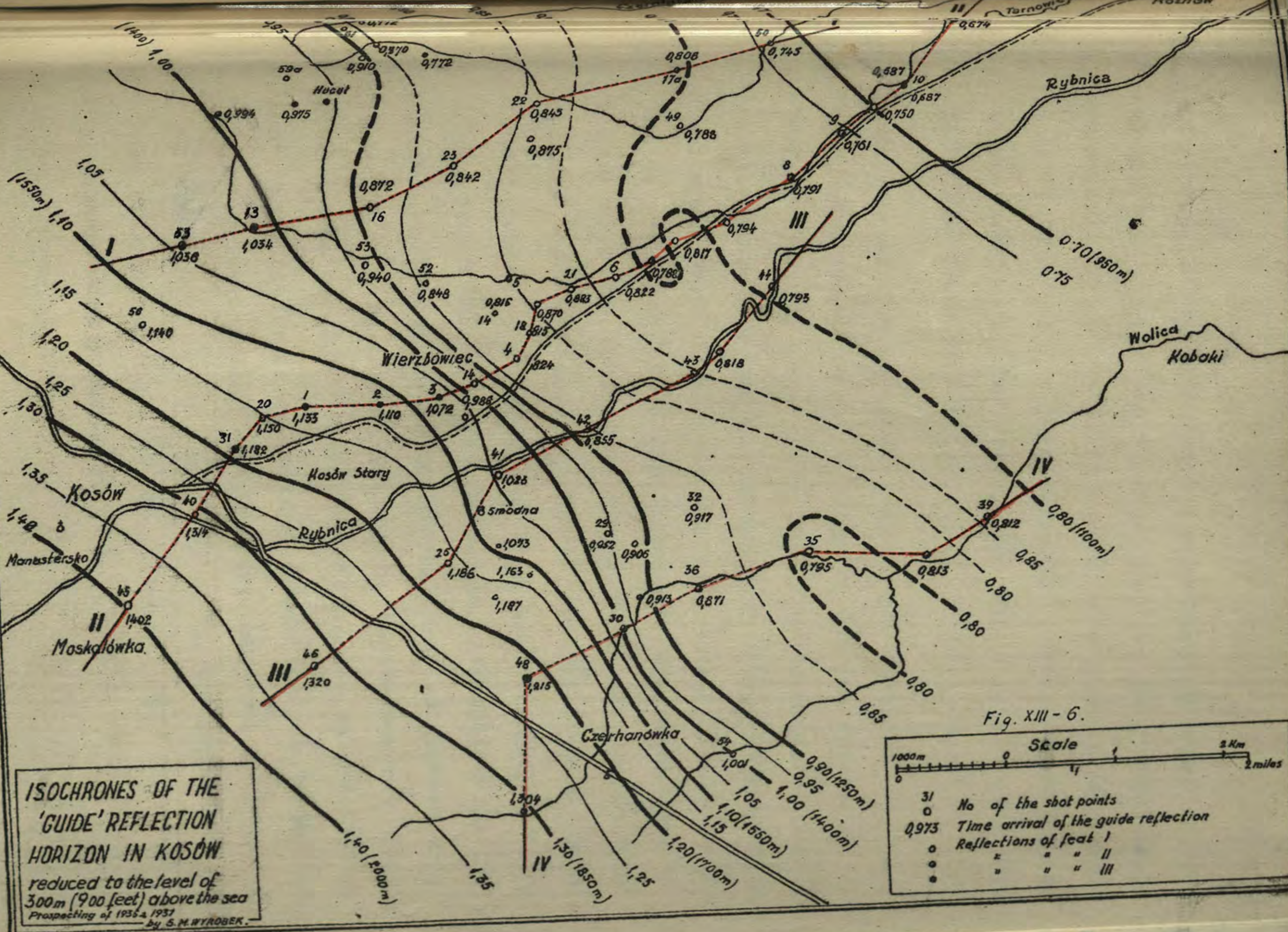
The interpratation of the registered impulses.

The reflection impulses registered occurred within the time-limits of 0,3 sec to 1,5 sec. At one S.P./No.56/ near the Carpathian border a very deep impulse at 2,15 sec. was observed. The depth of the corresponding reflection horizons computed from the velocity curve was 500 m to 1900 m. The shallow reflections in the main did not form any clear and net impulses from which one could distinguish their beginning, their maximum amplitude and their diminuition. They had the character of complex impulses as the result of the interference with weak reflection impulses with surface, direct, or refraction waves from the shallow discontinuities. From among these shallow reflections it was possible to chooses some lined up phases on the basis of which the dip could be calculated. They failed, however, to produce enough evidence to calculate their depth with sufficiemt accuracy and to correlate them over a wide area. Besides they were not constant in appearance and might have belonged to some more laminated beds, which lose that character further away.

The character of the subsurface shales, more sandy than in the Stryj area, as was proved by core drilling, was the cause of the higher velocity of the surface beds and thus evidently did not result in such an outstanding coefficient of reflection as in the area of Stryj. The deeper parts overlying the bedrock contain hard siliceous shale and limestone, which were not present in the "Premier" well. This meant that even the marker reflection could not be so outstanding as in the Stryj area, if considering only the thickness of the reflecting complex. Nevertheless, the "marker" group and the deeper reflections were more clearly discriminated than any of the shallow impulses. The marker was cut off fairly clear from the earlier vibrations, and had conformable phases along the record with slowly increasing amplitude which reached its maximum at the third peak. Below this reflection, as a rule, another increase in amplitude was observed very often, forming a clear second reflection, at a distance which varied along the profile from 0,10 sec to 0,15 sec. Both these impulses, appearing regularly along the whole area, formed a basis for seismical correlation, despite the changeable surface conditions. This group was important, particularly in cases where the prospection was passing over the disturbance zone which falls within the contact of the Tortonian unit with the Stebnik beds at the surface.

<u>The time- countour map.</u>

As has been previously mentioned, owing to the changeable surface conditions and the determination of the average velocity at one spot only of the area, it seemed more favourable to base the interpretation on the time rather than on the absolute depth and then attach to each izochrone a corresponding depth obtained


ISOCHRONES OF THE
'GUIDE' REFLECTION
HORIZON IN KOSÓW
reduced to the level of
300m (900 feet) above the sea
Prospecting of 1936 & 1937
by S. M. WYROBEK.
Scale
1000m
0
1
2 Km
2 miles
31 No of the shot points
0,973 Time arrival of the guide reflection
Reflections of feat I
" " " II
" " " III
Kosów
Kosów Stary
Wierzbowiec
Rybnica
Moskalówka
Manastersko
Czerhanówka
Smodna
Hucul
Wolica
Kobaki
Tarnowica
Rozno
Fig. XIII - 6.

from the velocity curve.

Therefore the correlation between the successive marker groups at each shot-point was carried out along the four mentioned profiles I to IV. The times of the impulses observed , after being corrected for the elevation and the weathering zone with regard to the S.P. were plotted on both sides of the shot-point from which both traverses were shot. A vertical time thus received was reduced to the common reference plane / 300 m a.s.l./ and the figures obtained were plotted on the map /fig.XIII-6/. The time contour map obtained in this way gives with some approximation the picture of the bedrock. Beside the time data, the depth with reference to the datum plane are given in brackets.

The reflection time profiles shown in fig.XIII-7, give evidence of a certain discontinuity of the marker horizon stressed by the reduction of the distinctness of the reflection impulses and by the abrupt change of the time distance. These discontinuities appear on profile I-I between the S.P. 13 and 16, on profile II-II between S.P. 3 and 4, and on profile III-III in the vicinity of S.P.41 and on profile IV-IV between S.P. 48 and 30.

These profiles allow some kind of zone of attenuation of the marker reflection to be located, the width of which may be estimated to be about 400 m. It was a characteristic fact that beyond the limits of this zone the marker was outstanding and weighted 3 or 2 at least. In the NE direction beyond this zone, a slight uplift of the marker in the

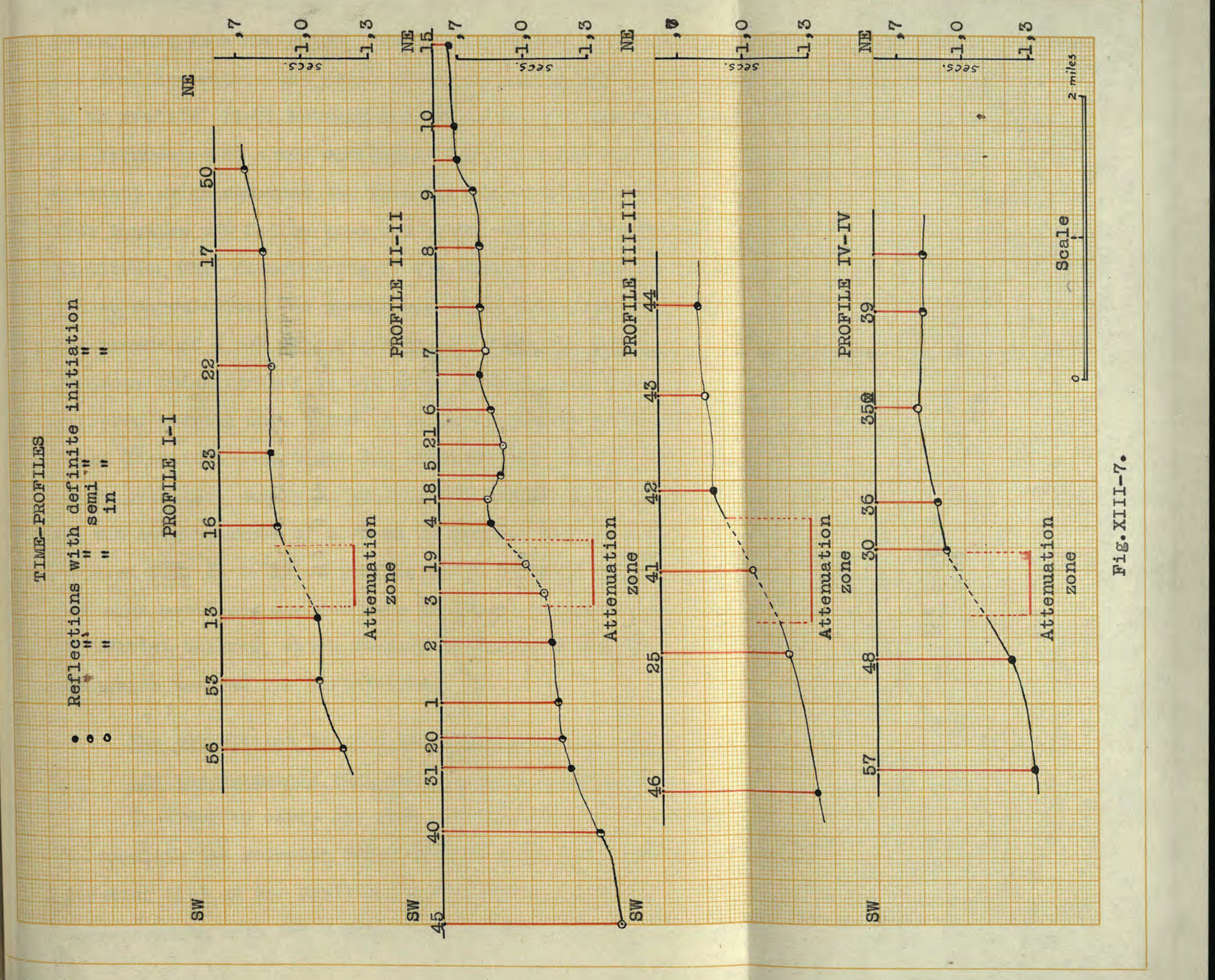
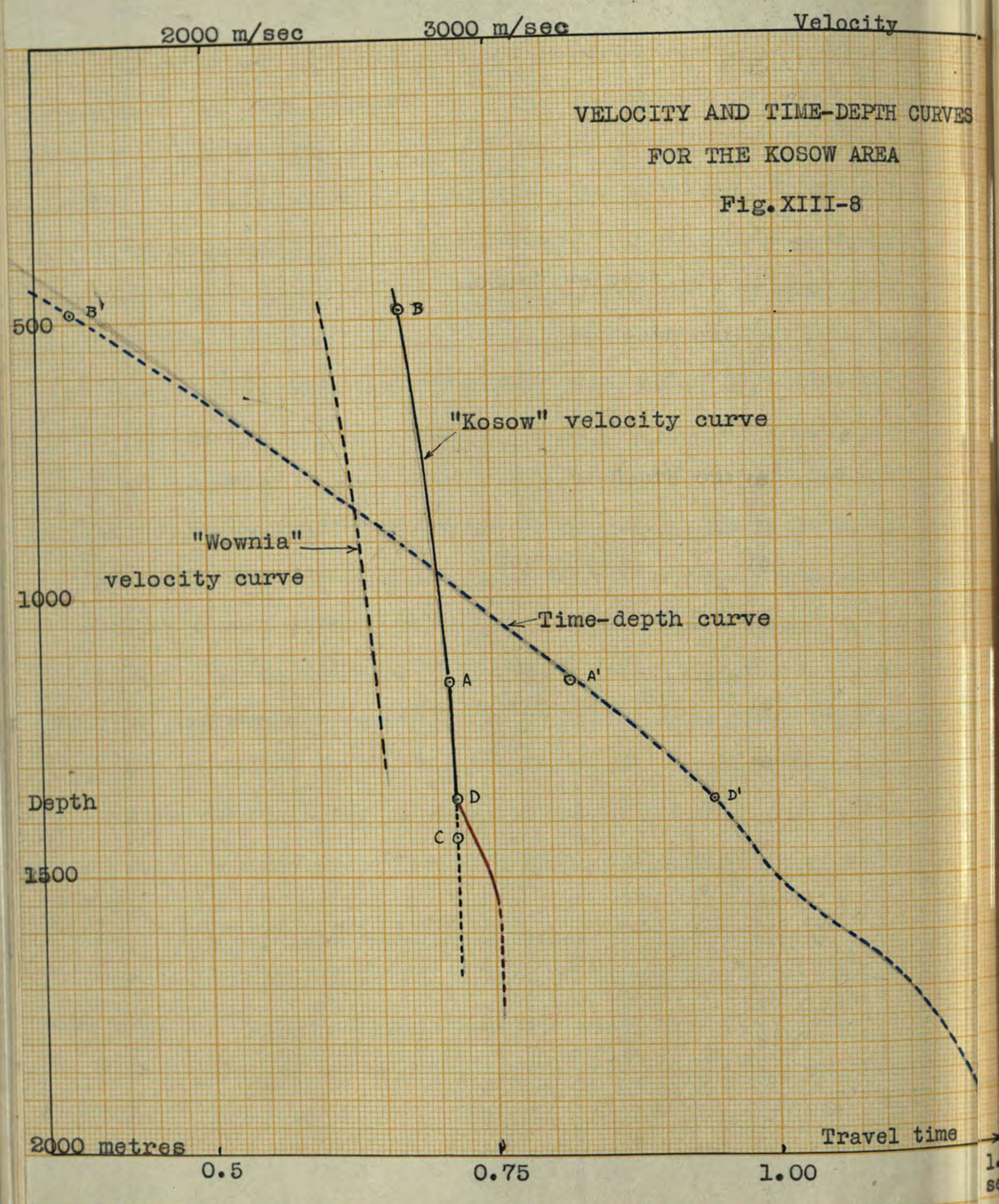

TIME-PROFILES
Reflections with definite initiation
" " semi "
" " in "
PROFILE I-I
PROFILE II-II
PROFILE III-III
PROFILE IV-IV
Attenuation zone
SW
NE
secs.
,7
1,0
1,3
Scale
0
2 miles

Fig.XIII-7.

neighbourhood of S.P. 23, 4, 42, and 50 can be observed and behind this is a new slight attenuation of the impulses. On all profiles within the first attenuation zone and particularly on profile II-II between S.P. 5 and 20, one could observe the occurrence of a new reflection impulse above the marker horizon, which hampered the interpretation the more so as this impulse was failry good and clear though of a smaller amplitude. This dismembering of the reflections was not helpful to correlation. The phenomenon might correspond with the occurrence of a new more rigid layer above the marker horizon, which further to the north a. south at SP 5 and 31 suffered wedging out, since it was not observed as a reflection. Identical conditions and impulses were observed on all other profiles, namely on profile I-I between S.P. 17 to 16, in the neighbourhood of S.P. 43 on profile III-III and between S.P. 36 to 39 on profile IV-IV. Towards the SW from the zone mentioned one can note an abrupt plunge of the reflection horizon, which further to the SW gradually submerges towards the Carpathians.

The correlation between the stratigraphical section and the seismical results. The final conclusions.

In order to carry out this correlation it is necessary to complete the velocity curve down to a depth of 1550 m. Assuming that at the depth-point D /diagram fig. XIII-8/ corresponding with the depth of the marker horizon encountered



2000 m/sec
3000 m/sec
Velocity
VELOCITY AND TIME-DEPTH CURVES
FOR THE KOSOW AREA
Fig.XIII-8
B'
B
500
"Kosow" velocity curve
"Wownia"
velocity curve
1000
Time-depth curve
A
A'
Depth
D
D'
C
1500
2000 metres
Travel time
0.5
0.75
1.00

in the well /1360 m/ the average velocity reaches a value of 2870 m/sec. Further down one will have an abrupt change in this velocity. To compute the theoretical course of the velocity curve one assumes that the whole complex of rocks from the top of the marker horizon down to 1550 m has an average velocity of 5000 m/sec, which is rather an underestimation, considering that the bedrock consists of hard gypsum, salt and anhydrite, but on the other side this bedrock is underlaid by thin limestone sandwiched with siliceous shale, which may have a lower velocity than 5000 m/sec. Applying the formula $V_a = Z/\Sigma(d_n/v_n)$, one obtains the values of the average velocity as shown in fig.XIII-8. Plotting them against the depth the curve as shown in red is reached. Using now the formula $T = 1/V_a \cdot \sqrt{4Z^2 + X^2}$ one will have the corresponding times of the reflections from a number of deep horizons. Plotting them against the depth the time-depth curve as shown in blue is obtained. /In the same way points A′ and B′ were obtained/.

The data published / O.Wysz.Foreland of the Kosow area Oil Industry,1938 in Polish/ concerning the deep well in the Kosow area, show that on the traverse shot across the well the following reflection times were noted: 0,485; 0.95; 1.10; 1.13; 1.20; 1,29; According to the time-depth curve drawn the following horizons could be attributed to these data:

0,485 sec gives the depth 610 m, which falls in with the beds of coarse sandstone about 10 in thickness embedded between a series of slightly sandy clays. This bed being of rather a small thickness from the seismical point of view could not yield good reflections especially as its coefficient of reflection was low. 70 m beneath this a similar bed of sandstone is noted. Both these beds could yield some reflected impulses and were the origin of the shallow group observed over the whole area, without however, the possibility of using them for correlation purposes, on account of their instability in occurrence as well as on account of the difficulties of freeing them from the surrounding secondary vibrations. Besides that, they did not always appear simultaneously, which predicted them only for dip-computations.

At a depth of from 1060 m to 1215 m one may note that there occurs in the well a series of sands and sandstone with conglomerates. They might give rise to the reflections which were observed above the marker horizon within the zone of its attenuation. As these were not observed beyond this zone, it is evident that this series of sands and sandstone either wedges out towards the SW as well as towards the NE or passes gradually into sandy clays and shales.

The reflection at 0,95 sec corresponds to the top of the bedrock which consists of a 35 m thick salt bed embedded in the gypsum and anhydrite. This bed, in the well of a thickness of 65 m, underlaid by a complex of limestone of slightly smaller elasticity, and overlaid by above mentioned sands and sandstone which themselves yield good reflections, could not produce outstanding reflections as was the case in the Wownia area.

The next reflection at 1.10 sec might correspond to a depth of 1660 m which was not reached by the well. It is thus evident that the second reflection from the marker group could not have been affected by the vibrations from the top of the first marker horizon, but by the numerous reflections which might have taken place at the bottom of the gypsum bed and at each discontinuity between the limestones and the siliceous shales embedding them . Hence arises the apparent prolongation of the marker reflection itself.

According to the geologists, the complex of gypsum salt and anhydrite form the bottom of the Lower Tortonian series and lies unconformably on the limestones of the Lower Cretaceous age, which as has been proved in the Carpathians, is unproductive, Thence, in the programme of exploration for oil, arises the important conclusion that any elevations in the sub-tortonian bedrock should be avoided and all investigation should be directed towards the depressions where there might be sedimentation of the Upper Cretaceous age.

Since in the Carpathians the thickness of the Cretaceous formation does not exceed 500 m, one may admit the same in the Kosow case. Adding to 1425 m the figure given above, the depth of 1925 m may be assumed as the bottom of the Cretaceous series. This depth may correspond to the reflection noted at the time of 1.20 sec. The kind of formation which will yield the reflection at 1,29 is more or less a guess.

From a comparison of the geological data with those obtained from the seismical investigations the following conclusions can be drawn:

1. The surface uplift of the direction SE-NW has its conformity in the deep bedrock, which forms a similar uplift, the South-western flange of which has a dip of 25°, whereas the north-eastern is flatter.

2. The deep uplift from the seismical point of view is characterised by the attenuation of the marker reflection group, though by no means by the complete deterioration of it, owing to which it is possible to compute the dip of the marker horizon, and locate the boundaries of the uplift fairly accurately.

3. The place of such an uplift in depth may be accentuated at the surface, in which case the surface beds may form favourable conditions for gas deposits. On the other hand, as has been proved by drilling, the deep uplift, or the elevations of the bedrock, are rather unfavourable spot as far as oil exploration is concerned. This, however, does not exclude the possibilities of oil accumulation in the Paleozoics beneath the Cretaceous, which, up to the present, has not been attempted.

Electrical logging.

To conclude this chapter, it seems worth while to mention the results of the electrical logging carried out here down to a depth of 1210 m. Porosity logging showed its maxima in the complexes 260-380 m,595-610 m and 1055-1140 m, in which the

the highest porosity corresponded to the thin beds of sandstone. The impedance /resistance/ logging was more difficult to interpret , particularly as far as the determination of which sandstones were to be considered as gaseous. The maximum of resistance,falling in also with those sandstones,suggested that in all these complexes sandstones may possess gas deposits, similar to those which occur nearer the surface.

These sand and sanstone complexes being the only outstanding petrographical discriminations within thr whole Tortonian series, were also , as was seen from the previous discussions, the only discontinuities within the series which formed the shallow reflecting horizons.

R e f e r e n c e s:

in Polish:

17. S.Wyrobek : Badania refleksyjne okolic Kosowa. Przemysł Naftowy. 1938. Zeszyt 6.
18. J.Czernikowski: Przedgórze Okolic Kosowa. Przemysł Naftowy 1938. Zeszyt 5.
19. O.V.Wyszynski: Głębokie wiercenie "Hucuł I" w Wierzbowcu. Przemysł Naftowy 1939. Zeszyt 1.

in English

loc. cit. refr. No.13., p.78.

C H A P T E R XVI.

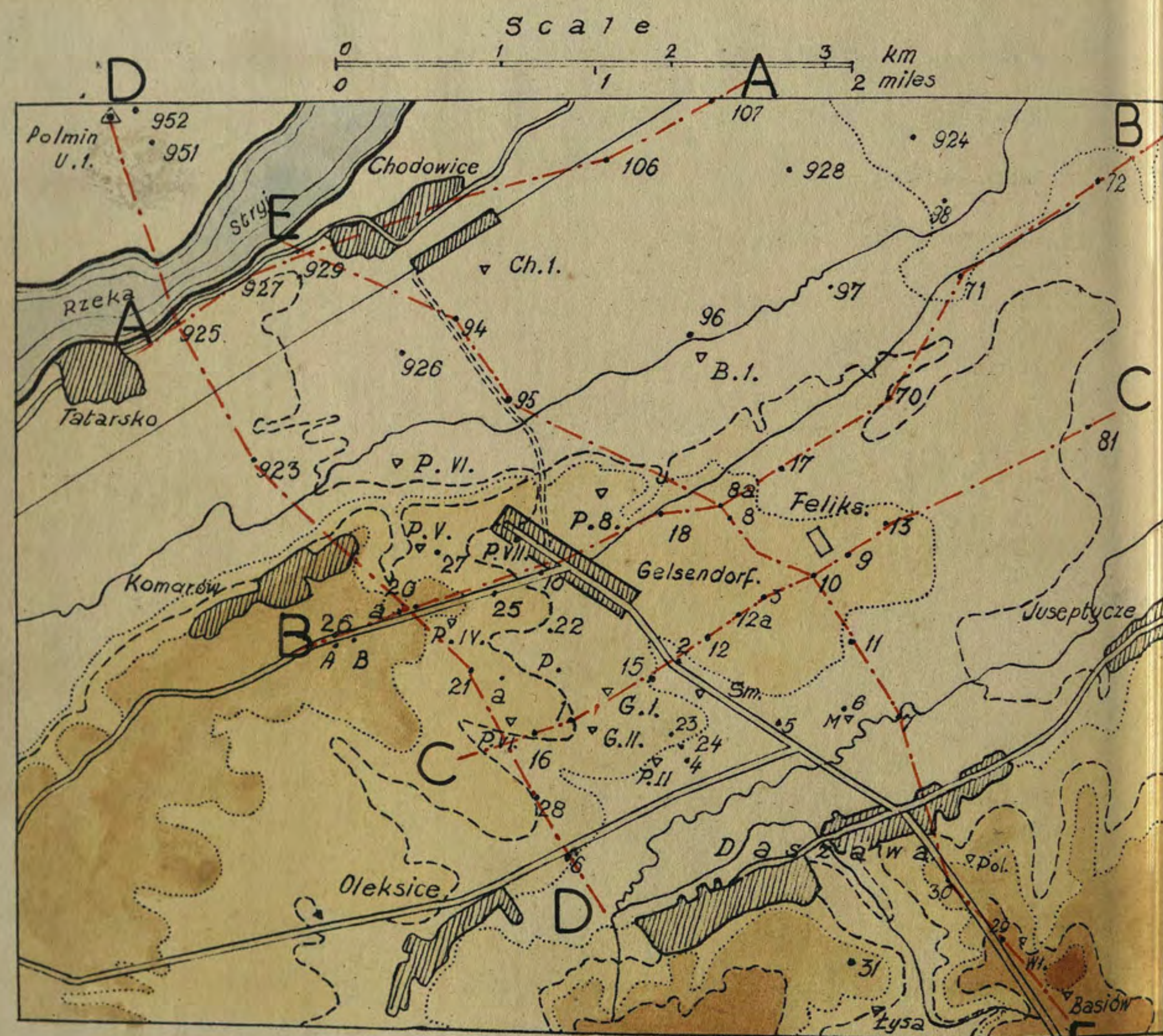
REFLECTION SURVEY OF THE DASZAWA AREA.

The Daszawa gas field, the biggest natural gas field in the foreland area, never ceased to interest geologists concerned with its strusture and tectonic origin. Situated a fair distance from the Carpathians/ 16 miles /, separated from them by two parallel belts, namely that of the Salt formation and that of the Stebnik beds, it was a problem which even a number of geological and geophysical prospections one after another was not able to solve entirely.

This region is rather a low hilled part of the country, with three terraces of gravels of the River Stryj , covered with a thick mantle of Diluvial clays /loess/, without any exposures of the subsurface rocks. A score or so of gas wells sunk down to about 700 m over a small area of 5 sq.km. did not reveal any outstanting structure within the depths reached. All this seemed to indicate that this area might present very favourable conditions for seismical exploration.

The ceaseless interest is here revealed by a series /list/ of seismical prospection carried out here from 1930, namely:

1930 -	refraction	prospecting	by	the	Seismos Co., Hanover.	
1932 -	"	"	"	"	Geological Survey of Warsaw,	
1934 -	reflection	"	"	"	Pioneer Co.	
1935 -	"	"	"	"	"	"
1936 -	"	"	"	"	"	"
1939 -	"	"	"	"	Geotechnika Exp.CO.	



Seismic prospecting at Daszawa.

Fig.XIV-1.

The first two surveys have been the subject of this paper in its first part pp.94-99.

The first reflection prospecting in 1934 was rather of an experimental nature, the object of which was primarily to test the apparatus and method in the part of the foreland which,on account of the wells, was better known than any other. This survey consisted of a series of profiles with shot-point numbered from 1 to 31 / Fig.XIV-1/. During the next surveyings / in 1935 and 1936/, which formed part of the reconnaissance prospection of the surrounding areas, the previous results were partly completed and tied into the surrounding areas by the additional shot-points /70-107 in 1935 and 923-952 in 1936/ shown also in the mentioned fig.

In 1939 a further enlargment of this survey towards the SE was carried out by the Geotechnika Co., which was begun from the middle of the area / in Gelsendorf/ and was carried out through Daszawa, Basiowka , towards Balicze and Turza W.

The results given below concern the surveys made here with the use of the six-geophone set of Seiscor, from 1934 to 1936. The area of interest shown in fig.XIV-1 is cut from the map Plate 7/ and may be divided into two parts, that of Daszawa, Gelsendorf, and Komarow in the middle, covered with gas wells, and that of Tatarsko, Chodowoce, Juseptycze, Oleksice, surrounding the former.

The first / inner / part has a surface of about 14 sq.km and was covered with a relatively thick net of 41 shot-points giving an average of 3 S.P. per 1 sq. km. The depth of the shot-points varied from 20-32 m /70-100 ft/ drilled through the thick mantle of clay and diluvial gravels to the underlying Miocene clays. Some of the holes drilled during the prospection reached only the top of the gravels and proved to be more successful than the deep ones, particularly as far as the reception of the shallow reflections was concerned.

The second /outer/ part covering the northern and eastern neighbourhoods of the Daszawa gas field has a surface of about 40 sq.km over which 40 shot-points were located, giving an average of 1 S.P. per 1 sq.km.

The following table gives other details: -

Part	Surface in sq.km	Number of S.P.	Size of charges	Total dynamite	Number of shots per hol
inner	14	41	0.1-15 kg	779 kg	15
outer	40	40	0.1- 2 "		5

The methods of field work in the inner part

As has been mentioned above, the main purpose of this prospection was to test the reflection method and the apparatus in the part of the foreland know from the drillings, to a depth at least 700 m / 2500 ft/. It necessitated the observation of the shallow impulses / reflections/ in order to tie them into the beds known from the wells. As the work continued, the attempt was made to observe and register the deep reflections, to obtain some indications regarding the structure of the unknown bedrock.

Since this prospection was carried out before that on the profile Stryj -Lwow, field experience was rather limited, based only on that acquired in the Nahujowice-Boryslaw area. A set of deep shot-holes was prepared in advance, but shallow holes were also used, the depth of which corresponded with the thickness of the surface clays . The effect of shallow holes was not so accentuated as on the Stryj road profile, but they made the shallow reflections more easily obtainable.

The surface conditions over the inner area were very changeable. In a way they were described in this paper on pp.96 and 97 and their effect on the reflection shooting was by no means better than that of the previous refraction work. The map /Fig.XIV-1/ shows the topographical contours of the area and it is easy to note three terraces of the Stryj valley: that of Tatarsko-Chodowice /280 m a.s.l./, that of Komarow - Gelsendorf /310 m a.s.l./ , and that of Basiowka /340 m a.s.l./ all composed of gravels and clays, the thickness of which grows by steps with the increasing distance from the river. Moreover, what is more important for the seismic prospection, they become less and less watered, so much so that the third terrace is covered with dry clays or loess, and the water level is here more than 30 m down from the surface of the ground.

The prospection in 1934 being confined to the second and third terraces, one had to deal with two different

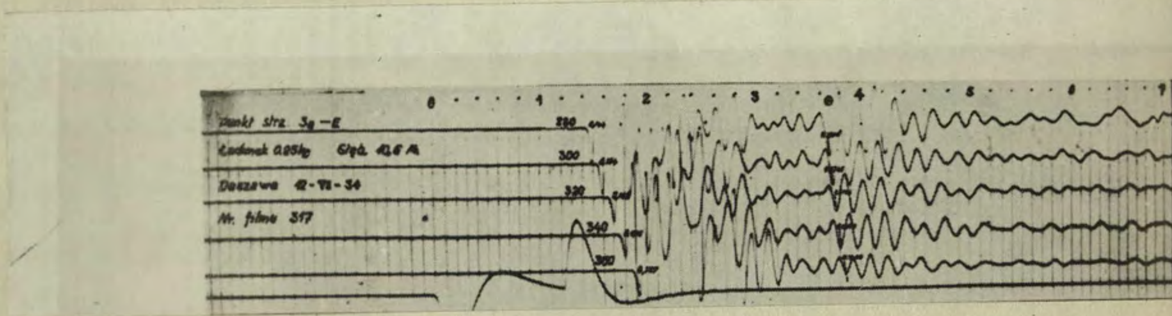


Fig. XIV-2.

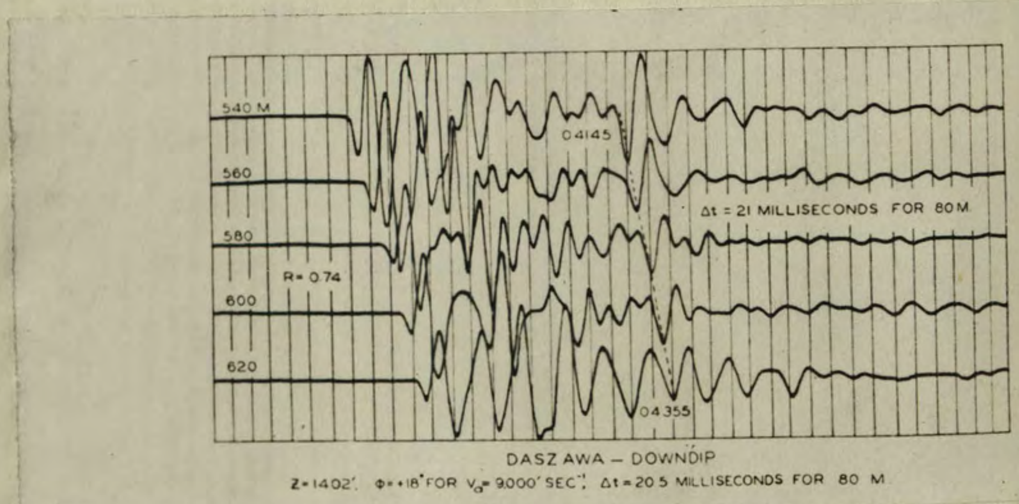


Fig. XIV-3.

seismical conditions:

1. The second terrace was characterised by a mantle of clay, the thickness of which varied from 10 m in the east /Feliks/ to 20 m in the west /Komarow/, whereas the thickness of the underlying gravels did not exceed 10 m, these gravels being fairly watered in the eastern part. The shallow reflections were easily observed and there were also some good traces of deep reflected impulses from the unknown bedrock. The relatively thick mantle of dry clay had to some extent a damping effect on the vivrations of the gravel beds when shooting from deep holes was carried out, but on the other hand it also damped the useful energy, and caused considerable "ground roll" which compelled the observer to use longer spreads even for shallow reflections. For instance, for a reflection of 0.4 sec, which was characteristic in the eastern part, the normal spread was 300-400 m, as shown in fig. XIV-2. In the western part the conditions were worse and so on account of the ground roll the spread had to be longer , as shown in fig. XIV-3, where the spread for a shallow reflection of 0.4 sec. was 540-640 m. The same applied to the observation of deep reflections, which, on account of the damping effect of the clays, required big charges /20 to 30 lbs/, the latter in turn causing a strong "ground roll", which necessitated the use of long spreads /from 600 m onwards/ which on the other hand were not favourable as far as the distribution

of useful seismic energy was concerned. It was a vicious circle, and many observations were taken from one shot-hole, before any hopeful results were obtained. All this required the high average of 15 shots per hole, with charges sometimes exceeding 20 lbs.

One phenomenon is worth noting. Along this terrace one could observe a close relation between the type of wave emanating from the vicinity of the explosion and the frequency of the shallow reflections. In the region of Gelsendrof /the eastern part of the terrace/ the explosion was accompanied by a sharp sonorous crack and the reflections were of high frequency /seismogram in fig.XIV-2/. In the region of Komarow /the western part of the terrace/ the explosion had a dull sound and the reflections were of lower frequency, at the same distance and depth. In the former case the gravels underlying the surface clay are more watered, whereas the same gravels in the Komarow region are deprived of water. The transmission of energy is therefore worse, because it suffers higher absorption. If, however, the geophones were placed in ditches or surface basins, the reflections were more distinct and partly free from the low frequency rolls, though the explosion itself sounded dull. In seismic survey, the first type of ground is called "good ground", the second "bad ground".

2. The third terrace, covering the Daszawa village and its southern neighbourhood, and characterised by a mantle of dry clays about 30 m thick was underlain by dry gravels to an additional depth of 10 m. Both shallow and deep reflections were difficult, if not impossible, to obtain. Only very shallow reflections were registered. The sound of the explosion was hardly audible, no matter what the size of the charge, placed on the top of the gravels in a shot-hole 30 m deep. All energy was absorbed by the dry clay and gravels. Some of the records hardly showed even the direct wave, which is supposed to carry the greatest amount of the energy. On account of this fact only 3 shot-points were used /29, 30, 31/. Much more sensitive apparatus was applied here in 1939 and it too did not succeed in registering any better impulses than those mentioned. It would be worth trying to investigate this area, if necessary, by using deep shot-holes /about 50 m/, the geophones being placed on wooden posts sunk down to at least the top of the gravel bed. This would reduce the thickness of the absorbing medium and allow more reflected energy to be brought to the geophones. On the other hand, however, by increasing the acoustic resistance of the medium the ration of the useful energy and of the noise would be such that it might be difficult to separate the former from the latter. It would be a matter of experience to establish the length of the posts. This is a long and costly way, and this kind of area may be consider as inaccessible to seismic prospection for the time being.

The methods of field work in the outer part.

Any deep reflections observed within the first area could not be referred to any know horizons. Only when the reconnaissance survey carried out during the next two years had covered the northern and eastern counties of the Daszawa gas field, could those deep reflections be recognised as belonging to the gypsum correlation. The northern counties as well as the eastern are a little above the level of the River Stryj and belong to the first terrace. Both areas were sutiable for reflection surveying and the reflections obtained here were on the whole as good as those observed in the Stryj-Lwow profile. The methods of field work were the same as in the second phase of work on the mentioned profile.

Discussion on the average velocity for the area.

At the time of the experimental survey in the Daszawa area it was possible to use the results of several long refraction lines from the work performed in this area by the Seismoc Co in 1930 and data from the survey carried out here by the seismic group of the Geological Survey of Warsaw in 1932. The longest refraction line /6 km/ carried out by the Seismos Co, supplied the following velocities for the subsurface beds:

V_1 = 2650 m/sec; V_2 = 3000 m/sec; V_3 = 3400 m/sec.

The refraction lines carried out by the Geological Survey being 3 km long supplied the following data: -
V_0 = 1700-1800 m/sec; V_1 = 2400-2700 m/sec; V_2 = 2900-3000 m/sec
thus showing a close approximation to the previous survey. Not having at hand the time-distance curve of this velocities it is difficult to say with any great degree of accuracy the depth to which they might be attributed. Considering that since at a distance D a depth of 1/6-to 1/4 of D is reached by the refraction wave /practical deduction/, the velocity of 3400 m/sec might be attributed to the horizon at about 700-1000 m deep /for D = 4 km/, and the velocity V_2 to the horizon at about 350-500 m deep /for D = 2 km/. Since it is known that at a depth of 1200 m are gypsum beds it is better to take the first figures, and thus V_3 assign to a depth of about 700 m, and V_2 to a depth of about 400 m. Down to a depth of 400 m one will thus have to assume a medium of velocity V_1, and to the surface beds underlying the gravels the velocity V_0, as it is known from the reflection survey that the weathering zone had a velocity of about 650 to 1000 m/sec.

Anyhow, whatever these velocities and their attributed depths were, they could not be used for the determination of the average velocity, since the observation data were charged with errors brought about by disregarding the weathering zone, which in that area is very changeable.

Moreover, these velocities represent the real velocities of some subsurface complexes, measured along their stratification, whereas the velocity used for the reflection calculations averages the velocities measured across the stratification, and as was pointed out before, these vertical velocities are about 10-40% smaller than those measured along the beds.

It was not possible to determine the velocity by shooting in some of the Daszawa wells, on account of their constant production under high pressure of gas; while the result obtained by shooting in the nearest well in Uhersko was not successful because of the effect of casings, which it was impossible to eliminate, it was therefore necessary to apply to Daszawa the data obtained in the "Premier 1" well in Wownia. It is true that the velocities encountered in the Daszawa area were about 5-10% higher than those observed in the Wownia region, but the accuracy in depth and dip computation by use of the "Wownia" average velocity curve was higher than that obtained by applying the average velocity determined either from refraction profiles or by empirical formulae from the reflection seismograms.

Discussion of the results.

Fig.XIV-1. shows the distribution of the shot-points within the inner and outer parts of the Daszawa area. The

Fig. XIV-4 a. PROFILE A-A

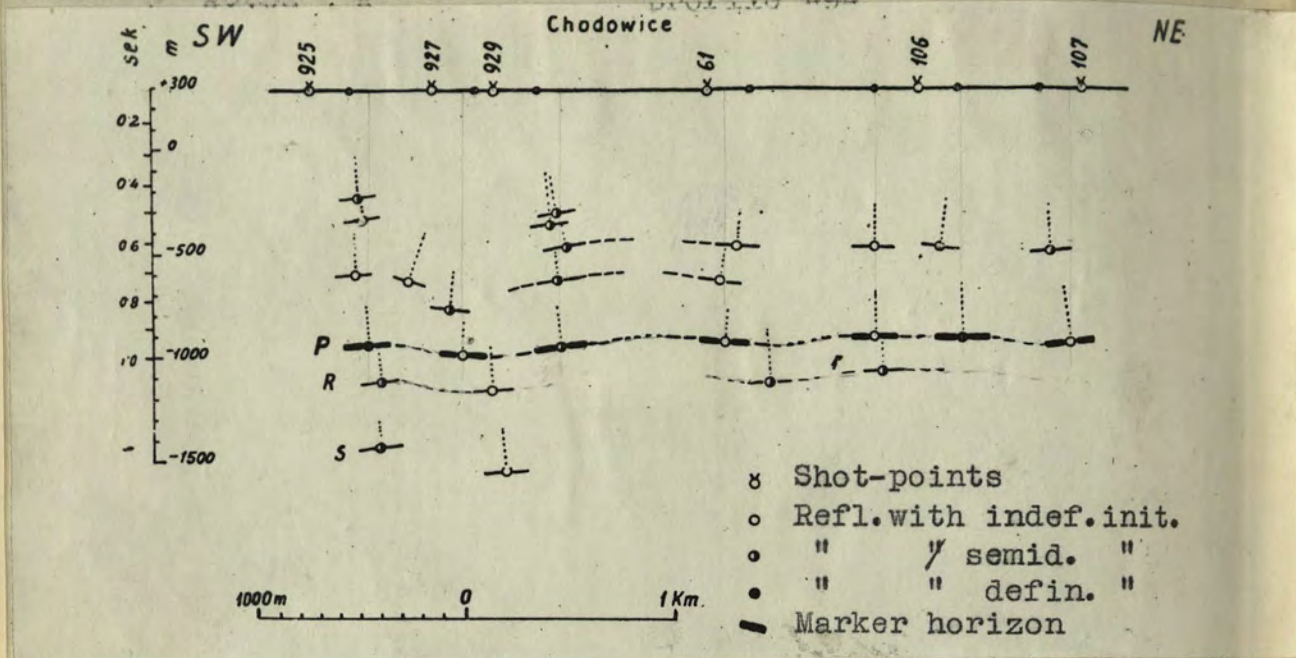


Fig. XIV-4 b. PROFILE B-B

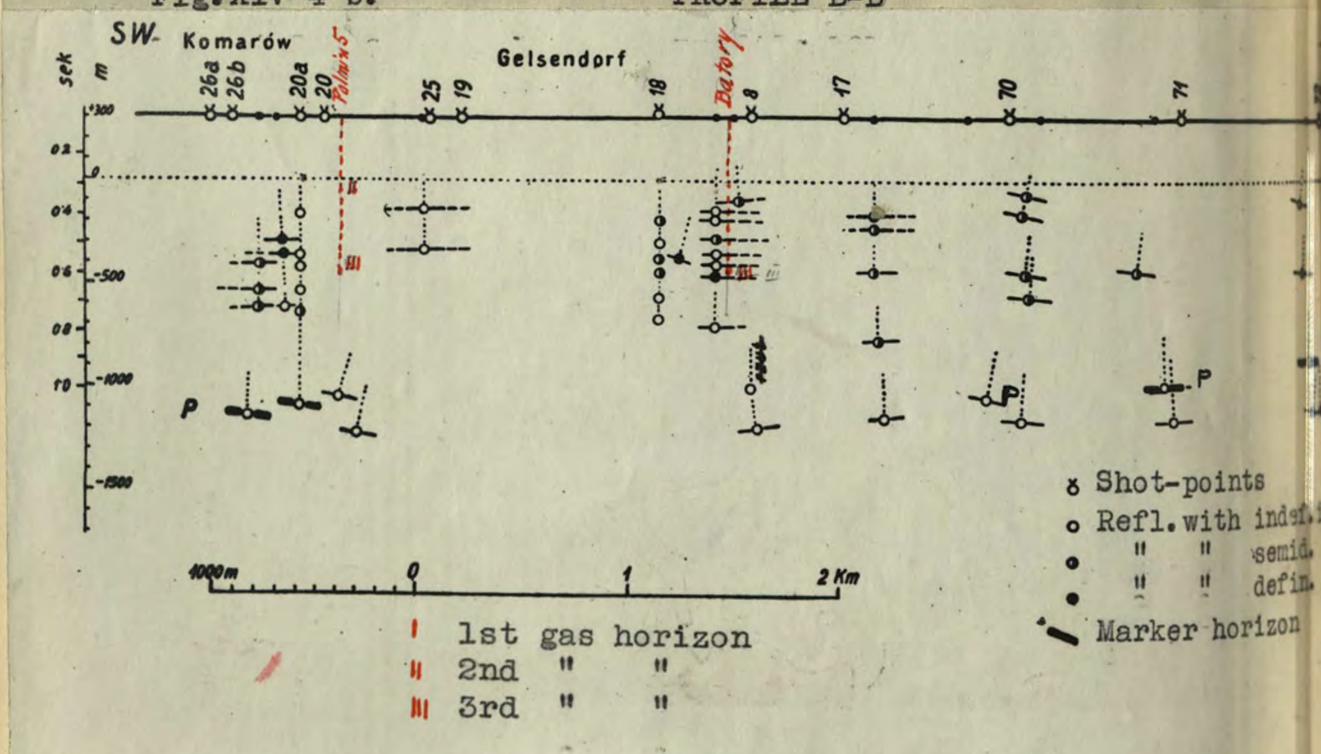


Fig. XIV-4 c. PROFILE C-C

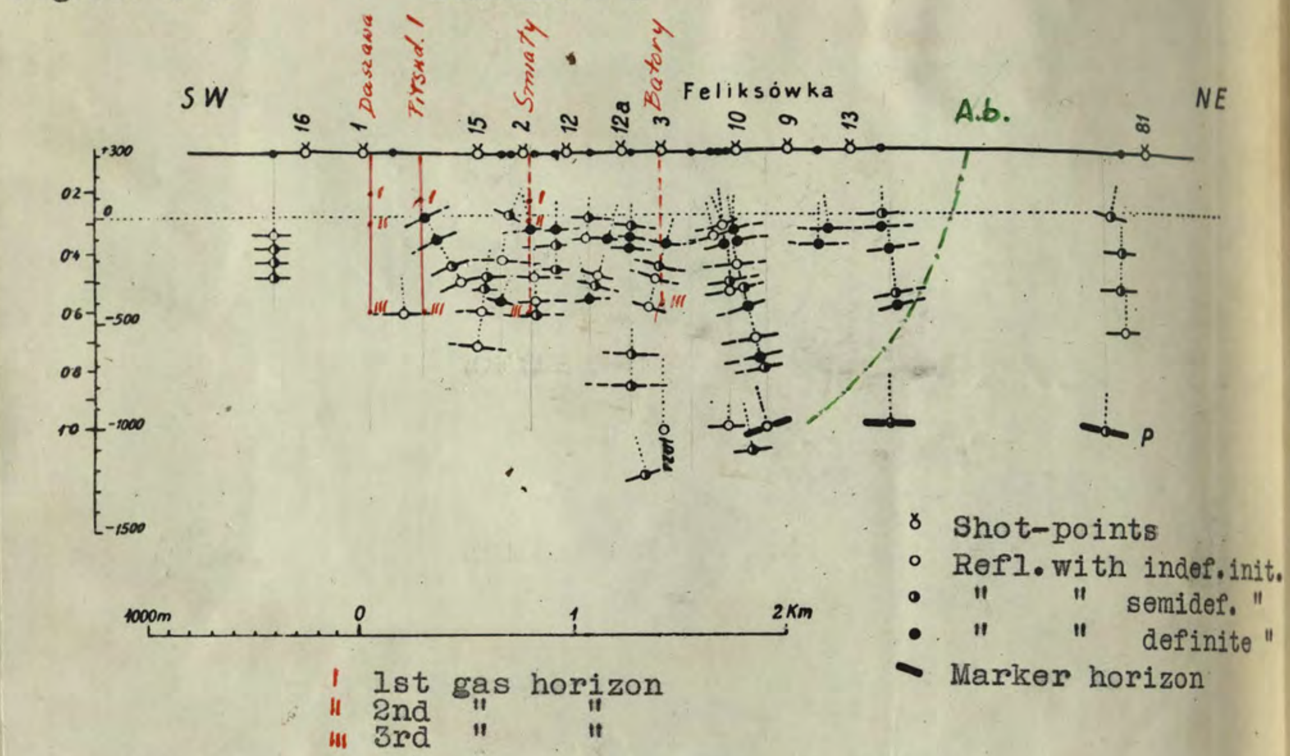


Fig. XIV-4 d. PROFILE D-D

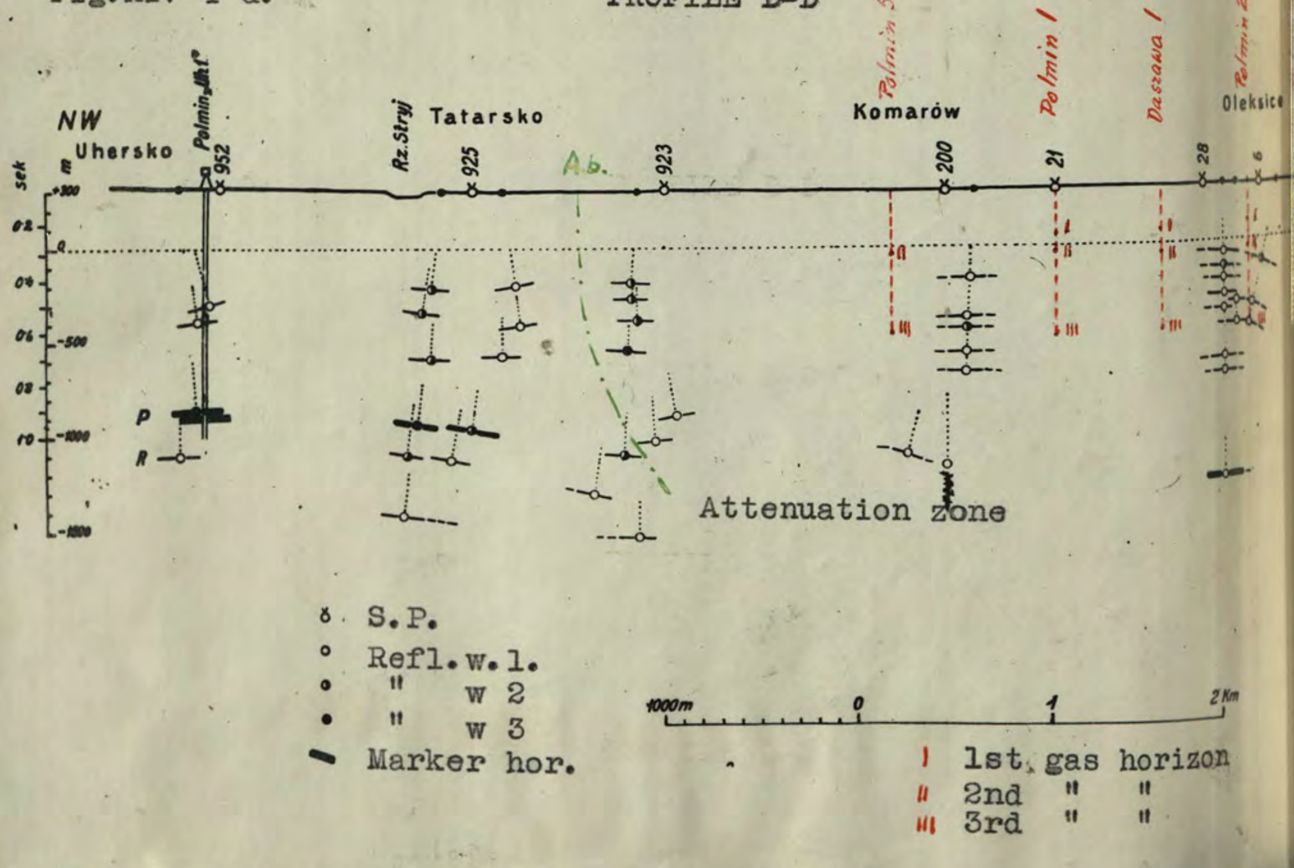
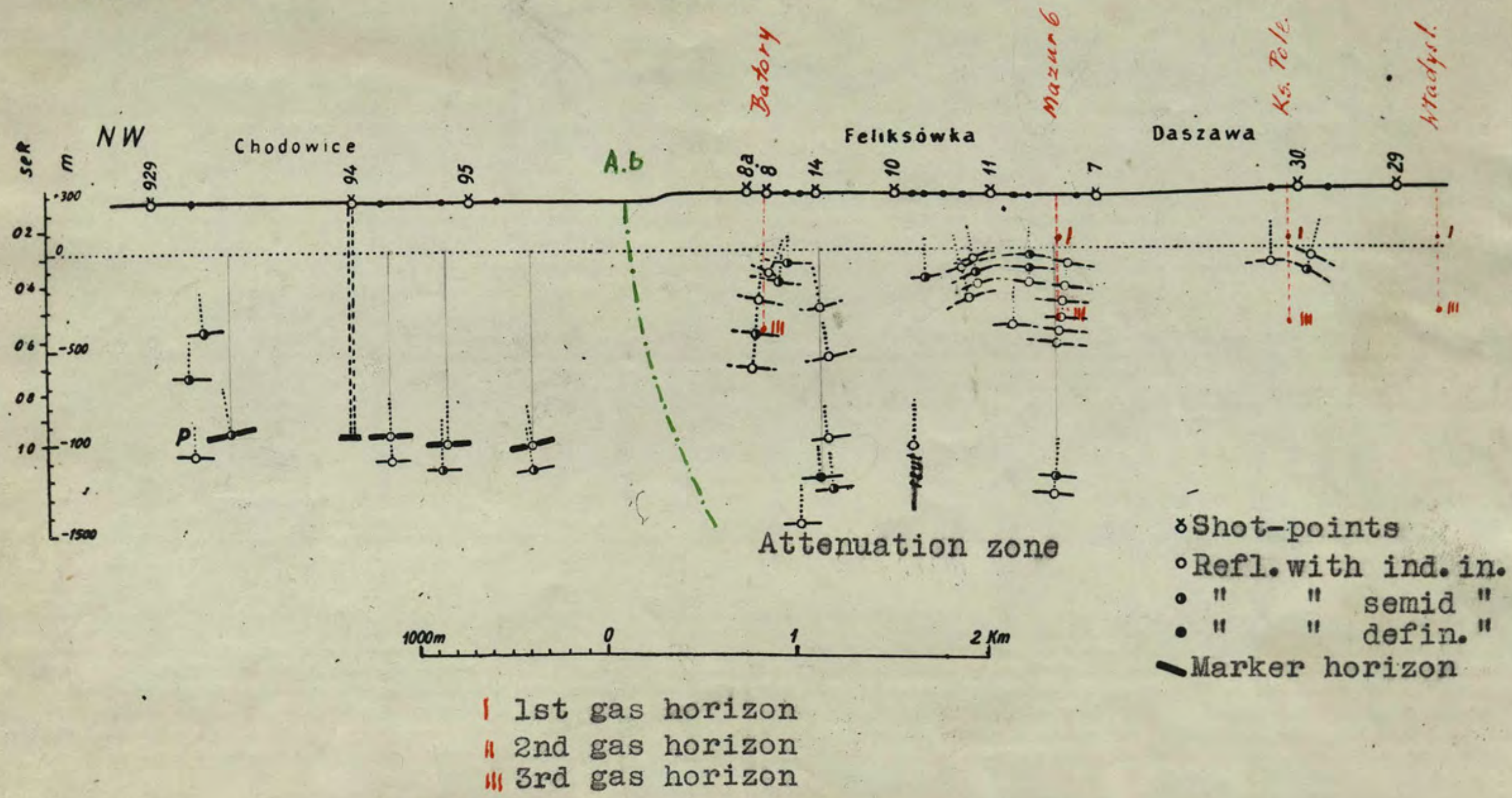


Fig. XIV-4 e.   PROFILE E-E



density of the shot-points shows the division of the whole regions into parts as described above, namely the area of the Daszawa gas field subjected to a more detailed prospecting and areas surrounding it which tied the reconnaissance survey of the Stryj region with that of Daszawa.

The behaviour of the registered reflecting horizons is shown on five profiles A-A, B-B, C-C, D-D, and E-E in fig. XIV-4 a,b,c,d,e. The first three have the direction NE-SW and are therefore transversal to the Carpathians, whereas the last two, run in the direction of NW-SE. These fig. are enlarged from the writer's report / "Badania sejsmiczne okolic Daszawy." Przemysł Naftowy Zesz.4.XIII.1938/.

In the present paper the writer thought it worth while to carry out a correlation on the strength of considerations given in earlier chapters and to draw a map of the bedrock, shown in detail in Plate 10. The background for this map is taken from the Tołwinski's paper /Les problemes des reserves de gaz naturel en Pologne. Pol.Tow.Geol.1936, XII. p.412./. On this map all the shot-points shown in fig.XIV-1, are plotted and corresponding profiles are marked as before /A-A, B-B,etc./. The data concerning the depth of the "marker" reflection horizon "P" are computed from the reflection profiles in fig.XIV-4 with regard to the reference plane 280 m a.s.l. They are given in table on the following page.

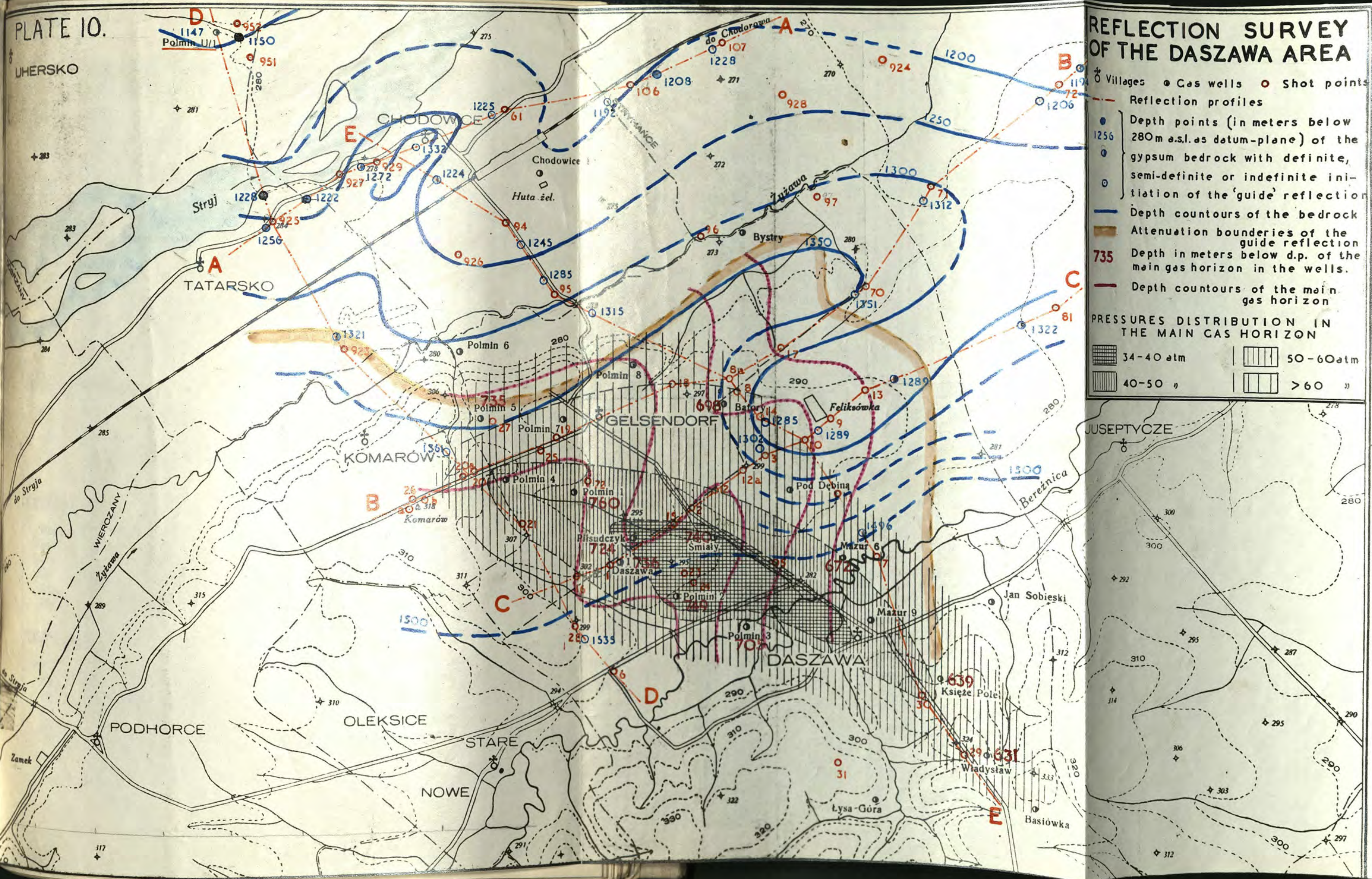


PLATE 10.
REFLECTION SURVEY OF THE DASZAWA AREA
Villages
Gas wells
Shot points
Reflection profiles
Depth points (in meters below 280m a.s.l. as datum-plane) of the gypsum bedrock with definite, semi-definite or indefinite initiation of the 'guide' reflection
Depth countours of the bedrock
Attenuation bounderies of the guide reflection
Depth in meters below d.p. of the main gas horizon in the wells.
Depth countours of the main gas horizon
PRESSURES DISTRIBUTION IN THE MAIN GAS HORIZON
34-40 atm
40-50 „
50-60 atm
>60 „
UHERSKO
CHODOWICE
TATARSKO
KOMARÓW
GELSENDORF
DASZAWA
JUSEPTYCZE
PODHORCE
OLEKSICE
STARE
NOWE
Stryj
Bystry
Chodowice
Huta żel.
Felikśówka
Pod Dębiną
Jan Sobieski
Księże Pole
Władysław
Łysa-Góra
Basiówka
Zamek
Polmin U/1
Polmin 5
Polmin 6
Polmin 8
Polmin 4
Polmin 7
Polmin 3
Piłsudczyk
Batory
Smiały
Mazur 6
Mazur 9

Shot point	Direc- tion	Dist- ance	Depth of the	Weight "marker"	Elev. of S.P.	corr. to 280 m	Corrected depth
Profile A-A							
925	E	300	1225 m	3	283	-3	1222 m
929	W	130	1270 m	1	278	+2	1272 m
929	E	300	1230 m	2	278	+2	1232 m
61	E	90	1220 m	1	275	+5	1225 m
106	W	200	1185 m	1	273	+7	1192 m
106	E	200	1200 m	3	272	+8	1208 m
107	W	60	1220 m	1	272	+8	1228 m
Profile B-B							
70	W	100	1350 m	1	281	-1	1349 m
71	W	100	1300 m	1	270	+ 10	1310 m
72	W	160	1200 m	1	274	+6	1206 m
Profile C-C							
81	W	250	1320 m	2	280	0	1320 m
13	E	200	1300 m	2	290	-10	1290 m
10	E	120	1305 m	1	295	-15	1290 m
3	projected		1320 m	1	298	-18	1302 m
Profile D-D							
Well of Uhersko			1180 m	3	280	0	1180 m
925	N	180	1230 m	3	282	-2	1228 m
925	-	0	1260 m	2	284	-4	1256 m
923	N	100	1320 m	2	280	0	1320 m
20a	N	200	1390 m	1	310	-30	1360 m
28	S	150	1550 m	1	295	-15	1535 m
Profile E-E							
929	S	400	1220 m	2	276	+4	1224 m
94	S	200	1240 m	1	275	+5	1245 m
95	N	140	1280 m	1	275	+5	1285 m
95	S	320	1310 m	1	275	+5	1315 m
14		0	1520 m?	1	295	-15	1505 m
7	N	220	1500 m	2	285	-5	1495 m

The reflection profile A-A offers no difficulty in the correlation of the "marker" the reflection group "P" and "R" can easily be followed along the profile, the former supplying sufficiently accurate data concerning the depth of the marker. The remaining four profiles show a certain discontinuity in the deep reflections. For instance, profile B-B at its NE end gives evidence of this horizon under S.P.72 and S.P.71, beneath which the horizon marked by "R" can be also unequivocally correlated under both shot-points. The difficulty arises under S.P.70 where the upper deep reflection may still be attributed to "P", but beginning from that point there is no clear evidence of this reflection. Under S.P. 8 it is revealed on a cross traverse along the profile E-E. Further to the SW, under S.P. 20 and S.P. 26a a group of deep reflections is apparent, but whether they form the same horizon or belong to three different horizons is difficult to establish, and therefore they were not taken into consideration. It is better discriminated on profile D-D, which under S.P.20a shows only one reflection. The same discrimination being carried out on other profiles, one arrives to the table given on page 122, from which the contours of the "marker" can be drawn.
A helpful factor in considering the correlation of the individual segments of this horizon was the assumption that, at the point of its attenuation or deterioration, the "marker" dips very slightly towards the SW, this assumption being based

on the behaviour of this horizon in the south border zone of the Stryj-Rozdoł profile / see chapter XII/.

Thus a characteristic boundary can be traced, within the limits of which the marker reflection shows deterioration with a simultaneous improvement of the deeper reflections. The second criterion which applies here is the fact that from this boundary towards the SW new groups of shallow reflections occur on each profile. These are not present on the northern side of the boundary line. This boundary is marked on each profile by "A.b." Plotting the surface points of this boundary on the map /Plate 10/, one obtains the attenuation line marked in yellow.

The cause of the attenuation of the marker horizon in the surface considered may be due partly to the surface conditions of the weathering zone, which, as has been shown, affected the distribution and absorption of the seismic energy, On the other hand, however, within the attenuation area the deeper reflections are sometimes better accentuated than the "marker" itself, as can be seen on profile C-C /S.P.3 and 10/ and on profile E-E /S.P.14/. Thus it may be assumed that the cause of this deterioration lies either in the deeper subsurface conditions caused by the presence of the Stebnik beds overthrusting the Tortonian formation or in the character of the "marker" bed itself.

Whether the boundary plotted corresponds strictly to the boundary of the mentioned overthrust is a matter of ing the geo-

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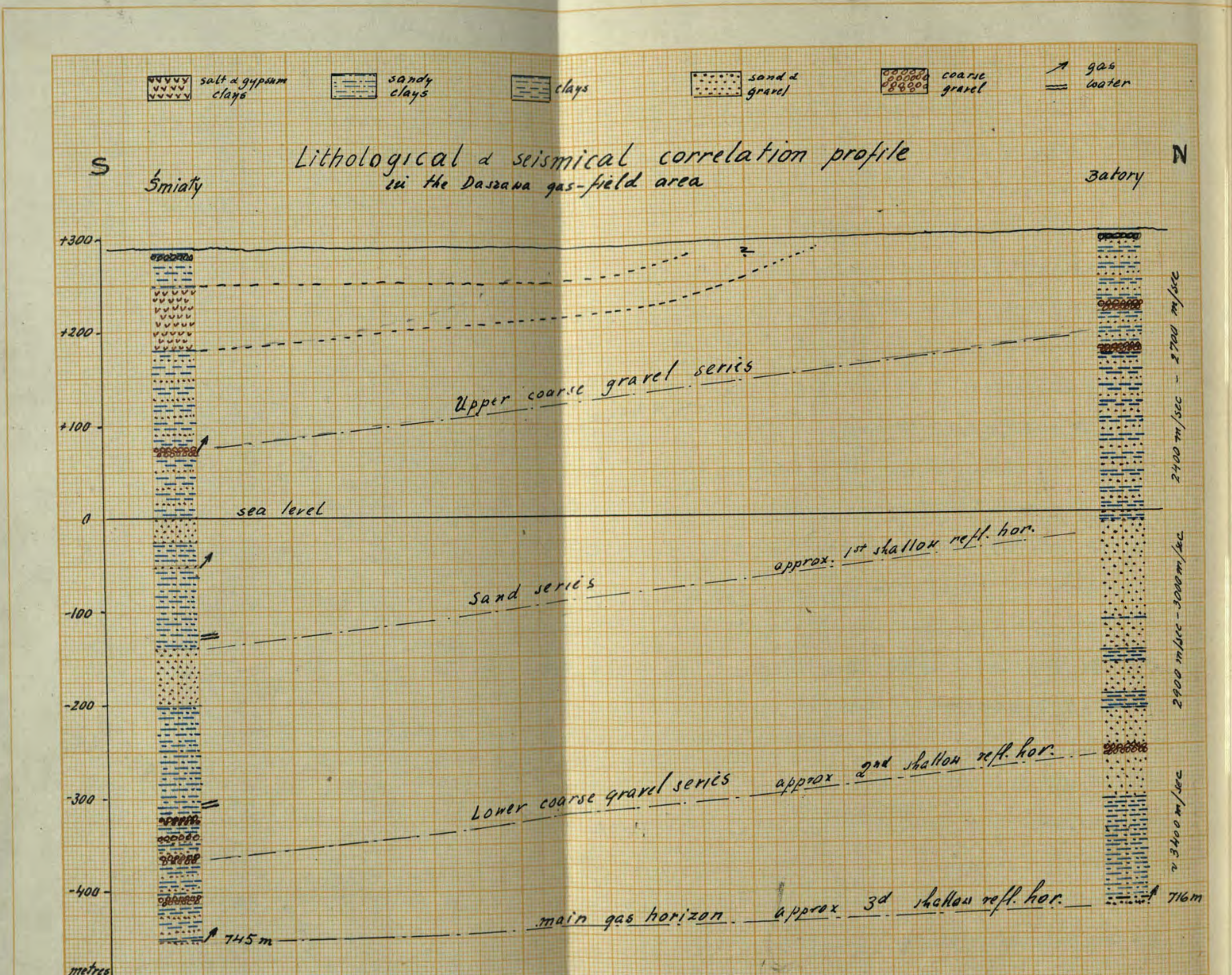


salt & gypsum clays
sandy clays
clays
sand & gravel
coarse gravel
gas
water
S
N
Lithological & seismical correlation profile
in the Daszawa gas-field area
Śmiaty
Batory
+300
+200
+100
0
-100
-200
-300
-400
metres
Upper coarse gravel series
sea level
approx. 1st shallow refl. hor.
Sand series
Lower coarse gravel series
approx. 2nd shallow refl. hor.
main gas horizon
approx. 3d shallow refl. hor.
745 m
716 m
2400 m/sec - 2700 m/sec
2900 m/sec - 3000 m/sec
~ 3400 m/sec

Fig. XIV.-5.

further reseach in the terrain. The data concerning the geology of this area has always been inadequate. Probably as the wells were drilled by percussion, no discrimination was carried out so far as the evidence of the Stebnik beds was concerned. Moreover, the problem of the boundary of the Stebnik beds arose in the years of 1935-36, while most of the wells sunk were, a long time before that date. Thus all the data published refer to the depth of the gas horizons, water horizons, casings, pressure, with very few references to the presence of the Stebnik beds.

Some help in the correlation of the seismic and geological data may be given by fig.XIV-5, which shows stratigraphical sections of two gas wells "Smialy" and "Batory", the distance, as seen from the plate 10, between them being 1 km. The upper part of the Smialy well consists of salt and gypsum clays; they are not seen in the corresponding part of the Batory well, which leads to the assumption that they outcrop somewhere between these two wells. According to Tołwinski, they may belong to the Salt formation, which in this area might appear as a result of some diapiric structures. This has not been proved, however, by any other instances, most of the beds having in their upper levels some indications of marly red shales which could be attributed to the Stebnik formation.

There is some possibility of correlation between the individual beds within the limits of these two wells. In general it is evident that each well contains in its upper and lower levels a series of coarse gravel. These one may call the upper and lower coarse gravel series, as is shown on the figure. These two series are separated by a medium complex of sand and fine gravel. They dip as a whole towards the south. Now, these three horizons may to a certain extent be correlated with the shallow reflections and refraction horizons. Shallow reflections revealed under S.P. 3, 12a and 12 on profile C-C have weight 3 and form the first distinct horizon , the depth of which will fairly well agree with the sand and gravel series, which are highly watered at the top. A reflection from this bed was shown in fig.XIV-2. The second distinct reflection on profile C-C may correspond to the lower coarse gravel bed /series/, whereas the third reflection, occurring close to the second one is easily attributed to the series of sand and gravel which form the reservoir rock of the main gas horizon in the Daszawa area.

The sedimentation conditions and partly the lithological character of the individual series varies along the correlated section. The medium sand and gravel series varies in thickness, and passes into sandy clays towards the south. The same applies to the lower coarse gravel bed which in the Batory well form a single layer embedded in the sand series, while in the Smialy well one may note four coarse gravel layers separated by sand and clay. The above is a proof of the fact that all the mentioned reflection horizons were no t continuous and did not retain the same distinctness and the same weight along the prospected profile C-C.

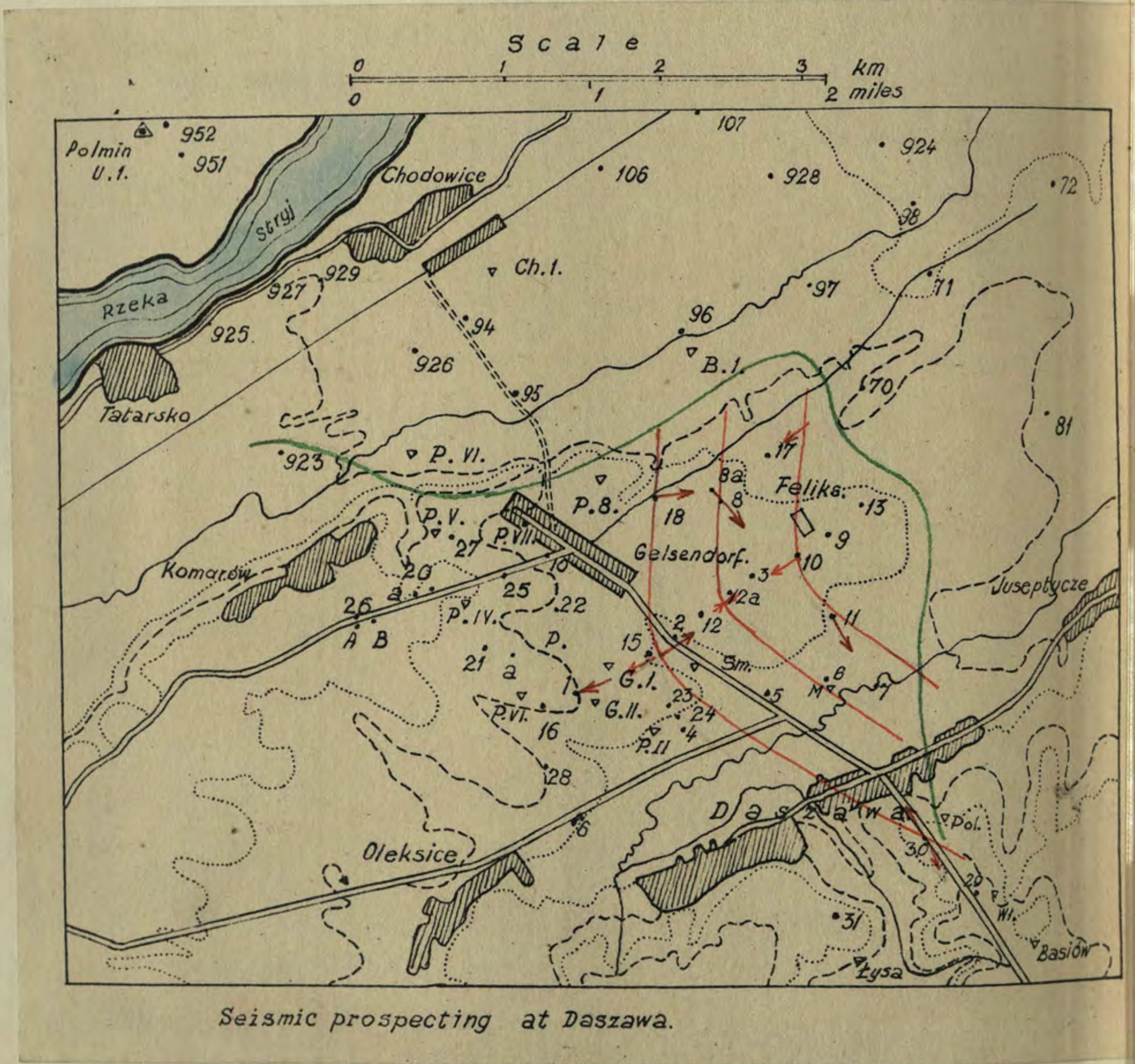
The Daszawa gas field contains two shallow and one deep gas horizons. Both shallow gas horizons occur approximately no more than 70 m above and below the sealevel. They are not continuous and in some wells the upper, in others the lower horizon is missing. Much more steady is the deep gas horizon occurring at a depth of about 700 m below the surface of the ground. The table on page 128 gives the figures concerning the depth of all these gas horizons as they occur in the gas wells of the area. Also the water horizons are included in the table. As it is evident they are of different slope from that of the gas horizons. Plotting on the map /Plate 10/ the depth points of the main gas horizon /with regard to the assumed reference plane of 280 m a.s.l./ the contours of this horizon can easily be drawn . To facilitate the consideration all three gas horizons are plotted on the individual reflection profiles. The inferences may be as follows:

The shallow gas horizons and their reservoir rocks, not being continuous over the area, the shallow reflections within this area and particularly within the area south of

Synopsis of gas and water horizons in the Daszawa wells.

Name of well	elev. a.s.l.	Gas horizons depth from the surface	Main gas h.	Water horizons depth from the surface
Basiowka	329	75, 121, 184, 292 336	439	28, 184, 336,
Batory	298	693,	716	110,
Daszawa 1	298	76, 218, 255, 349 552, 604	754	20, 182, 229, 367 435, 611
Ks.Pole	308	81, 264, 313, 361 430, 510	667	12, 388, 510, 621
Mazur 6	282	230, 327, 494 583	674	274, 439, 449, 640
Piłsud.1	296	206, 344	740	11, 114, 164, 234, 380, 597, 690,
Polmin 1	298	102, 234, 148, 314 403, 465, 604	778	25, 373, 420, 604, 662,
Polmin 2	288	96, 174, 209, 300, 340, 383, 646	757	11, 226, 300, 383, 428, 588, 646,
Polmin 3	283	215, 284, 397, 472, 571	708	18, 244, 420, 580,
Polmin 5	304	335 568	759	568, 671,
Smiały	285	216, 254, 340 518, 635	745	292, 401, 584, 643, 688,
Władysł.	321	169, 220 284 480	672	20, 291, 480, 640,

All figures in metres. Figures underlined refer to the two shallow productive horizons. Others refer to some traces of gas. Main gas horizon is given separately. Figures are taken from Tołwinski's graphs in his article : Les problemes de reserve de gas naturel en Pologne. Pol.Tow.Geol. loc.cit. Ref.No.15. p.78.



Seismic prospecting at Daszawa.

Axes of anticlines and synclines of the shallow refl.hor

Directions of dipping of the shallow refl.hor.

Attenuation boundary of the deep horizon

Fig.XIV-6.

the boundary line cannot be continuous. This fact is clearly evident from the individual reflection profiles. Nevertheless their summary behaviour is characteristic. Considering the dip and plotting points of the "highs" and the "lows" of their "Phantom" horizons along each profile on fig.XIV-6, their space folding is obtained; it gives some idea of the direction of the overthrust of the Stebnik formation. Furthermore the contours of the main gas horizon /Plate 10/ which shows a good agreement in shape with the upper lines of foldings of the shallow reflections, point out a disconformity between the structure of the Tortonian series and that of the Cretaceous formation underlying it.

Type of gas deposits in the Daszawa area. Relation between the lithological character of beds forming the reservoir rock of the gas deposits and the character and occurence of the impulses reflected from them.

All the gas wells sunk in this area /the first in 1924/ show that the deposits of natural gas are almost horizontal and very regular and of great production capacity. /From 1924 to 1935 the production exceeded 1 milliard of cu.metres/. In the region of the wells explored, these gas deposists are slightly and regularly dipping towards the W and S. /as shown in Plate 10/. The Tortonian formation of Daszawa consists, as shown in fig.XIV-5, mainly of clay or shaly clay, in which one encounters particularly in their deeper levels sands and sandstones with fine gravels. These form the reservoir rocks for the gas. Besides there are here and there several beds of coarse gravels cemented with clay, some of them occurring even close above the main gas horizon. According to the faunistic assemblages all these series are ascribed to the Upper Tortonian age. The thickness of the whole gas formation and its extention, has not yet beee definitely stated.

Tołwinski's map of the gas deposits /background of the Plate 10/ shows the state of pressure within the main gas horizon, as it was in 1935. The picture is of some interest and shows that in the middle part, which contains the oldest wells, the pressure dropped to the level of 34-40 atmospheres. Beginning from this depression towards the outside boundaries, the pressure grows, as show, forming two additional regions with pressures 40-50 atm and 50-60 atm respectively.

The surface of the Daszawa gas field explored is about 5 sq.km. The resources of these gas deposits are estimated to be about 4 milliard cu.metres.

At a distance about 2 miles away towards the NW from the main Daszawa area, the well "Polmin 1" in Uhersko was sunk, reaching a depth of 1332 m. Down to 1142 m it crossed the beds of the Daszawa type in which slight traces of gas were found. From 1142 to 1154 m the hard beds of gypsum and anhydrite which formed the basis of the reflection correlation survey, were encountered. From 1154 to the final depth, it passed through the sandstones intercalated with shales and slates. These sandstones had no traces of any gas, moreover they were highly watered.

A few miles further away in the same direction the well "Premier 1" reached the gypsum beds at 1174 to 1185 m, not meeting with any traces of gas in the whole Tortonian overburden. Below the gypsum beds the same type of sandstones were passed as before; Tołwinski ascribes them to the Upper Cretaceous age.

Geologically speaking these two wells are situated towards the NE from the axis of the Daszawa gas field. From the results obtained from both wells it follows that on the way from Daszawa towards "Polmin" and "Premier" wells, there exists some kind of attenuation of the gas productivity in the Tortonian horizons. Moreover, as the reflection survey revealed, the bedrock along this direction, as well as towards the North of the Daszawa gas field axis is almost horizontal. Except for the slightly dislocated Wownia zone, which occurs near the Premier well, there was no evidence of any structural changes either in the bedrock or in the overburden. Thus to the NE as well as to the N, there is no structure closing the gas deposits in the area of Daszawa, and the only cause of attenuation of gas productivity can be ascribed to the petrographical change of the gas sand and sandstones. From the well logs /even if considering the alloted logs in fig.XIV-5/ it is evident that these changes might have taken place. It is a well know fact, that when passing from the coarse grained sediments of the fresh water or border type, towards fine grained sediments of bay type and finally towards clays and marls of deep sea type, at the zones of change one nearly always encounters occurences of ~~the ...~~ hydrocarbones. One may thus arrive at the conclusion that the Daszawa gas deposits are of a stratigraphical type rather than of a strutural one. The sandstones and sands containing natural gas, may change and, according to the evidence are changing towards the N amd NE into less and less sandy clays, the fact yielding the conditions which in geology is called "the stratigraphical traps" or "trapping structures", beyond which any infiltration of gas or other bitumens is impossible, owing to the complete petrographical change of the reservoir rock.

The results of the geochemical prospecting carried out over the area of the south border zone, the Wownia zone and over part of the middle zone, "classified as those on the profile Stryj Rozdoł/, may also throw some light on the above assumptions. The chemical analyses of the samples taken from the bore-holes along this profile showed that:

a/ the rocks of the Tortonian ages contain 0.01% - 0.03% of soluble bitumen,

b/ the rocks of the series of Stebnik are almost deprived of soluble bitumen. The maximum content amounts to 0.005%.

The contours of the equal content of soluble bitumen

/the map not published/ are drawn in blue in Plate 7. It may be seen that the maximum of this content falls within the vicinity of S.P.13 and S.P.14, being here 0.018%. Towards the N, S, and W this content drops down to reach 0.010% near the "Premier 1" well and 0.001% over the part covered with the Stebnik beds. The writer has no knowledge of the eastern part, but it follows from the map that this content should grow towards the Daszawa main gas field, diminishing from it towards the NE and SW.

The diminishing content of hydrocarbons in the surface samples of the Stebnik beds proves that the Stebnik beds form a fairly solid cover, which preserves the gas deposits occurring in the underlying Tortonian formation and prevent their reaching the surface.

So far the southern extention of the gas deposits has not been located. The wells in Balicze /South-east of Daszawa/ and in Opary /NW of Daszawa/ show considerable gas pressure in the beds of the Tortonian formation under a thick mantle of the Stebnik beds. This mantle as is known grows thicker towards the south and about 4 miles from the overthrust boundary /in Gaje Niżne/ has a thickness of 1500 m. In this complex of the Stebnik beds no gas occurences were found. The underlaid formation was not drilled.

A new well, the drilling of which began before the war, in Chodowice / 1.5 miles to the north of the main Daszawa gas field - see plate 10/ has recently reached a depth of about 1200 m, at which the existence of the gypsum beds has been proved. It was less productive in gas than any of the wells drilled further to the south. This is thus additional evidence of attenuation of the gas productive beds towards the North.

Consider now the conditions revealed by the reflection survey:

Sand and sandstone series containing natural gas deposits have emphasised their presence in the reflection survey. New shallow reflections, not present outside the area, were registered within the Daszawa main area. These reflections, as has been shown, can be attributed to the sandy deposits containing gas. The survey described though done with little field experience, with shot-points placed at random, at spots most convenient for drilling, nevertheless ,however, with an elaboration of all reflections supplied enough evidence for the statement that the gas sandstones and sands yield reflections , not present outside the area.

Thus according to the belief of the writer a very careful survey, performed with modern equipment, could trace in the terrain the zones where these sandy beds will reveal themselves as reflections, analogically as in a geological survey it is possible to trace a gradual occurrence of sandy layers within the clay series. A tracing of the boundaries of those lithological changes on a geological map is very often identical with the location of the boundaries of the bituminous deposits.

It is a well know fact that a regional analysis along a geological profile is not an easy matter. It is an important thing to establish the gradual change of the lithological composition along the profile in the same direction. The same could be applied when endeavouring to prospect the area by reflection shooting. It would be very important to study the character and occurrence of the reflections along a profile with the same length of the traverse laid in the same direction. The main difficulty here to be dealt with, would be the changeable weathering conditions, but in general it is a matter which could be solved fairly satisfactorily in areas even as difficult as that of Daszawa. It is understood, that a continuous profiling both by correlation and by dip-shooting will have to be applied.

R e f e r e n c e s:

in English :

loc.cit, ref. No.13. p.78.

in Polish :

20.S.Wyrobek and Z.Mitera: Badania seismiczne okolic Daszawy Przemysł Naftowy. Zesz.4.rocz.XIII.1938.p.95-97

21.M.Kleinman: Les analyse chémique des substances bitumineuses dans les roches oligocenes and miocenes de Pologne. Congres Mondial du Petrol.1937.P.1.
loc.cit. ref.15. p.78.

C H A P T E R XV.

SEISMIC PROSPECTION OF THE DEEP HORIZONS WITHIN THE CONTACT ZONE OF THE STEBNIK AND TORTONIAN FORMATIONS IN CONNECTION WITH THE LOCATION OF PROBABLE OIL ACCUMULATIONS. FINAL CONCLUSIONS.

The behaviour of the deep marker horizon in the contact zone of the Stebnik and Tortonian formations, until now solely known and studied by reflection methods, deserves further consideration.

The examples of the prospection from the regions of Opary, Stryj, Daszawa, and Kosow, along the zone mentioned, discussed in the previous chapters /XI to XIV/ though not identical in details, reveal the same characteristic attenuation of the marker horizon with the simultaneous improvement in some areas of the deeper reflections.

Since these phenomena are attached particularly to the zone of existing gas deposits, it will be of value to consider them from both the geophysical and commercial points of view, the latter mainly because of the probability of existence here of oil accumulations on a commercial scale.

First of all it seems necessary to consider these probabilities. They are determined by three conditions:

1. Sedimentation, 2. Accumulation, 3. Preservation.

As is known, the oil formations with regard to their lithological character are divided into two large groups, namely: sandstone series in which the reservoir rock are sands ar sandstones, and limestone series in which the oil deposits are connected with the beds of limestones.

To the first class in Poland /ref.22/ besides the Flysh formation belong all kind of series in which the sandy content is more or less accentuated.

The second category of oil rocks comprises the beds of pervious limestone, sandwiched between the marly impermeable formations.

Oil impregnations are also known in massive limestones with slightly developed intercalations of marls and calcareous shales /England, Persia/.

Both kinds of oil rocks form various combinations and reciprocal interchanges, so much so that oil bearing sands are found very often in the limestone series, or oil bearing limestones occur interbedded within the sandy series.

So far as the genesis of the oil series in general is concerned it is known that four fifths /ref.22/ of them owe their origin to the coastal conditions of sedimentation in lagoons or in coastal lakes. In addition there are also oil bearing formations of terrestial character as well as formations composed entirely of deep sea sediments.

From the examples previously given it follows that the condition of sedimentation and the existence of rocks favourable for the deposition or accumulation of oil are present in the foreland area. The wells in the Kosow, Daszawa and Stryj areas revealed the presence of sandstones /Stryj/ or limestones /Kosow/ of Cretaceous age. The reflections survey revealed their extention over a large area of the foreland under the cover of the Tortonian formation, the thickness of the latter varying from 500 m to 3000 m. Apart from the existence of natural gas deposits in the Tortonian formation no traces of oil were found, and from the known areas at least this formation may be excluded from this account. The deeper rocks, however, of the Cretaceous and Paleozoics, being so far unknown, must be considered.

When passing from the north to the south along the profile Stryj-Rozdoł /Chapter XI/ geological drillings demonstrated the gradual change from deep sea to coastal sediments. There was no well drilled in the "Middle zone" of the Tortonian belt, but on the basis of seismic survey results it is possible to state that the marker horizon which gave the best results /records/ in this part, slowly and gradually deteriorates towards the south with a simultaneous improvement of deeper reflections. If this improvement was wanting, one might ascribe the deterioration to the more and more sandy nature of the Tortonian formation towards the south, which fact would have its effect on the distribution of seismic energy. In the Stryj area the deeper reflections can be attributed to sandstones underlying the "gypsum correlation"

/"Premier" well/. If one assumes that the small amplitude of these reflections in the north is partly due to the well consolidated gypsum bed, and partly to the small thickness of the sandstones mentioned, and that the improvement of these deeper reflections could be attributed to the growing thickness of these sandstones, when moving towards the south, one would have proof of approaching the coastal region somewhere within the limits of the boundary of the Stebnik and Tortonian formations. Thus, according to the previous statements one would encounter here not only sediments favourable for oil accumulation but also the most suitable conditions as far as the genesis of oil rocks is concerned.

There are also other factors which favour the contact zone. One is that it has been established beyond any doubt that the occurrence of natural gas in the Tortonian formation is strictly connected with a geological phenomenon, namely, the unconformable contact of the older beds /Stebnik formation/ overthrust on the younger beds /Tortonian formation/.

The second important factor is the chemical composition of the encountered gases. In the Kosow area it has been stated that the content of heavy hydrocarbons /i.e. the sum of propanes and butanes/ amounts to 2% , the rest being accounted for by ethane 12% and methane 86% /ref.18 /. The percentage of methane in the Daszawa gas amounts to 95% in the higher horizons, and to 94% in the main horizon, in which the percentage of heavy hydrocarbons rises to 1% / ref.15/. It

This indicates that the natural gas encountered here is not so "dry" as was first though, and that this natural gas may have its origin in some accumulations of heavy hydrocarbons in deeper parts of the bedrock, or in parts situated further to the south, from which it migrated northwards.

Furthermore, if ever there is any connection between the Carpathian and Podolian Cretaceous formations, then in these southern regions /see Plate 9/, covered with a thick mantle of the Stebnik formation, there must exist changes from the Carpathian Flysh facies to the facies belonging to formations outside the Carpathians. In the tectonic structure of thse sediments weak undulations should occur, the amplitude of which would diminish towards the north and grows towards the Carpathians /ref. 22/. In this case a favourable condition for the accumulation of oil should be encountered that is to say a suitable structure. Here, however, one cannot expect to find the types of structure prevailing in the Carpathinas, which form a unit closed within themselves, where a close relation between the structure and the oil accumulation exists. Application of this relation ship to the foreland area, especially within the contact zone considered, might lead to conclusions which are completely wrong. One should expect here, according to the Polish geologists, slight undulations, and it has been proved in one instance, that such an undulation exists about 1 mile away to the south from the contact boundary /see chapter XII/, where a syncline in the bedrock has been revealed by seismic prospection. This kind of structure may to a certain extent help the accumulation of oil, but would not be a decisive factor. In this part of the foreland area, according to Zuber /r.22/ one should rather approach such problems not from the point of view of the relation between the structure and the accumulation, but by studying the relationship between the quality of the sediments and the changes in the lithological character of rocks and the accumulation of oil. In this case one may have to deal with so called "trapping structures" or stratigraphical occurrences of oil. If this is so, then the oil accumulations encountered would be found in their primary position and therefore probably in sufficient quantity to be of commercial value, provided that the third condition is fulfilled, i.e. the preservation of the deposited or accumulated oil.

Before coming to the third condition, another fact must be taken into account, namely that oil accumulations even in their primary position would occur in large areas of the uplifted parts adjacent to the older formations and still more often where the phenomenon of wedging out of certain series takes place. The reflection survey along the boundary of the Stebnik overthrust has revealed /as has been shown in previous chapters/ that the bedrock formations plunge from the boundary mentioned gradually towards the Carpathians and this plunge may have occurred in a series of folded steps, of which the first was located by the reflection survey /Kosow/, or in a series of slight undulations the amplitude of which grows towards the south /Stryj, Opary/.

The southern flanks of this first step and of all the following undulations which probably occur in the bedrock would yield favourable conditions for oil accumulations in situ.

In an attempt to prove the presence of the wedging out of certain series and thus the presence of probable stratigraphical oil occurrences on the basis so far supplied only by the reflection survey, one has to consider the behaviour of the marker horizon within the contact zone.

The reflection power of this horizon, as was stated before, decreases gradually with simultaneous improvement of the deeper reflections. The decreasing reflection power of a reflecting horizon, may to a certain extent be due to the following factors:

a/ A lithological change of the rocks in the overburden - this is to a certain degree responsible for the distribution of seismic energy.

b/ A change in slope of the reflecting bed,- this causes diversion of the reflected impulses.

c/ A change in the thickness of the reflecting bed. The reflection power lies in close relationship with the thickness of the reflecting medium. The best results are obtained when the thickness of this medium is greater than half the length of the seismic wave.

d/ A deterioration of the reflecting surface itself caused by cracks, dismembering of the same layer, lamination etc,- these separately or altogether diminish the elasticity of the whole system.

All these factors play their role in the zone under consideration.

a/ Beginning with a/, one has here to deal with two types of new sediments in the overburden: that of the Stebnik beds overthrusting the Tortonian formation and that occurring within the Tortonian formation as a result of lithological changes, revealed by new shallow reflections not registered on the northern side of the zone. Both these sediments should simultaneously have a deteriorating effect not only on the marker horizon, but also on the deeper reflections. It is not, however, the case, because these deeper reflections improve.

b/ A rapid change in slope as that in the Kosow uplift, the southern flank of which dips at 25^{o}, has to a certain extent diverted the reflected impulses along different routes from those usually considered for the spread applied. In the Daszawa area this kind of slope may also be present /see plate 10/, if the chosen impulses are correct and if the countours shown are right. Even in this case, the deeper reflections are better and they usually follow the general slope of the upper horizon.

c/ As far as change in thickness is concerned it has previously been stated that the gypsum beds in the Stryj area must be at least 50 m thick in the"middle zone" and are only 15 m thick in the "Premier" well near the bo-undary. On the other hand the underlying sandstones being of small thickness in the "Premier" well would increase in thickness towards the south at the cost of shales and clays which are interbedded with them. Thus one may have to deal with lateral alteration within the beds such as changes from shales to sandstones and these changes within the contact zone may be fairly rapid analogous to those observed in the Tortonian formation in the Daszawa gas field area.

d/ Coming to the last point which is the deterioration of the reflecting horizon itself it may be assumed that at the place where the gypsum beds change their slope there must also exists an area of cracking as the gypsum is of high rigidity and therefore sufferes disruption more easily than is the case with salt or limestone. Dismembering of the gypsum beds into individual thin beds, separated by rapidly thickening sand and sandstones leads to the conclusion that lateral changes of the lithological nature have occurred within the bed. If oil is to be accumulated here, the zone of this accumulation may begin from the place where the deterioration and attenuation of the marker horizon is revealed, the most likely place for this accumulation being the southern flank of the step encountered first. Nevertheless, these accumulations may also occur in the synclines further to the south, where among the sand and sandstone of the Cretaceous formation these oil accumulations may be trapped.

The existence of a suitable condition of sedimentation as well as a favourable structure are not alone sufficient for the presence of oil deposits of economic value. There must also exista favourable condition for conservation at the time and place of origin together with preservation during subsequent geological periods. According to the known facts the oil formations in sand and sandstones are less easily destroyed /by erosion, tectonic movements,etc./ than limestone formations. Both kinds of deposits , as has been said, may be expected in the Cretaceous and Paleozoic formations of the foreland. In the Stryj area and in the Daszawa area one may have sandy oil formations, while in the Kosow area limestone oil formations may prevail. If this is the case, then the fissured limestones being more permeable and forming deposits covering widely spread areas may not have been able to preserve oil so well as the sandstones which usually form lens-shaped deposits of smaller area, and therefore not so liable to destruction. Whatever is the case some preservation must have occurred, if one assumes that the rich gas depposits are the result of the migration of hydrocarbonds from the south towards the north. Moreover, the preservation of these deposits during the following geological periods was also assured by the existence of the thick mantle of marly Stebnik beds, in which no hydrocarbons have been found and which to the present knowledge have preserved the existing gas deposits.

Final conclusions concerning the seismic prospecting of zones suspected of forming stratigraphical oil traps.

From a study of the bedrock of the Creataceous age underlying the Tortonian formation, the latter overthrust by the Stebnik beds, the following observations and inferences were obtained:

1. The unconformity between the Cretaceous and the Tortonian formation.

2. A slightly folded structure in the Cretacesous bedrock formations.

3. Probability of lateral lithological changes within the rocks of the Cretaceous.

Assuming that the premises considered in previous pages are right, then the area south of the boundary

Fig. XV-1

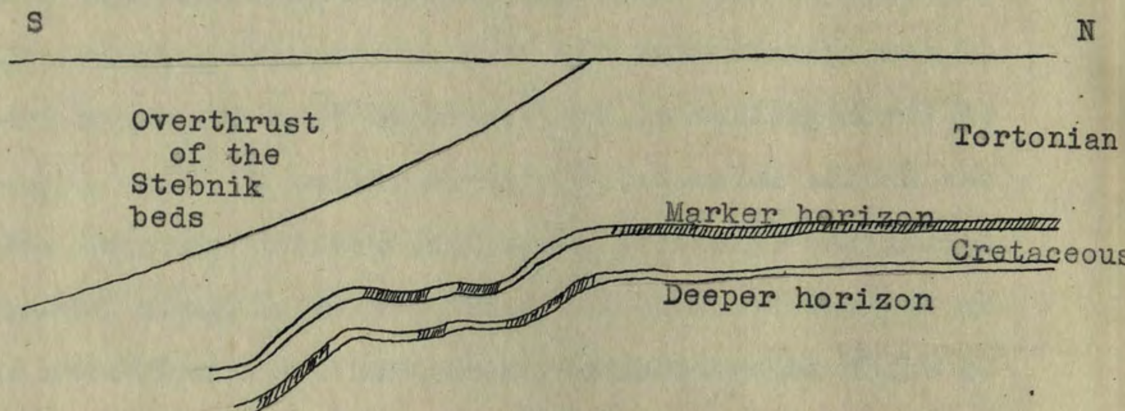
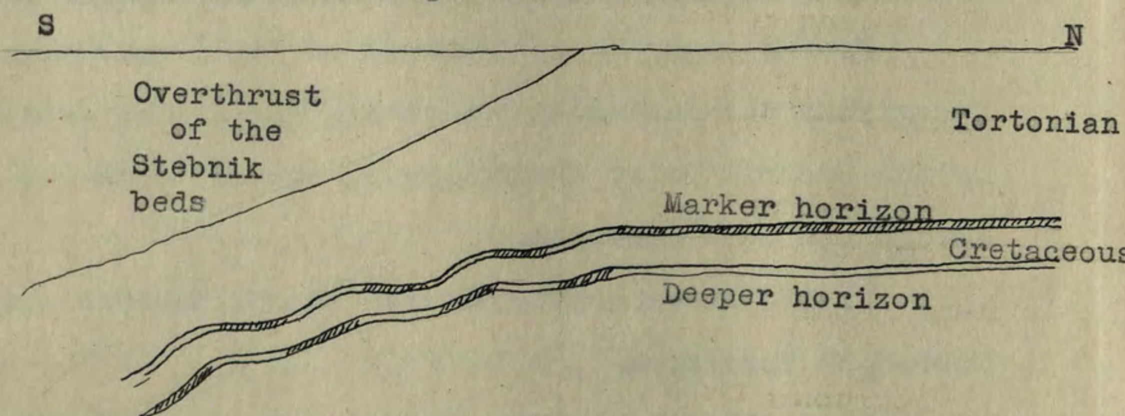


Fig. XV-2.



considered, should be regarded as highly promising from the point of view of oil accumulation.

Fig.XV-1 and 2 give two probable sections across this zone from S to N. In the first fig. a series of folded steps is assumed to be present, while in the second a series of slight undulations with their amplitude growing towards the south. In both cases the bedrock is gradually plunging towards the Carpathians.

A suggested plan for the reflection work should comprise:

1. A study of the structure of the bedrock, revealed by the deep reflections. This could be done by a thorough observation of the slopes shown by the reflections.

2. A study of the changing character of the deep impulses reflected. The latter according to the considerations previously given, should improve in the deeper parts of the bedrock alternatively as the upper reflections deteriorate or attenuate, in places shown by shading in both figures.

A survey therefore would include a dip-shooting supplemented by a thorough correlation of the reflections over a continuous line of geophones. 12 to 24 geophones strung along between two shot-points on a spread 0-350 m would be necessary.

A reflection survey of this kind should be supplemented by a refraction shooting, the purpose of which would be to locate the exact situation of the line of the overthrust on the surface of the ground /under the Diluvial sediments/, if this line is not located by a previous geologi cal survey. Refraction surveying should also be carried out on a continuous line towards the south with the same length of the traverses, in order to disclose the changes in the average velocity caused by the gradual thickening of the Stebnik overthrust. To what extent it will be possible to carry it out, would be shown by the survey itself, and it is difficult to draw any definite conclusions at the present time.

The study of the character of the deep reflections, if all the interfering factors are taken into account, may, give a satisfactory answer as far as the lithological changes within the same beds are concerned. As shown in Fig.XV-1 and 2, better marker reflections could be registered on flat portions of the structures, while deeper reflections would be more outstanding on the remaining parts. These changes would not occur rapidly. The alter - nating accentuation and attenuation of the reflections would occur gradually, and therefore the observation should include besides dip-study a thorough investigation of the character of these reflections, that is to say, their first phase, their amplitude, their number of cycles and their damping factor. Good deep reflections may split into two or more small impulses separated or not by a distinct change of phase.

This study therefore shoudl be conducted along a straight line with the same spread of geophones analogous to that proposed for the observations of shallow reflections in the Daszawa gas field area /p.135/.

The present knowledge of the energy distribution, permits only the time of the reflections to be picked up and the depth and dip of the reflected horizons to be computed. Still very little is known about the absolute value of the character of the reflection. Therefore, on the basis of the observed variations in the character of these reflections, it is probably impossible to discover the absolute thickness and lithological character of the reflecting beds. Nevertheless, the relative changes, observed on several parallel lines across the zone considered, and the repetition of the same phenomena along the same line in the same direction, if plotted on a map together with the strustures revealed by dip-shooting, should be able to a certain extent to disclose areas which could be interpreted as the most suitable for oil accumulation of the stratigraphical type.

R e f e r e n c e s:

in Polish:

22. S.Zuber: "Zarys możliwosci regionalnych poszukiwan w Polsce" Przemysł Naftowy ,1938.Z.XII. str.305.

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This part contains 37 figures and 10 plates.

ACKNOWLEDGMENTS.

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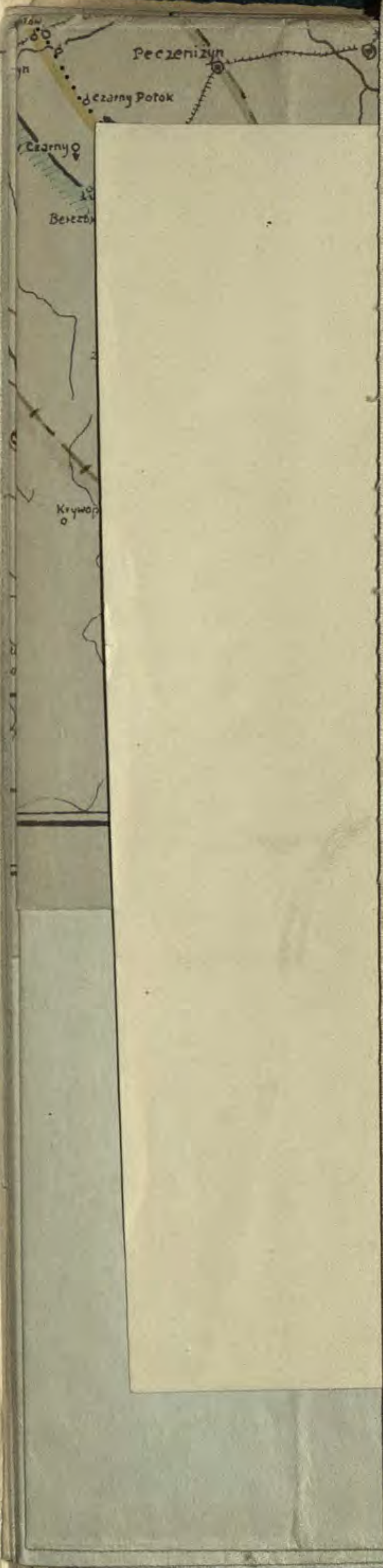
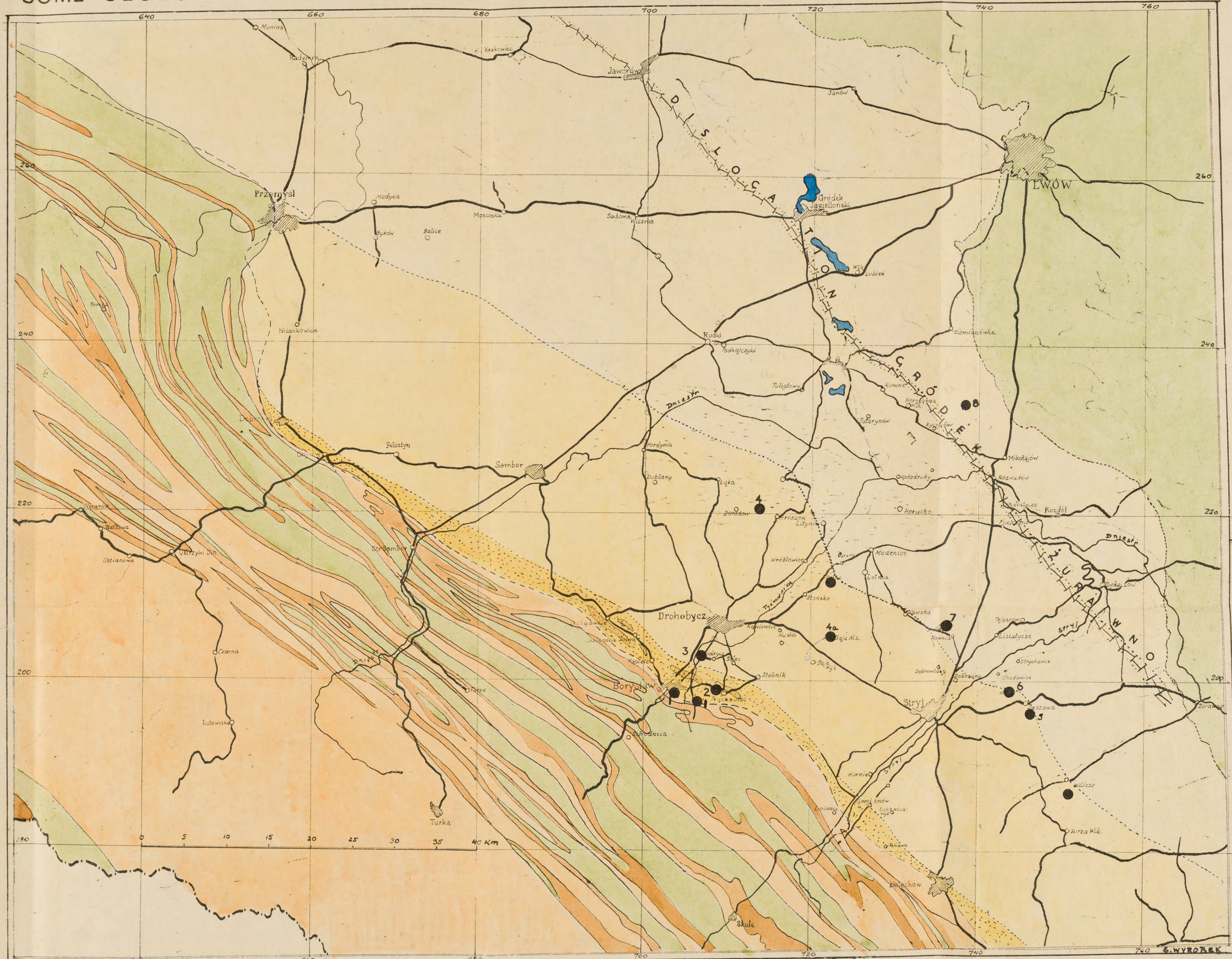

Peczenizyn
Czarny Potok
Czarny


CARPATHIAN AND FORELAND'S OIL AND GAS FIELDS
OBSZARY NAFTOWE I GAZOWE POLSKI
w Karpatach i na przedgórzu
KARPACKI INSTYTUT GEOLOGICZNO-NAFTOWY
W BORYSŁAWIU
Skala - Scale
SEISMIC PROSPECTING IN THE CARPATHIAN
AND FORELAND'S AREAS FROM 1934 TO 1939.
OBJAŚNIENIA
Klippen zone
Magura zone
Suboutcrops of the gypsum bedrock
Stebnik overthrust
Salt formation
Central Depression
Oil fields
Oil mines
Natural Gas field
Research wells
Natural wax mines
SAINT-CROSS MOUNTAINS
KRAKOW PLATEAU
LUBLIN PLATEAU
PODOLIAN PLATEAU
CZECHOSŁOWACJA
KRAKÓW
LWÓW
STANISŁAWÓW
KOPALNIE
NAFTOWE I GAZOWE
W KARPATACH I NA PRZEDG.
GRAVITY-MAP OF
THE CARPATHIAN FORE-
LAND
Anomalie
Gravity countours in miligals
with the Bouger's correction
OBJAŚNIENIA
D.S.H. DIP-SHOOTING
COR. CORRELATION
REFLECTION PROFILES
R.F.L.R. RECONNAISSANCE REFLECTION
R.F.L.D. DETAILED CORREL. REFLECTION
R.F.R. REFRACTION PROFILES
carried out by
PIONIER CO.
in 1934-1939
D.S.H. DIP-SHOOTING CONT. PROFILING
R.F.R. REFRACTION CONTIN. PROFILING
R.F.L. DETAILED CORR. REFLECTION
R.F.R. DETAILED CORR. REFRACTION
carried out by
GEOTECHNIKA CO.
in 1938-1939

SOME GEOLOGICAL DATA OF THE SOUTH EASTERN POLAND. PLATE 2.



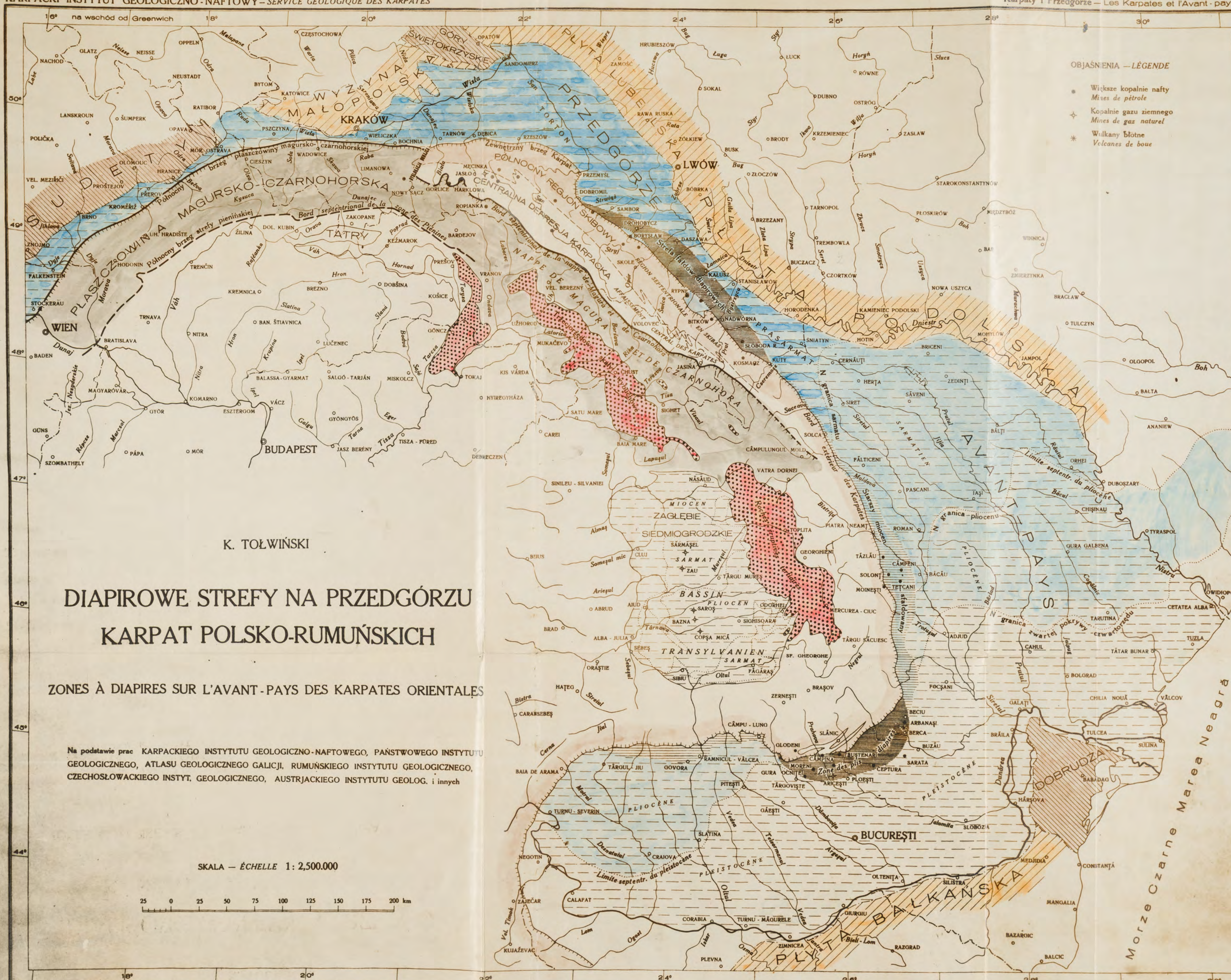
CRETACEOUS | EOCENE | OLIGOCENE
OF THE THE CARPATHIANS

SALIFEROUS BELT | STEBNIK BELT | TORTON BELT
OF THE FORELAND'S MIOCENE

CRETACEOUS
OF THE POD. PLAT.

● 1, 2 Research wells ● 3 4 5 6 R.w. ● 7, 8 R.W.

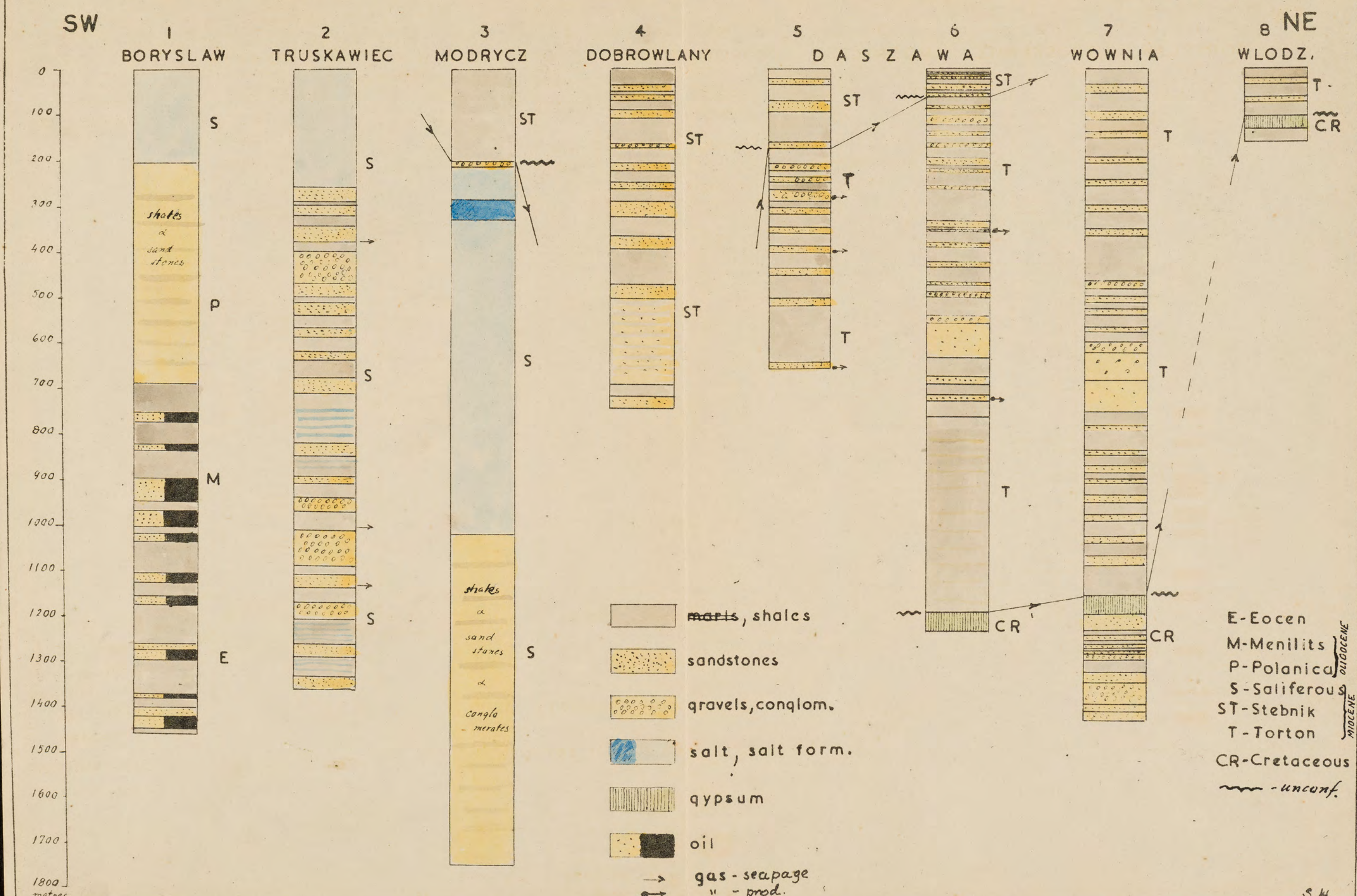
KARPACKI INSTYTUT GEOLOGICZNO-NAFTOWY – *SERVICE GÉOLOGIQUE DES KARPATES*

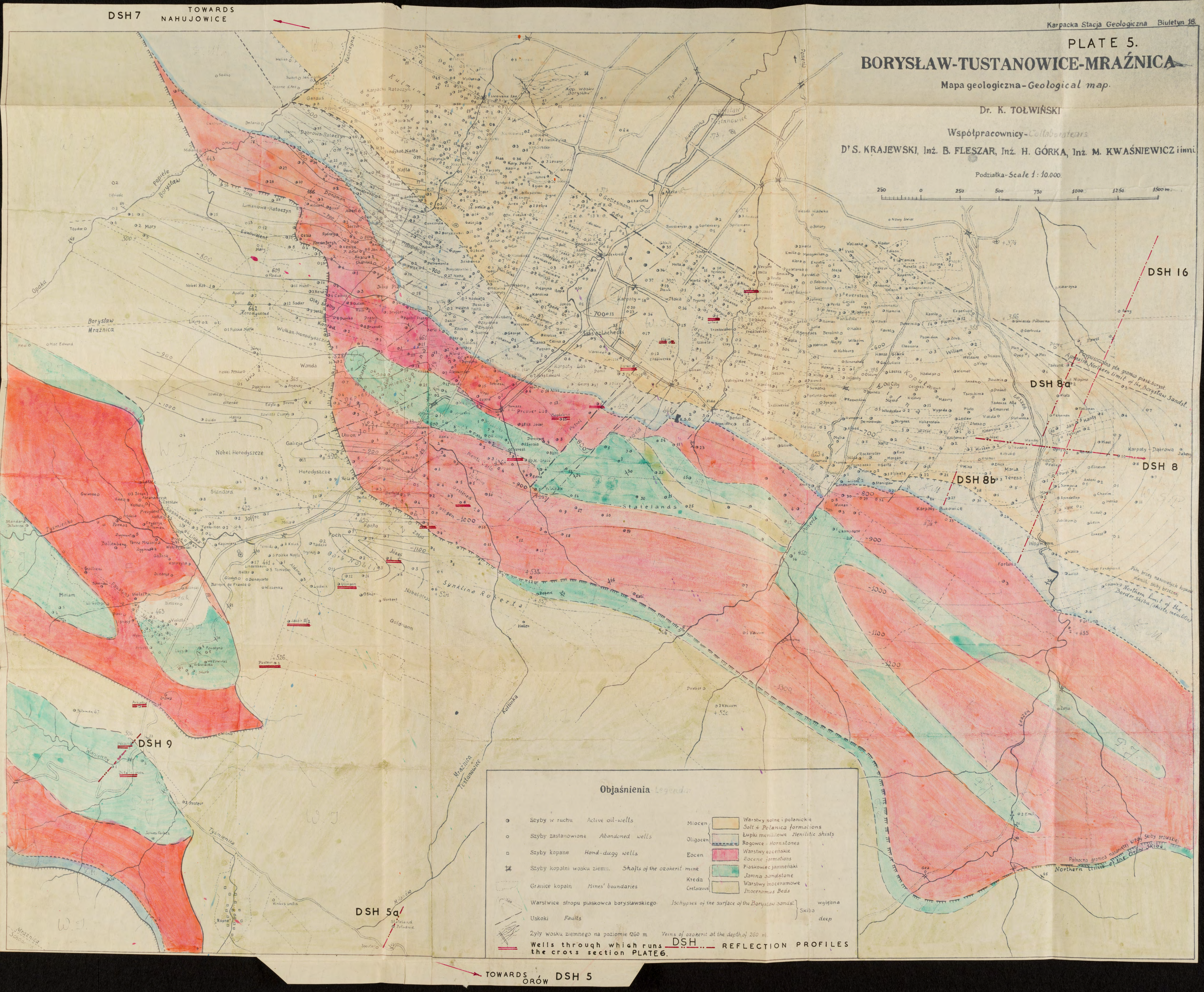


1935

Odbito w Zakl. Graficznych KSIĄŻNICA-ATLAS S. A. we Lwowie

PLATE 4.


SW
NE
1 BORYSLAW
2 TRUSKAWIEC
3 MODRYCZ
4 DOBROWLANY
5 6 DASZAWA
7 WOWNIA
8 WLODZ.
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
metres
S
P
M
E
shales & sand stones
shales & sand stones & conglo-merates
ST
T
CR
marls, shales
sandstones
gravels, conglom.
salt, salt form.
gypsum
oil
gas - seapage
" - prod.
E-Eocen
M-Menilits
P-Polanica
S-Saliferous
ST-Stebnik
T-Torton
OLIGOCENE
MIOCENE
CR-Cretaceous
- unconf.
S.W.


DSH 7
TOWARDS NAHUJOWICE
Karpacka Stacja Geologiczna Biuletyn 18.
PLATE 5.
BORYSŁAW-TUSTANOWICE-MRAŹNICA
Mapa geologiczna - Geological map.
Dr. K. TOŁWIŃSKI
Współpracownicy - Collaborateurs
D'S. KRAJEWSKI, Inż. B. FLESZAR, Inż. H. GÓRKA, Inż. M. KWAŚNIEWICZ i inni
Podziałka - Scale 1 : 10.000
250 0 250 500 750 1000 1250 1500 m.
DSH 16
DSH 8a
DSH 8
DSH 8b
DSH 9
DSH 5a
Objaśnienia Legenda
Szyby w ruchu Active oil-wells
Szyby zastanowione Abandoned wells
Szyby kopane Hand-dugg wells
Szyby kopalni wosku ziemn. Shafts of the ozokerit-mine
Granice kopalń Mines' boundaries
Warstwice stropu piaskowca borysławskiego Ischypses of the surface of the Borysław sandst.
Uskoki Faults
Skiba wgłębna deep
Żyły wosku ziemnego na poziomie 260 m Veins of ozokerit at the depth of 260 m
Miocen
Oligocen
Eocen
Kreda Cretaceous
Warstwy solne i polanickie Salt & Polanica formations
Łupki menilitowe Menilitic shists
Rogowce - Hornstones
Warstwy eoceńskie Eocene formations
Piaskowiec jamneński Jamna sandstone
Warstwy inoceramowe Inoceramus Beds
Wells through which runs the cross section PLATE 6.
DSH REFLECTION PROFILES
TOWARDS ORÓW DSH 5

GEOLOGICAL SURVEY OF THE CARPATHIANS. K. TOŁWINSKI.

CROSS-SECTION THROUGH THE BORYSLAW OIL-FIELD AREA

Scale 1 : 20,000

PLATE 6.

SEISMIC PROSPECTING BY THE REFLECTION METHOD

PLATE 7.

RESULTS OF SEISMIC REFLECTION PROSPECTING IN CARPATHIAN FORELAND OF DROHOBYCZ-STRYJ-MIKOLAJOW AREA
Scale 1:100,000
0 1 2 3 4 5 6 7 8 9 10 km
Contours of the "marker" horizon
Contours of the content of soluble bitumen
see fig. XII-3.
DSH. 10.
DSH. 7.
DSH. 16.
DSH. 6.
DSH. 8
DSH. 4.
OVERTHRUST OF STEBNIK-BEDS
DISLOCATION GRODEK-ŻURAWNO
OUTCROPS OF PODOLIAN PLATEAU
'WOWNIA' HORST
DROHOBYCZ
BORYSŁAW
STRYJ
PREMIER I.
U. POLMIN I.
see PLATE 7.
see PLATE 10.
Dniestr
Stryj
Bistrzyca
Bronica
Dobrowlany
Rolow
Litynia
Wola
Jakubowa
Rabczyce
Opary
Wroblowice
Lipowiec
Dothe
Medenice
Letnia
Joselsberg
Königsau
Kawsko
Michałowice
Słońsko
Dołwa
Neudorf
Bolechowce
Gaje Niżne
Gaje Wyżne
Stebnik
Solec
Modrycz
Truskawiec
Tustanowice
Dabrowa
Mraźnica
Dereżyce
Jasienica Solna
Uniatycze
Lisznia
Stara Wieś
Ruchcice
Waconice
Radelicz
Horucko
Rudniki
Krynica
Bilcze
Las Bilczewski
Woods
Brygidyn
Nadiatycze
Piaseczna
Czernice
Rozdół
Kijowiec
Demenka Leśna
Derżów
Iwanowce
Turady
Cucułowce
Tejsarów
Pietruczany
Lisiatycze
Kawczy Kąt
Pukienicze
Wownia
Pcczany
Pokrowce
Stryhańce
Hnizdyczów
Ruda
Manowce
Żyrawa
Żurawno
Nowe Siolo
Łysaów
Dobrowlany
Dobrzany
Uliczno
Gnidowice
Tatarsko
Komarów
Golrendorf
Kozicze
Podhorce
Olesnice
Daszawa
Nierczany
Juseptycze
Mikolajow
THE CARPATHIANS
THE SALIFEROUS
THE FOLDED BELT OF STEBNIK SERIES
THE TORTONIAN BELT
A
B
B
C
J. Hyrtek

SEISMIC REFLECTION CROSS SECTION along STRYJ-MIKOLAJOW road

PLATE 8.

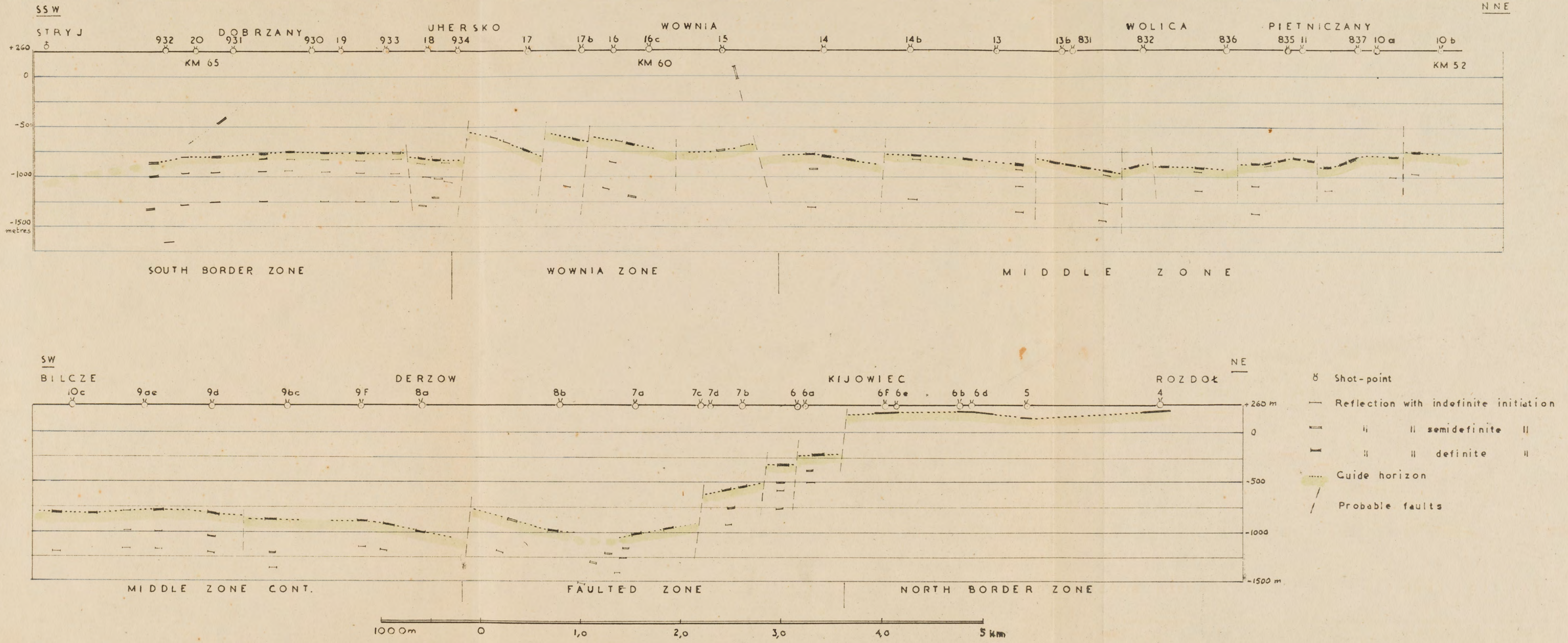
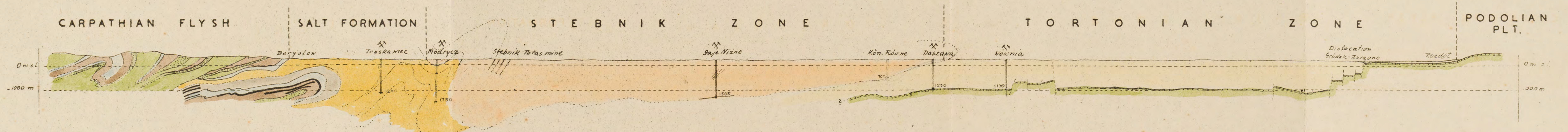


PLATE 9.

SW | NE

GEOLOGICAL SECTION ACROSS THE CARPATHIAN FORELAND

— SOUTH-EASTERN POLAND —



Cretaceous — Sandstones; Gipsum, Anhydrites

Eocene — Oil; Shales, Sandstones

Oligocene — Menilit Shales, Oil sandstones

Upper Oligocene — Polanica beds

Aquitanian — Salts, Shales, Sandstones, Conglomerates

Helvetian — Sandstone, Salt, Shales, Marls

Tortonian — Marls, Gravels, Shales, Sand & Sandstone

Scale 1:100,000