Pre-Feasibility Study Report on The Coal Development Project at The Offshore Area of Zonguldak Coal Field in The Republic of Turkey

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Japan International Cooperation Agency

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PREFACE

In response to the request of the Government of the Republic of Turkey, the Government of Japan decided to conduct a Preliminary Feasibility Study on the Zongldak Off-shore Coal Mine Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Turkey a 7-man survey team headed by Mr. Masaaki Inoue from March, 1981 to March, 1982.

The team exchanged views with the officials concerned of the Government of Turkey and conducted a field survey in Zongldak coal field. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Turkey for their close cooperation extended to the team.

Tokyo, September, 1982.

Keisuke Arita

President

Japan International Cooperation Agency

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Note: * — Separate Volume

I. SUMMARY AND RECOMMENDATIONS

I. SUMMARY AND RECOMMENDATIONS

1. SUMMARY

1-1 As the working area of the Kozlu coal mine reached to the offshore area in its northwestern part at the working level of below sea level (b.s.l.) 425 m., and also the main coal seams, especially the upper seams, had started to be truncated by the Simal fault in near future possibly at about b.s.l. 700 m. for the Sulu seam, the exploration of the geological structure of the coal bearing Kozlu formation in the offshore area became one of the most essential and urgent subject in this mine.

In order to solve the above-mentioned subject, the drilling exploration at the present underground level in the Kozlu mine and also in the offshore area would be the most appropriate methods to be taken. However, the drilling exploration in the offshore area is very costly because the employment of the big offshore rig for petroleum exploration would be required due to the abrupt deepening of the Black sea. Then, the indirect exploration method, i.e. geophysical exploration, has to be applied for the exploration in the offshore area.

1-2 After the in-depth consideration and the following experimentations, the following measures had been taken eventually:

A. Two horizontal (+5°) drilling operations, No. 1 hole (62.56 m.) and No. 2 hole (120.6 m.), were carried out at the end of b.s.l. 425 m. 22926 gallery and succeeded to verify the geological structure beyond the Simal fault.

B. As it seems very difficult to obtain the geological structure only from the seismic reflection survey due to the existence of thick limestone formations directly above the coal bearing formations, a kind of synthetic method had been employed by compiling the results of various geological and geophysical surveys, such as seismic reflection survey, velocity survey by refraction method, magnetic and gravity survey, etc.

1-3 The final results obtained according to the above-mentioned various exploratory surveys are summarized as follows:

A. Regarding the underground drilling exploration in the Kozlu coal mine;

(1) As the coal bearing Kozlu formatior have been thrown by the Simal fault at

about 600 to 700 m. long and also be standing steeply (60° to 70°) toward the north, only the one coal seam, Büyük seam which is the upper most working seam in this mine, would be expected to be workable in the area from b.s.l. 500 m. to 1,000 m.

(2) Based on the geological data in hand, a total of approximately 6.3 million metric tons of probable coal reserves in place was computed tentatively but it must be confirmed by underground drilling to be conducted from each working level when it is lowered.

B. Regarding the geophysical exploration at offshore Zonguldak area;

Through the repeated trials to improve the quality of seismic reflection data, it was a remarkable result of successfully eliminating the visible refraction multiples from the processed reflection sections. And also, the employment of various geophysical methods on obtaining the necessary geological and stratigraphical data in order to supplement the insufficient reflection events on the seismic reflection sections would be worthy of mention as a special technique in this case.

For example, these methods are a) introduction of velocity informations obtained from the refraction method by using the first arrivals on the seismic reflection original record in order to estimate the rock facies at the sea floor less than 100 m. in depth; b) employment of magnetic intensity on identifying the high magnetic susceptibility bodies, such as the tuff breccia of Senomanian and Coniacian stages in the offshore area; and c) adoption of gravitational anomaly for estimation the feature of dense structural bodies and the possible location of fault zones, etc.

The main topics have been described in the following:

(1) Two events, horizons green and brown, were picked up from the seismic reflection processed sections and the general geological structure in the offshore area was estimated from especially the green horizon's structure showing the monoclinic structure going down to the north at an average dip of 30 to 40 degrees.

(2) The area near the coast was interpreted by compiling various data, such as velocity data at sea floor less than 100 m. deep, magnetic intensity anomalies along the coast, and gravity anomalies, etc.

Then, at least, the following geological zoning of sea floor was carried out in the offshore area:

(a) To delineate the possible Santonian-Coniacian tuff breccia formations based on the magnetic anomaly zone and the 4 km/sec velocity line at sea floor;

(b) To estimate the northern boundary of limestone formations along the coast line referring the non-magnetic zone adjacent to the south side of the magnetic high anomaly zone.

(3) Under the assumption of average velocities of horizones green and brown at 2 km/sec and 4 km/sec, the stratigraphical horizones of green and brown were estimated to nearly the upper most part of the Cretaceous system, possibly the top of Campanian Biotite andesite formation, and nearly the basal part of the Coniacian tuff breccia formation, respectively. The structures of green and brown horizons plotted in the geological sections are in comparatively good accord with the above-mentioned stratigraphical horizons made by onshore geological data, e.g. stratigraphical successions and the thickness of each formation.

(4) The coal reserves to be developed which would be less than b.s.l. 1,000 m. are existing near the coast, not more than 500 m. off the coast line. The exploratory drilling program would be reviewed in the future.

2. RECOMMENDATIONS

2-1 Underground Exploratory Drilling at Kozlu Mine

Regarding the underground exploration for the coal bearing formation beyond the Simal fault in the Kozlu mine, the following exploratory program would be recommended:

(1) In order to confirm the minability of the Büyük seam, the underground horizontal (+5°) drilling from the cross cut galleries of each level below the estimated depth, e.g. b.s.l. 550 m. at 22925 section, would be necessary over its expected developing area.

(2) With regard to the underground drilling, the closer to the Simal fault is better with its rig site and also the bigger is better with its guide pipe to penetrate the wide disturbed fault zone.

(3) For the better safety measure of driving cross cut into the Simal fault, pre-gas-extraction drillings, including water seepage sounding, would be preferable so as to extract gas and water by the drill holes conducted in the shape surrounding the gallery to be driven.

2-2 Geophysical Exploration in the Offshore Zonguldak Area

For the future geophysical exploration, the following items would be recommended to improve the quality of the results:

A. Regarding the seismic reflection survey, the following modifications of its specifications would be recommended with the future survey:

(1) Use of longer streamer cable, such as 1,200 m. or sometimes 2,400 m. one, so as to possibly obtain more accurate velocity study after the sufficient experimentations.

(2) Employment of bigger acoustic energy for air gun, e.g. a total volume of 700 cubic inch at more than 2,000 psi pressure, to obtain true events as many as possible. To determine the most adequate source energy, an experimental study will be necessary prior to the routine survey.

(3) Adoption of laser beam type display unit with transparent film will be necessary to improve quality of the final section.

(4) Application of long air gun array for better penetration of energy into the formations.

(5) Introduction of the wavelet processing technique as well as conventional deconvolution filters would be recommendable.

B. For the identification of faults and fractured zones at the sea floor from the low elastic velocity data, it would be desirable to increase the survey lines in order to have closer spacing, i.e. 500 m. interval or less.

2-3 Training of Drilling and its Related Techniques in Japan

The transfer of the horizontal drilling techniques by using Koken's EP-1W drilling machine seems to be nearly completed during the on-job training of 7 months period and the successive execution of No. 3 drilling at 22929 gallery in the Kozlu mine, but the further training of the responsible staff from E.K.I. would be recommendable with the overall drilling techniques, especially with the mud making-up, and the other geological sounding techniques related to the drilling which is including various logging techniques and analyses of drilling cores, etc.

II. GENERAL

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1. OBJECTIVE OF THE STUDY AND THE CONTENTS OF WORK

In response to the request of the Government of the Republic of Turkey (hereafter called the Turkish government), this study aims at cooperating with the Turkish government in the exploration of the offshore Zonguldak coalfield located off the northwestern part of Turkey through geophysical surveys, geological surveys and drillings to obtain the basic information about the geological conditions of the offshore area, to confirm the coal reserve in some part and to collect and arrange in order the basic data necessary for the planning of exploration and development of the coal mine.

The area to be explored is the Zonguldak coalfield in the northwest of the country and its surrounding area. The main objectives of the study are based on the "Scope of Works" (hereafter called S/W) which was signed between the Turkish governmental organization and the Preliminary Survey Mission from Jica consisting of six members of specialists headed by Mr. Toshiatsu Bojo (hereafter called the survey mission) in February 1980, which was later revised according to the results of the 1981 Pre-Feasibility Study conducted by Mr. Masaaki Inoue and his six members in March 1981.

The contents of the works are as follows:

1-1 Technical Guidance for Exploratory Drilling in Galleries

a) To receive and assemble the drilling machine "Koken EP-1" transported from Japan at Kozlu mine and to drill (vertical drilling) on the ground, in order to instruct the Turkish trainees how to operate the drilling machine and its auxiliary equipments.

b) To instruct the installation of the drilling machine together with the safety equipment in the gallery and then to introduce the technique of underground horizontal drilling.

1-2 Technical Guidance of Analyses and Interpretations of the Geophysical Survey Results

a) Computer processing – stacking – of the reflection records (A total of 200 line km)

To instruct the stacking method by using MTA's computer for processing the reflection data which were obtained by MTA's survey boat SISMIK-1 in accordance with the specifications which were signed between JICA and MTA in March 1981 at the Pre-Feasibility Study based on the proposal from JICA to run a 200 line km of survey line for seismic survey.

b) To instruct how to distinguish primary reflections from other events in the seismic sections obtained from the method a), and how to analyze the distribution of these primary reflections and finally how to conduct a geological interpretation on the above.

c) To instruct the refraction analysis to examine rock facies at sea floor.

d) To instruct the analyses of gravity and magnetic records ncluding the onland data.

1-3 Geological Survey

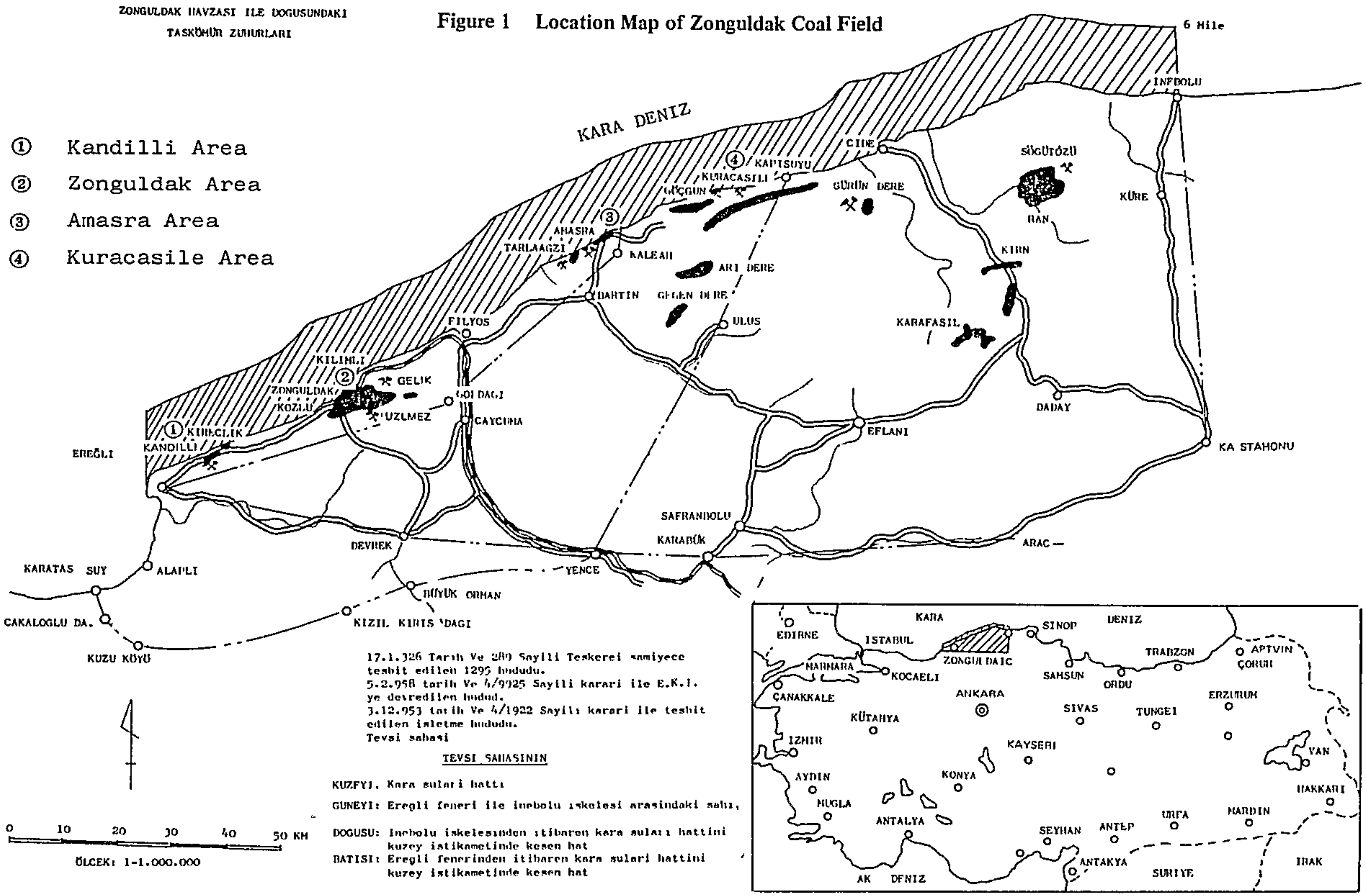
a) To conduct a field geological survey on land area to draw up a geological map and profiles covering the whole area to be explored.

b) To conduct the underground geologic survey in the Kozlu mine including the core sample analysis for interpretation of the data from drilling operations in the mine.

In fiscal year (fy) 1979, at the start of this project, the Republic of Turkey produced approximately 16 million tons of coal in total, of which 4 million tons were hard coal (sub-bituminous to bituminous coal) and 12 million tons were lignite (brown coal). Hard coal has been produced from five mines in the Zonguldak coalfield and used for the metallurgical use in the iron works. However, in the two major mines of the Zonguldak coalfield, such as the Kozlu and the Amasura mines, the mining operation has moved into deeper zones in recent years and partly already into the offshore area. And it has been felt essential to study the feasibility of coal development in the offshore area.

Among various prospecting methods in a coal field area, drilling gives the most accurate and most desirable information on interpreting geologic conditions. However, the drilling operation in the offshore area costs higher than that on land. When the water depth at the drilling site is very shallow, the operation cost is not so high because it needs extra expense only for the derrick that must be constructed at the sea bottom and other incidental works compared with the operation on land. But the Black Sea deepens sharply immediately from the coastline and it is required to use an offshore oil drilling rig for the deep sea in order to conduct the exploratory drilling operation, which requires a huge amount of money. To avoid such an extravagant spending, an idea has been introduced using the techniques and methods of geophysical surveys for offshore oilfields in combination with the underground exploratory drilling for the purpose of prospecting the statuses of the coal-bearing formations and coal deposits.

Figure 1 Location Map of Zonguldak Coal Field



2. HISTORY OF THE INVESTIGATION

The background of this study has been briefly described in the previous section. At the beginning, the Turkish government in 1977 requested Japan to cooperate in developing the offshore Zonguldak coalfield with her long and rich experiences and the successful results in the offshore coalfield development in her country.

The request for cooperation included supply of equipment and dispatch of two experts (geology, geophysics, mining) to Turkey for two years. They were, according to the Turkish government, necessary for conducting the feasibility study on the coal development project in the offshore Zonguldak coalfield to grasp the potential of the coal deposits in the offshore area as well as to prepare the coal mining program.

Prior to that, a geophysical exploration (1970)(1) off Kozlu and a survey of the Kozlu Coal Mine (1976)(2) had been carried out between the Republic of Turkey and Japanese private enterprises.

After deliberation over the above situation and the contents of the request of the Turkish government, JICA first dispatched two experts – Mr. Toshiatsu Bojo (geologist) and Mr. Hiroji Tsu (geophysicist) – to Turkey from February to May in 1979 for the purpose of overall evaluation of the existing basic data (geological, geophysical and drilling) concerning the offshore Zonguldak coalfield development. The results of the above study came out in October 1979 as the "Technical Cooperation Report on Exploration Offshore Area of Zonguldak Coal Field, Turkey" by JICA.

The report concluded that on the whole the offshore prospecting of the Zonguldak coalfield was still at the preliminary stage and that it was too early to give any reliable geological interpretation yet to the data obtained so far, in view of the complicated geological conditions on the adjacent land area. The report further suggested that in order to obtain the overall geological information in this sea area, the comprehensive surveys were required including not only seismic reflection method but also magnetic and gravity surveys over the sea area within a few kilometers from the coastline by using the survey boat of the Turkish government. Concerning the seismic reflection survey, in particular, the report mentioned that similar method could be taken as in the oil exploration, but that special attention would be required to select a proper energy source because of the existence of complex geological conditions as follows:

Note: (1) Hosono M. et al. (1970)
(2) Jin-nai A., Mitsui, M. (1976)

(1) The formations to be explored belong to the Palaeozoic system, and be covered with a considerable thickness (650 – 3900 m) of the Cretaceous system, which is presumably further covered with the Tertiary formations. Among these formations, the Palaeozoic and the Mosozoic are expected to bear fairly hard rock facies and to be dipping sharply.

(2) Limestones in the Mesozoic show higher velocities than the sandstones and conglomerates in the coal-bearing formations of the Palaeozoic.

The report further stated that the magnetic survey aimed at obtaining data of volcanic rocks in the upper Cretaceous and estimating their distribution status, and that the gravity survey aimed at acquiring the overall information of geological structure, especially of the lower Palaeozoic system. In addition, as a means of exploration in the offshore Kozlu mine, the report recommended to conduct long, horizontal test drilling at the galleries in the Kozlu mine to prospect the distribution of the coal deposits.

Based upon the above recommendations by JICA, MTA conducted an experimental offshore geophysical exploration off Zonguldak in June 1979, which was followed by data processing and analyses. However, due to the difficult geological conditions observed in this offshore area such as the existence of thick limestones overlying the coal-bearing formation and very steep dipping of the strata, sufficient seismic reflection record sections could not be obtained through MTA's previous conventional data processing, which forced MTA to suspend the seismic survey.

During February and March 1980, the 1980's Preliminary Survey Mission of six specialists including Mr. Toshiatsu Bojo as the team leader (geology - 1, geophysics - 3, boring - 1, and business management - 1) was dispatched from JICA to Turkey. Upon careful examination of the results of the above experimental operation by MTA such as the seismic reflection record sections and the data processing methods, the Preliminary Survey Mission concluded that the quality improvement would be possible with the use of the latest processing and analyzing methods and proposed reprocessing and reanalysis of these field data in Japan.

In the meantime, the Preliminary Survey Mission framed a future planning together with the Turkish governmental organization, which included examination of the existing data of the area under exploration, a rough field survey covering a part of the area, and other works to be done in achieving the given tasks. These programs were compiled into the "Scope of Works" (S/W) and signed between the two countries.

In accordance with this S/W, various field data were sent to Japan from MTA for re-examination and two geophysicists from MTA (Messrs. K. Eres and S. Kavukçu) came to Japan as trainees and were engaged in the analyses of the geophysical data together with the Japanese geophysicists from October 1980 to March 1981 (The training ended in December 1980).

This data reprocessing solved the pending problems to a considerable degree and its results verified the possibility of elucidating the geological structure of the area. While the reprocessing of the seismic reflection data was going on, the refraction results and gravity/magnetic data were examined at the same time. These reprocessing and reanalyzing of the geophysical data provided significant results useful for future exploration planning, which were compiled into "The Interim Report of Pre-Feasibility Study on the Coal Development Project at the Offshore Zonguldak Coal Field in the Republic of Turkey - Geophysical Study Section." (hereafter called "The Interim Report").

In March 1981, the 1981 Pre-Feasibility Study Team consisting of Mr. Masaaki Inoue and six members visited Turkey to report the results of the joint study mentioned above to TKI and MTA. Then, upon consultation with the Turkish counterpart, the mission laid down the specifications of the survey methods and their details for geophysical prospecting of the Offshore Zonguldak Coal Field to be conducted by MTA in fy 1981. Prior to that, the mission members visited SISMIK-1, MTA's geophysical survey boat, for inspection of the capacity of the boat, equipment, and instruments for measurements, and the ability of the geophysical engineers, etc. as the base for the next survey planning. Its summary titled "Proposals and Recommendations for the Specifications of the Geophysical Survey and their Analyses" was attached to the minutes of the conference between the Turkish government and the Japanese mission. Scheduled length of the seismic lines was approximately 220 km recommended by JICA. Including the supplementary lines required by MTA, the total length became approximately 500 km. The lines proposed by JICA were specified on the proposed location map.

Concerning the underground exploratory drilling in the Kozlu mine, detailed specifications for fy 1981 were laid down based on the data of the underground geologic conditions of the mine, with special attention to the safety measures against gas blowout and violent water seepage. According to the specifications, drill hole No. 1 was to start from the heading of the gallery No. 22926 (at 423 m BSL) and drill hole No. 2 from the heading of the gallery No. 22925, both of which were aimed at drilling in the direction of each gallery with a slight up dip of 5 degrees from horizontal line.

These plannings were fairly revised from S/W which had been laid down by Mr. Bojo and the members of the 1980 Preliminary Survey Mission. Especially the plan for underground exploratory drilling was extensively revised since S/W due to the new evidence on the geological conditions obtained at the Kozlu mine, which gave a different geological view and made the former scheme on drilling locations unavailable. (Originally, drilling was scheduled beyond the Simal Fault.)

3. THE 1981 FEASIBILITY STUDY

3-1 Outline of the Study

The 1981 Feasibility Study was conducted based on the operation plan which was drawn by the 1981 Pre-Feasibility Study Team in March 1981 after reviewing the development of the whole project. Its outline is as follows:

(1) Exploratory drilling in galleries

At the Kozlu mine, Zonguldak coalfield, the mining operation is presently underway at the depth of 425 m below sea level (BSL). Between the present working area and the area under the sea bed, there lies the Simal fault with presumably an extremely big throw. It is important to grasp the geological structure and distribution of the coal seams beyond this fault both for planning the coal development project in this whole area and for securing the future coal reserves in the Kozlu mine. However, in the shallow sea area near the coast, the seismic prospecting is difficult as well as expensive. Even if the survey is conducted, it would be difficult to obtain good seismic reflection records in case the formations beyond the fault are dipping steeply. Consequently, it became inevitable to operate the underground exploratory drilling in the Kozlu mine from the heading of the gallery No. 22926 at the –425 m level to confirm the geological structure and distribution of the coal seams beyond the Simal fault. For this purpose, a drilling machine "Koken EP-1" was transported from Japan to perform this drilling scheme.

As EKI's drilling engineers did not have the technique of long, horizontal drilling, two drilling specialists were dispatched from JICA (Mr. Masanori Hanada and Mr. Norihiko Kotani). They came to Turkey in March 1981 as members of the 1981 Pre-Feasibility Study Team and remained to train the Turkish engineers. At first they drilled a test hole of about 49.95 m in depth beside the Kozlu mine office and practiced the handling of the drilling equipment. Then, the drilling equipment was hauled into the heading of the gallery No. 22926 at the –425 m level for exploratory drilling. At first, it was scheduled to carry out one each horizontal drill hole (+5 degrees) at each gallery No. 22926 and No. 22925 at the depth of 425 m BSL, but as the heading of the gallery No. 22925 collapsed due to the strong earth pressure, two holes were conducted at the heading of the gallery No. 22926 by changing the direction of the second hole at 15 degrees westward.

(2) Offshore geophysical prospecting

MTA's survey boat "SISMIK -1" was used for geophysical prospecting at the offshore Zonguldak region. Based on the specifications (SPEC) for geophysical surveys (seismic reflection, seismic refraction, gravity, magnetic surveys and radio navigation system) and the program of survey lines signed between MTA and JICA in March 1981, MTA conducted the field survey and the results were processed by MTA's computer under the guidance of the Japanese specialists. It has to be attempted to elucidate direct signs of coal seams or coal bearing formations at the offshore area on the seismic reflection profiles obtained from the computer processing. However, due to the existence of thick limestones overlying the coal-bearing formation, it was assumed to be difficult to grasp the structural status of the coal seams by the seismic reflection data only. Therefore, comprehensive analyses and interpretations on various geophysical data were attempted, as follows: a) the velocity analysis by refraction method using the reflection records for assuming rock facies and the geological conditions at the seafloor (less than 150 m deep), b) the total magnetic intensity analysis for estimating the distribution of rocks with high magnetic susceptibility on the sea bed, and c) analyses of various gravity survey results on estimating the overall geological structure and locations of faults, etc.

(3) Surface geological survey

To ascertain the geological conditions of the onland area, surface geological survey was carried out, mainly of the outcrops on the national highway along the coast and its surroundings. As a result, the stratigraphy of all the strata from the Tertiary to the Palaeozoic was recorded.

(4) Other surveys

a) While the geological survey mentioned above (3) was underway, the magnetic susceptibilities of various rocks were measured on major outcrops as the basic data for analyzing the zones showing high magnetic susceptibilities in the offshore magnetic survey results.

b) In order to convert the processed seismic reflection sections (time sections) to the depth sections, it is desirable to have the data of either acoustic velocity logging in a deep well or of well-shooting. But there was no such data so far of the existing wells on land. Therefore, the in situ velocity survey by refraction method was conducted with the several fresh successive outcrops representing the various rock facies to be occurred at the sea bottom in the objective area.

(Its results would be a good reference at least for estimating the velocities of the rocks below the sea bottom.)

c) As the basic data for gravity analysis, important rocks were sampled and their densities were measured.

The survey results were reported every time to the Turkish counter organizations. After every discussion, necessary matters were recorded in the minutes for smooth business performance.

3-2 Personnel Constitution

The 1981 Feasibility Study Project covering various geological and geophysical surveys has been conducted by the members from the Dia Consultant Co., Ltd., which consist of one geologist, four geophysicists (seismic reflection analysis and processing, interpretation of seismic reflection profiles, refraction data analysis and gravity/magnetic analysis) and two drilling engineers.

The members were dispatched to the survey site in five stages in accordance with the progress of the survey program.

The assigned duties and the survey period of the members are as follows:

Table 1 Personnel Constitution and the Survey Period

Name	Duties	Survey period
Masaaki Inoue	Leader, Geology	2nd : Jul. 26 – Aug. 24, '81 4th : Nov. 4 – Nov. 28, '81 5th : Jan. 5 – Jan. 24, '82
Kiyoshi Mori	Member Geophysics (seismic reflection)	5th : Jan. 5 – Feb. 16, '82
Katsuichi Nakajima	Member Geophysics (seismic reflection)	3rd : Aug. 30 – Oct. 29, '81
Hirosuke Ohbayashi	Member Geophysics (refraction)	5th : Jan. 5 – Mar. 20, '82
Kuniyuki Katayose	Member Geophysics (gravity & magnetics)	5th : Jan. 5 – Mar. 20, '82
Masanori Hanada*	Member Exploratory drilling	1st : Mar. 21 – Nov. 20, '81
Norihiko Kotani*	Member Exploratory drilling	1st : Mar. 26 – Jul. 31, '81

* Messrs. Hanada and Kotani were on duty continuously from the 1980 Pre-Feasibility Study.

3-3 Survey Program

As mentioned above, the 1980 Survey covered various aspects of exploration and was conducted from April 1, 1981 to March 20, 1982 in five stages in compliance with the requirements of individual survey. The total working days by the team members were 687 days.

Table 2 The 1981 Feasibility Study Program

Team	Name and period		Objective
1st team	Hanada:	Mar. 21 – Nov. 20, '81 (45 days)	Exploratory drilling in the Kozlu mine
	Kotani:	Mar. 26 – Jul. 31, '81 (128 days)	
2nd team	Inoue:	Jul. 26 – Aug. 24, '81 (30 days)	Analyze drilling data of Kozlu mine (incl. drilling termination of No. 1 Well)
	Hanada:	as mentioned above	Geological survey and magnetic susceptibility measurement at the east of Zonguldak.
3rd team	Nakajima:	Aug. 30 – Oct. 29, '81 (61 days)	Seismic reflection data processing (with MTA's computer)
4th team	Inoue:	Nov. 4 – Nov. 28, '81 (25 days)	Analyze drilling data of Kozlu mine (incl. drilling termination of No. 2 Well)
	Hanada:	as mentioned above	Geological survey and magnetic susceptibility measurement to the west of Zonguldak.
5th team	Inoue:	Jan. 5 – Jan. 24, '82 (20 days)	Velocity measurement Seismic reflection data analysis & interpretation
	Mori:	Jan. 5 – Feb. 18, '82 (45 days)	Seismic reflection data analysis & interpretation
	Ohbayashi:	Jan. 5 – Mar. 20, '82 (75 days)	Velocity measurement Interpretation of undersea geological condition by refraction method
	Katayose:	Jan. 5 – Mar. 20, '82 (75 days)	Analysis of gravity/magnetic record

III. SUMMARY OF EACH WORK

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III. SUMMARY OF EACH WORK

1. SURFACE GEOLOGICAL SURVEY

Geological survey was conducted on the route along the coastline to study the geological structure, the stratigraphy and the magnetic susceptibilities of main rocks on land area referring to the offshore area to be explored. Its results, as summarized below, turned out to be useful for interpretation of the geophysical survey results.

(1) The geological map on the scale of 1 to 50,000 drawn by MTA is quite accurate except for a few errors and can be used for extensive regional geological interpretation.

(2) The result of the stratigraphical and structural study of mainly the Cretaceous system shows:

(a) Formations of the Cretaceous system surround the anticlinal group (Amurtçuk Anticline, Kozlu-Karadon Anticline, Amasura Anticline from the west) running in the direction of ENE-WSW almost parallel to the coastline with its center at Zonguldak city. These Cretaceous formations are traceable almost all over the area only with regional differences in their development.

(b) The Cretaceous stratigraphy was clarified. Of the above, it was found that the tuff breccia of the Santonian - Coniacian stages shows quite high magnetic susceptibilities (more than 3 – 10 times as high as those of other rocks). It is a significant datum for correlation with the magnetic survey results in the offshore area.

(c) Contrary to (b), limestones show low magnetic susceptibilities (0 – 0.02 x 10^{-3} SI unit) regardless of age, which are also very useful for assuming limestone facies of the sea bottom.

(d) Clarified Cretaceous stratigraphy can be useful for making assumption of the average velocity of each Cretaceous formation.

2. EXPLORATORY DRILLING SURVEY IN THE GALLERY

The exploratory drilling survey in the gallery was carried out with the purpose of elucidating the geological structure near the coastal area which is not explorable by the present offshore geophysical survey and to study the feasibility in mining coal at the deeper Kozlu Mine below –425 m level beyond the Simal Fault. As a result of two drill holes, No. 1 and No. 2 holes, at the gallery No. 22926, the following assumptions have been made on the geology beyond the Simal Fault:

(1) The fractured zone found at No. 2 hole in the interval from 45 m to 65 m in depth runs in the direction of NNW-SSE judging from the relation with the drilling results of No. 1 hole. In view of its strike, this fractured zone is considered to be the Incirharman Fault.

(2) At No. 2 hole, the interval of about 50 m thick from 69.15 m to the bottom (120.6 m) with a dip of 60 – 70° is correlatable to the Karadon formation characterized by thick fist-sized cobblie beds. This Karadon formation will be correlated with the steep dipping (approximately 20°) Karadon Formation of about 200 m thick observed in the gallery No. 22727 at –300 m level beyond the Simal Fault. From the above, the Kozlu coal-bearing formation is considered to have a big throw to the north of the Simal Fault (approx. 200 m to the east, 600 m at the center and over 700 m to the west of the fault). Accordingly, the Büyük Seam, the uppermost working coal-seam of the Kozlu coal-bearing formation, is considered to lie in the depth below –550 m BSL and each formation in the block beyond the fault dips steeply to the north.

(3) Assuming the fault encountered at No. 2 hole to be the Incirharman Fault, the Simal Fault is considered to have been displaced to the north by the Incirharman Fault, and as a result, the south block of the Simal Fault is considered to have widened. Therefore, the coal reserves in this block would became larger than the previous estimation. However, in order to confirm the above assumption, it is necessary to conduct explorative drilling survey by a horizontal hole from the heading of the gallery No. 22929 at –425 m BSL level.

By the comprehensive analyses of the existing geological data of the Kozlu Mine together with the results of these drill holes in the gallery No. 22926, efforts have been made to estimate the distribution of the Büyük Seam in the north block of the Simal fault for its future development. Probable or possible coal reserves are estimated at about 6.3 million tons. However, proving the reserves is left for the future study.

As the coal seams in this area show dips of over 50° with the maximum dip near 80°, a special technique will be required for mining. Also, as most coal seams lie in the offshore area, special measures should be taken for safety.

3. OFFSHORE GEOPHYSICAL EXPLORATION

3-1 Field Recording and Data Processing

Shooting and recording were carried out by MTA with its survey boat "SISMIK-1" over the JICA's seismic lines (233.45 km) and the MTA supplementary lines (246.175 km). Seismic reflection, gravity and magnetic surveys were simultaneously conducted in accordance with the stipulated specifications. The obtained data were processed by MTA's computer and analyzed under the guidance of the specialists from JICA. The analysis results are summarized in the following II-3-2.

3-2 Data Analyses of Seismic Reflection Survey

(1) Overall structural feature of the reflection plane presumably of the upper most part of the Cretaceous system (horizon green) shows a SW-NE trend and dips slightly toward the north but deeps abruptly from around 3 – 4 km off the coast.

(2) At the northernmost part of the offshore exploration area, the depth contour of the horizon green tends to bend from the SW-NE to the W-E trend. This tendency corresponds well to the onland geological structure near the coastline to the southwest of the Flyös river mouth. This viewpoint leads to an assumption that the Cretaceous system of Zonguldak Coal Field forms a huge anticlinal structure roughly running parallel to the coastline with its north flank in the offshore area as had been expected.

(3) On the contrary, a prominent nose structure was delineated on the structure map of the green horizon to the north of the Zonguldak town so as to divide two broad basinal structures at the further offshore area.

(4) In the offshore area near the coastline, the reflection events from the deeper horizon, presumably of the basal part of the Coniacian volcanic tuff breccia, were partly recognized, but they could not be traced toward the offshore area.

(5) The reflection waves from the Palaeozoic which are presumably situated at the further depth, could not be recognized because of the power shortage of energy source.

3-3 Interpretation of Refraction Data

(1) According to the velocity measurement of the outcrops onshore, the Turonian glauconite had the highest velocity in the investigated area, followed by the Coniacian tuff breccia, limestone, andesite, the Albian blue marl and the Tertiary siltstone in order of their decreasing velocities. The velocity of limestone was unexpectedly low. This phenomenon would be caused by the presence of the numerous cracks and

fissures in the measured limestone body.

(2) Interpretable area by the refraction method was restricted to the area of the shallow water less than 100 meters.

(3) The low velocity zone where the measured velocities range less than 4 km/sec. or 3.5 km/sec. was found in the area between the continental shelf and slope at 3 – 5 km off the coast. This was thought to indicate the distribution of soft sediments at the seafloor.

The area existing shoreward from this velocity boundary appeared to be covered by some hard rocks being shown by a relatively high velocity, higher than 4 km/sec. This velocity boundary corresponds, with a good approximation, to the area where the shallow reflection events were truncated by the seafloor.

(4) The zone sandwiched between the axes of high and low magnetic anomalies was inferred to correspond to the high magnetic susceptivility rock bodies, e.g. Coniacian and Santonian tuff breccia. And judging from the velocity distribution at the sea floor, the area between the near low magnetic anomaly axis and the 4 km/sec velocity line would be considered to be the area where the tuff breccia formations or the thick andesitic lava conceal below sea floor.

(5) Glauconitic alternation formation, which showed the highest velocity at the velocity measurement of outcrops on land, appeared to be correlated with the area where the velocities higher than 4.3 km/sec. were obtained. The area of glauconitic alternation formation runs nearly parallel to the coast line and seems to be related somewhat with the seabottom topography.

3-4 Interpretation of Gravity Data

The basic logics on interpreting gravity survey results were established by the correlation between the gravity data and the onshore geology. Then, the interpretation of the offshore geological structure was carried out by referring to the above-mentioned logics in each case. The followings are the main points derived from the interpretaion.

(1) Density boundary drawn by summarizing the density measurement data of the typical rock seems to samples, lie nearly between the top of Aptian limestone and the top of Albian calcareous sandstone. The interpretation with the onshore geological section, however, supports the idea that the density boundary is nearly to the top of the Albian calcareous sandstone.

(2) It was inferred that the high residual gravity anomalies were closely related to the big mass of limestones, such as the lower part of the Cretaceous or the Palaeozoic

limestones.

(3) A steep gradient in the gravity contour map, which would correspond to possible faults, runs parallel to the coast line. Another fault-like pattern on the gravity contour was recognized in the vicinity of Kozlu as the one cutting across the above-mentioned gravity contours.

(4) From the fact that the density of the Carboniferous coal-bearing formations is smaller than the surrounding limestone formations, the area where the coal-bearing formations develop at the shallow part shows a relatively low gravity anomaly.

In relation to this, it was considered to be reasonable that the portals of the coal mines distribute within the low gravitational area.

(5) On the other hand, the area, where the coal-bearing formations are overlain by the thick limestones or sandstones, situates in a high density zone. (Area represented by the density of 2.67)

3-5 Interpretation of Magnetic Data

The interpretation of the magnetic survey results was carried out by considering the following experimentation and correlation: a) correlation between the geology on land and the results of land and offshore magnetic surveys, and b) measurement of the magnetic susceptibilities for various rock specimens. The followings are the major points from the interpretation.

(1) The magnetic anomalous bodies in this area were recognized as the Santonian-Coniacian tuff breccia, Kampanian andesite, and Turonian glauconitic alternation beds. Among them the magnetic susceptibility of the glauconite alternation beds were smaller than those of the tuff breccia and the andesite, also it was thought to give minor local disturbances to the magnetic anomalies.

(2) Consequently, the major magnetic anomalies observed in the offshore area will be the extension of the thick tuff breccia formations on land. It may be reasonable to consider that the glauconitic alternation body occurs locally along the shore of the tuff breccia body.

(3) General pattern of the magnetic anomalies observed offshore tends to bend its direction off Kozlu. This means that there is a possibility of fault at this location such as the case observed in the Bouguer anomaly map.

(4) Widely spaced magnetic contour lines were recognized in the area near the coast line, especially in the areas off Zonguldak, Kozlu and Iluksu. These widely spaced areas seemed to correlate with the distribution of the Aptian and Barremian limestones and also with the high residual gravity anomalies.

IV. GENERAL SITUATION AND BACKGROUND OF THE PROJECT

IV. GENERAL SITUATION AND BACKGROUND OF THE PROJECT

1. COAL INDUSTRY OF THE REPUBLIC OF TURKEY

1-1 Overview of Energy Industry in the Republic of Turkey

Development of power resources was started in 1902 in the Republic of Turkey. In 1973, due to shortage in foreign currencies and sharp increase in demand of energy, the energy supply was brought to a stalemate, resulting in the unbalanced demand and supply. The pace of development could not catch up with an increase in demand.

To keep the industry going and maintain the economy under healthy condition, measures should be taken to develop energy. And the Turkish government is making efforts to develop domestic energy resources.

The present rate of increase in energy demand in Turkey is 10 % which is almost equal to the rate of the world. Accordingly, by the end of this century, demand for electric power will be 27 billion to 200 billion Kwh. In order to meet this demand, not only development projects of lignite mines but also the projects of power generation must be accomplished within a short period. In view of the above, the Turkish government has been giving priority to energy development project among general industrial development projects. Table 3 shows the trends of electric power generations by thermal and hydraulic generations during the period between 1951 and 1980.

Table 4 shows the percentage of the volume of energy sources used for power generation since 1960.

Productions of electric power and also those of coal and petroleum in the past four years are shown in Table 5. The decrease in use of hard coal for power generation can be explained by the fact that its use for the iron and steel industry has been increased. The lignite consumption has been gradually increasing, but its growth rate is diminishing recently. Hydraulic power generation keeps growing steadily.

Table 6 shows the forecast of electricity consumption, and Table 7 shows an outlook for total energy demand. The main domestic resources which can meet the above increase in demand will be the electric power by lignite and hydraulic generation. The capacity of power generation is estimated at 9 million Kw by lignite and 18.6 million Kw by hydraulic generation.

Table 3 Installed Power and Electricity Production Development in Turkey

YEARS	THERMIC Production (Gwh)	THERMIC Installed Power (MW)	HYDRAULIC Production (Gwh)	HYDRAULIC Installed Power (MW)	TOTAL Production (Gwh)	TOTAL Installed Power (MW)
1951	843	399	45	24	888	423
1961	1746	879	1265	445	3011	1324
1971	7171	1706	2610	872	9781	2578
1972	8038	1819	3204	893	11242	2712
1973	9822	2207	2603	985	12425	3192
1974	10121	2283	3356	1449	13477	3732
1975	9719	2407	5904	1780	15623	4187
1976	9908	2491	8375	1873	18283	4364
1977	11972	2854	8592	1873	20564	4727
1978	12361	2988	9365	1881	21726	4869
1979	12218	2988	1304	2131	22522	5119
1980	11348	2988	11927	2131	23275	5119

Table 4 Dispersion of Fuels or Sources for Electricity Production in %

YEARS	HARD COAL	LIGNITE	PETROLEUM PRODUCTS	THERMIC TOTAL	HYDRAULIC TOTAL	GENERAL TOTAL
1960	35.8	18.9	9.7	64.4	35.6	100.0
1965	25.3	19.5	11.2	56.0	44.0	100.0
1970	16.5	16.7	32.1	64.8	35.2	100.0
1971	14.9	15.6	42.8	73.4	26.7	100.0
1972	12.7	13.3	45.5	71.5	28.5	100.0
1973	12.1	14.0	52.9	79.0	21.0	100.0
1974	11.3	17.4	46.4	75.1	24.9	100.0
1975	9.2	17.3	35.9	62.2	35.8	100.0
1976	7.4	16.3	30.5	54.2	48.5	100.0
1977	6.2	17.5	34.5	58.2	41.8	100.0
1978	5.6	20.2	31.1	56.9	43.1	100.0
1979	4.7	21.9	27.6	54.2	45.8	100.0

Table 5 Transition of Supply of Primary Energy in Turkey

Classification	Annual Production			
	1978	1979	1980	1981
Electric Power				
Thermal (Gwh)	–	12.218	11.927	11.908
Hydraulic (〃)	–	10.304	11.348	12.692
Sub-total (〃)	21.726	22.522	23.275	24.600
Imported (〃)	–	1.042	1.358	1.700
Coal				
Hard Coal (ton)	4,295,237	4,051,338	3,602,172	4,300,000
Lignite (〃)	14,760,000	11,975,000	16,300,000	17,545,000
Sub-total (〃)	19,055,237	16,026,338	19,902,172	21,845,000
Petroleum				
Domestic (10^3 ton)	2,736	2,831	2,311	1,812
Imported (〃 〃)	14,859	12,387	13,249	17,012
Sub-total (〃 〃)	17,595	15,218	15,560	18,824
Others	18.977	19.886	20.630	–

Table 6 Electricity Consumption Forecast

YEARS	CONSUMPTION (Gwh)
1981	32.6
1982	34.5
1983	37.5
1984	40.9
1985	46.5
1986	52.8
1987	60.0
1988	68.1
1992	95.0
1997	146.0
2002	185.0

Table 7 General Energy Demand in Turkey

(1000 ton equivalent hard coal, TEC)

Years	Energy Demand (1000 TEC)
1981	66,194
1982	72,085
1983	78,501
1984	85,488
1985	93,096
1986	101,386
1987	110,405
1988	120,231
1989	130,932
1990	142,585
1991	155,275
1992	169,094

* – Ton Equivalent Hard Coal: 7000 Kcal/kg.

1-2 Coal Industry in the Republic of Turkey

Turkey has a long history of coal industry. Zonguldak Coal Field was discovered in 1822. In 1848 the coal mines belonging to the Emperor of the Ottoman Empire were opened and since then domestic and foreign enterprises were engaged in coal production under the supervisions of the Turkish Navy and the government until World War I. After the war, the coal mines left the hands of the former government and coal mining was conducted by a French private enterprise until 1936. Later, the government of the republic purchased back the mines from the French company and placed it under the jurisdiction of ETI Bank which controls national mining and electricity industry. In 1940, the national Ereğli Coal Corporation (E.K.I.) was established to start active coal development replacing the hitherto small companies.

After World War II, rebuilding of the existing coal mines and development of new coal fields started with the economic aid under the U.S. Marshall Plan. In 1949 when the above objective having been accomplished, the national Turkish coal corporation (T.K.I.) was established with E.K.I. to control the coal industry. Also Arumtçuk coal corporation (A.K.I.) was newly started to take charge of Zonguldak Coal Field.

Lignite, being well developed in the Miocene formations of Tertiary stage, has been produced for over 50 years. It is distributed all over the Turkish land. Most extensively exploited coalfields are those west of Anatoria (Tunçbilek, Seyitömer), operated by the national enterprise G.L.I., and Soma Coal Field. The lignite from these coalfields has low calorific value (1,100 – 4,500 Kcal/Kg). Good quality lignite is used for heating purpose in the cities, but mostly it is used for the purpose of power generation at specific plants constructed near the working place. New power plants are being constructed one after another.

Hard coal potentiality can be detected in the Zonguldak sedimentary basin. At the present stage of the exploration, positive, probable and possible reserves of hard coal are reportedly estimated at approximately 1.4 billion tons (See Table 18).

On the other hand, the possible reserves of lignite is reported to be about 7 billion tons. The main producing area is Afsin - Erbistan sedimentary basin where a 3.2 billion tons of lignite was discovered and is now being exploited.

Hard coal is mainly used for iron manufacturing and the related industries.

As mentioned before, of all the coal in Turkey, hard coal is produced exclusively by T.K.I. As of lignite, 85 % is produced by T.K.I. and 15 % by private sectors. Table 8 shows production of hard coal and lignite since 1970.

The future demand for lignite, mainly arising from the demand for power generation, is estimated as shown in Table 9.

The production plan of hard coal and lignite corresponding to the future demand above mentioned is shown in Table 10.

T.K.I. has eleven susidiaries including E.K.I. and is engaged in production of hard coal and lignite. The coal production in fy 1981 was 3,973,000 tons for hard coal and 15,043,000 tons for lignite, totaling 19,016,000 tons. (Refer to Table 11 and Fig. 2) Table 12 shows qualities of the major coal from major mines of T.K.I. subsidiaries.

T.K.I. is now developing the lignite mines at Afşin - Elbistan by open-pit mining. Under this project, about 20 million tons/year is to be supplied for Plan A which is to produce 1,360 MW of electricity at four plants with 340 MW capacity each. Consecutively, Plans B and C are scheduled. Besides the above, T.K.I. is now planning the lignite development projects at Muğla - Yatağan, Soma - Işiklar, Tinaf - Bağyaka, and Sekköy. Table 13 shows the power plants now undergoing plans and operation. Details concerning Zonguldak Coal Field will be mentioned in the following Chapter, IV-2.

Table 8 Saleable Hard Coal and Lignite Production (1000 Tons)

YEARS	HARD COAL PRODUCTION	LIGNITE PRODUCTION TKI PRODUCTION	LIGNITE PRODUCTION PRIVATE MINES	TOTAL LIGNITE PRODUCTION
1970	4,573	3,992	1,938	5,930
1971	4,639	4,221	2,174	6,395
1972	4,642	4,786	1,989	6,775
1973	4,642	4,894	2,852	7,746
1974	4,965	5,424	3,518	8,942
1975	4,813	6,198	3,513	9,711
1976	4,632	7,526	3,892	11,418
1977	4,405	8,293	4,707	13,000
1978	4,292	9,326	5,434	14,760
1979	4,051	11,064	911	11,975
1980	3,600	14,000	2,300	16,300
1981	3,973	15,057	2,300 Estimate	17,357

Table 9 Demand for Lignite

YEARS	(1000 tons) DEMAND FOR LIGNITE	DEMAND FOR LIGNITE BY THE POWER STATIONS (1000 tons)
1981	21,348	6,455
1982	26,305	10,966
1983	38,123	20,296
1984	51,608	35,198
1985	62,715	47,996
1986	70,230	51,816
1987	81,860	62,021
1992	101,045	78,771

Table 10 Production Plan of T.K.I.

YEARS	HARD COAL PRODUCTION (Saleable 1000 tons)	LIGNITE PRODUCTION (Saleable 1000 tons)
1981	4,500	15,100
1982	4,380	20,300
1983	4,456	34,483
1984	4,516	34,483
1985	4,598	59,743
1986	4,726	66,913
1987	4,880	77,998
1988	4,960	88,028
1989	5,095	95,093
1990	5,180	97,033

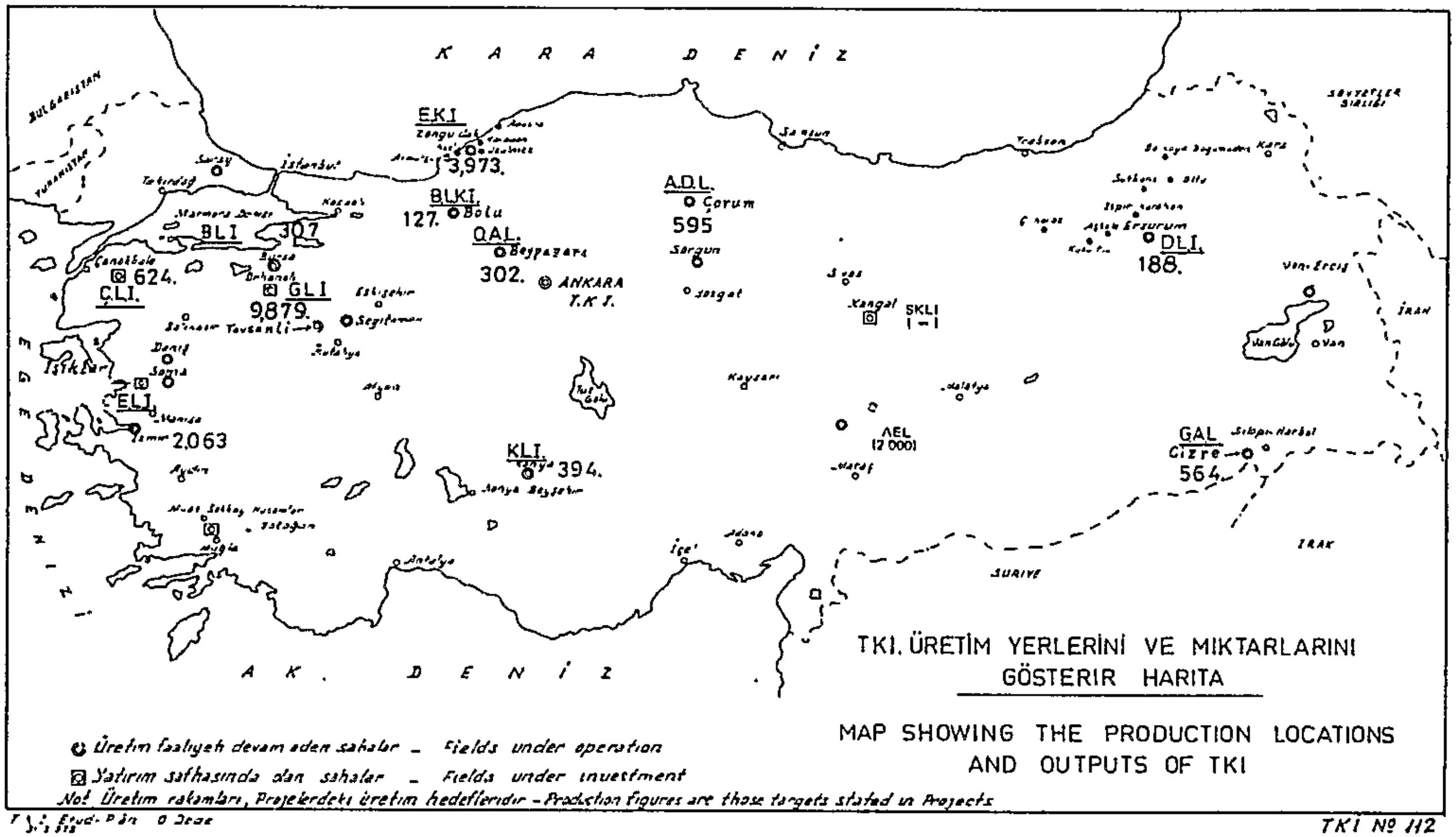

Figure 2 Location Map of Coal Enterprises of T.K.I. Including Outputs in 1981

Table 11 Coal Mines and Production of the Subsidiaries of T.K.I.

Subsidiary	Location of Office	Number of Coal Mine	Name of Main Coal Mines	Production in 1981 (mt)	Remarks
E.K.I.	Zonguldak	5	Armutçuk, Kozlu, Üzülmez, Karadon, Amasura(all U/G)	3,973,228	Hard Coal
G.L.I.	Tavsanli	2	Tunçbilek, Seyıtömer	9,879,446	Lignite
E.L.I.	Izmir	3	Soma, Aydin, Yatağan(U/G+O.P.)	2,063,188	Lignite
A.D.L.	Çorum	2	Dodurga(U/G), Alpagut	594,905	Lignite
O.A.L.	Beypazari	1	Beypazari	301,588	Lignite
D.L.I.	Eruzurum	5	Balkaya(U/G), Askale(U/G), Oltu (U/G), Ispir(U/G), Karliova(O.P. + U/G)	187,729	Lignite
C.L.I.	Canakkale	1	Çanakkale(O.P.+ U/G)	623,649	Lignite
B.L.I.	Bursa	2	Orhaneli(O.P.+ U/G), Keles	307,041	Lignite
K.L.I.	Konya	2	Ilgın, Ermenek(U/G)	393,733	Lignite
G.A.L.	Cizre	2	Sirnak, Silopı	564,400	Asphaltite
B.L.K.I.	Bolu	1	Mengen(U/G)	126,872	Lignite
Total				19,015,779	

Remarks: No designation has been made for mines under open pit mining.

Table 12 The Representative Coal Quality at the Main Coal Mines of TKI in Each Coal Field

Coal Field	Coal Mine	Coal Quality Moist.	Ash	F.C.	Sulph.	Vol.	Cal. V.(Kc/kg)
Zonguldak (EKI)	Armutçuk(U/G)	5.74	6.20		1.50		7,390
	Kozlu (U/G)	2.25	8.30		1.50		7,720
	Üzülmez (U/G)	8.26	8.22		1.00		7,670
	Karadon (U/G)	3.16	7.50		1.00		7,900
	Amasra (U/G)	2.84	16.70		1.40		6,650
Tavşanli (GLI)	Tunçbilek	15.0	10.0		1.5		4,000
	Seyitömer	33.54	19.1		1.36		2,750
Izmir (ELI)	Soma(Center)	18.0	20.0		1.30		4,200
	Yatağan(Eskihisar)	34.93	20.75		2.26		2,180
	Aydin(Soke-U/G, & O.P.)	16.0	22.0		3.16		3,800
Çorum (ADL)	Dodurga(U/G)	19.13	19.62		1.55		4,100
	Alpagut						
Beypazari (OAL)	Beypazari	29.77	16.5		4.56		3,000
Eruzurum (DLI)	Balkaya(U/G)	9.78	29.80		2.84		4,500
	Askale (U/G)	5.66	36.44		3.74		4,500
	Oltu (U/G)	6.24	32.51		1.20		4,200
	Ispir (U/G)	21.25	23.75		1.62		2,620
	Karliova(U/G & O.P.)	43.00	24.63	15.15	0.57	18.25	1,663
Çanakkale (CLI)	" (O.P.+U/G)	21.43	30.37		3.34		2,805
Bursa (BLI)	Orhaneli(O.P. & U/G)	29.96	20.33	29.14	1.95	27.59	2,823
	Keles	33.65	22.94		4.32		2,404
Konya (KLI)	Ilgin	50.31	11.38				2,239
	Ermenek	42.90	9.95				3,000
Cizre (GAL)	Sirnak(Asphalt-ite)	1.08	32.85		4.37		4,500
	Silopi(")						
Bolu (BLKI)	Mengen	17.35	10.85	32.08	7.60	46.71	4,800
Erbistan (Under develop')	Kislakoy	52.18	20.02	8.84	2.00	19.83	1,100
Sivas (Under develop')	Kangal	49.83	19.04		3.57	20.09	1,494
Kuruncasile (New discovery)		3.69	42.5		1.05		4,070
Azdavay (New discovery)		3.68	22.3		1.31		8,544

Remarks: Mines under open pit mining have no designation.

Abbreviation: U/G-Underground mining; O.P.-Open pit mining

Table 13 The Planned and Operating Power Plants in Republic of Turkey

NO	NAME OF THE PLANT	COMMISSIONING DATE (MONTH/YEAR)	GENERATION (Gwh/YEAR)
1	AMBARLI	-	4200
2	HOPA	-	350
3	ALİAĞA	-	360
4	ÇEVRIM	6/1982	180
5	BORNOVA	-	135
6	SEYDİSEHİR	-	360
7	ÇATALAĞZI	-	800
8	SİLAHTAR	-	350
9	İZMİR	-	200
10	SEYITÖMER 1-3	-	2700
11	SEYİTÖMER 4	12/1983	900
12	SOMA-A	-	310
13	TUNÇBİLEK-A	-	600
14	TUNÇBİLEK-B	-	1800
15	SOMA-B-1,2	8/1981, 10/1981	1980
16	SOMA-B-3,4	10/1983, 4/1984	1980
17	GEOTERMAL	6/1982	90
18	YATAĞAN-1,3	12/1982, 4/1982, 9/1983	3780
19	ELBİSTAN-A-1,2	12/1982, 6/1983	3900
20	ELBİSTAN-A-3,4	12/1983, 6/1984	3900
21	KANGAL 1,2	12/1984, 3/1985	1800
22	ÇAYIREAN 1,2	9/1983, 12/1983	1800
23	YENİKÖY 1,2	6/1984, 12/1984	2520
24	YENİÇATALAĞZI	12/1983	900
25	ORHANELİ	12/1984	1200
26	KELES	1/1985	1200
27	BEYŞEHİR	12/1985	1200
28	B.KARLIOVA	1/1987	900
29	ELBİSTAN-B-1,2	1/1987, 7/1987	3900
30	ELBİSTAN-B-3,4	1/1988, 7/1988	3900
31	SARAY-1	1/1988	900

NOTE: Çatalağzi, Silahtar, İzmir, Soma-A and Tunçbilek-A thermal power plants will be retired in 1984.

2. GEOGRAPHY OF ZONGULDAK COAL FIELD AREA

IV-2 deals with the location, meteorology, topography, transportation and industries of the area related with this project.

2-1 Location and Meteorology

The main body of Zonguldak Coal Field ranges from Ereğli in the west to Amasra in the east, located in the coastal area of the Black Sea between 41°20′ and 41°50′ of north latitude and between 31°20′ and 32°30′ of east longitude. Temperature and other meteorological figures of the area are shown in Table 14. The weather is typical of the Black Sea area, relatively mild and moderate in comparison with other parts of Turkey. The past experiences indicate that onland and offshore field surveys and exploratory operation should be conducted between early April and early November. The operations in winter may be disrupted by various adverse conditions such as low temperature, snow fall, rain and rough waves, etc. Offshore operation will be most effective during May and September, depending upon the kind of boat and method to be adopted.

Concerning the sea bottom conditions, recent data were not available. Fig. 3 shows frequency diagram of wave heights and periods. This diagram shows the old marine observation data collected during 10 years from 1937 to 1947 when the Zonguldak port was under renovation. The range of the tide is quite small.

2-2 Industries and Transportation of the Zonguldak Coal Field Area

Zonguldak Coal Field, which includes the 4 areas to be explored under this project, is located in the Zonguldak Prefecture (¡L), one of 67 prefectures in Turkey. Zonguldak city has the seat of the prefectural government. The city and its vicinity have a long history of coal mining. There are also agriculture and fishery, though small in scale. Flint clay is also produced from a part of the coal field. Thus, Zonguldak city is a center of these productions and distribution. The population is 108,000 at present, of which about 40,000 are engaged in coal mining industry.(1) The remaining population are also mostly considered to be related with coal mining in one way or another. Coking coal from this coal field are to be supplied to the ironworks at Ereğli and Karabük.(2)

Fig. 4 shows the main traffic routes in Zonguldak city and its vicinity.

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(1) E.K.I. employees in 1980 was 38,000 (excluding season laborers).
(2) Located at approx. 70 km southeast of Zonguldak city.

Table 14 Monthly Average Temperature, Precipitation and Humidity

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Remarks
Temperature (C°)	5.4	5.9	6.0	10.3	15.2	19.1	21.5	20.9	17.5	15.3	10.6	7.3	Average of Past 3 Months
Precipitation (mm)	19	14	15	11	10	5	7	9	9	13	15	18	
Humidity (%)	79	80	77	81	81	82	80	82	80	83	83	81	

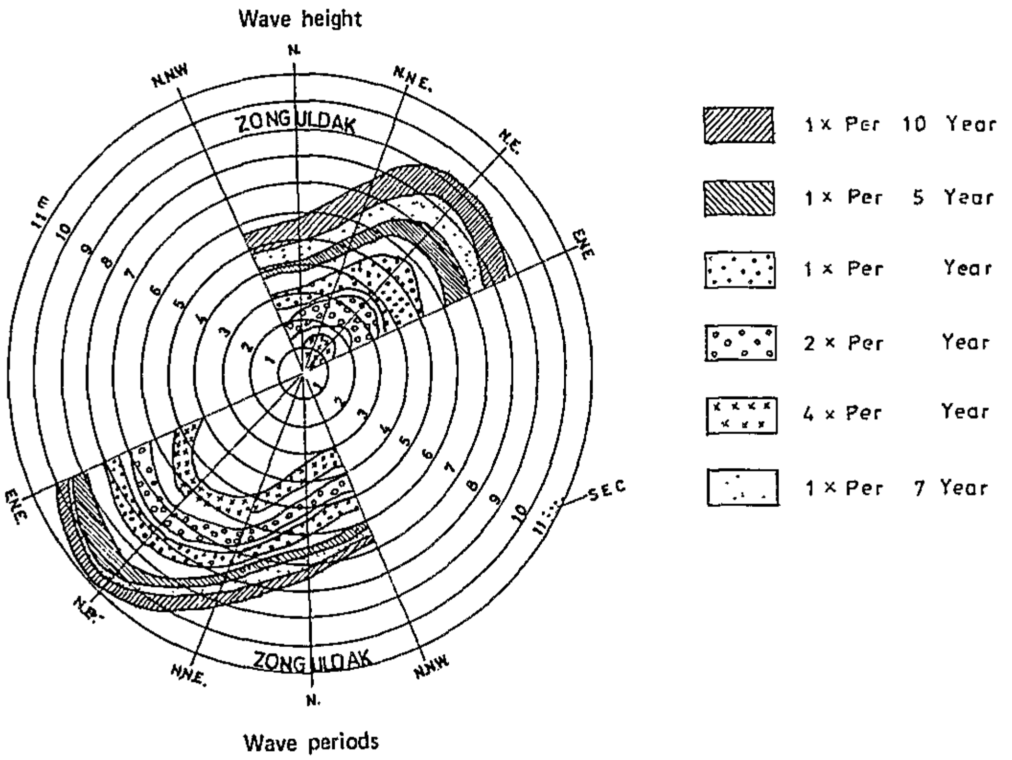

Figure 3 Frequency Diagram of Wave Heights and Periods at Zonguldak Port

	ROUTE		MILAGE km	ROUTE No.
MAIN ROAD	ZONGULDAK	ANKARA	284	35
	〃	EREĞLİ	63	12
	〃	AMASRA	115	35
	〃	ÇAYCUMA	33	
	〃	ISTANBUL	334	12, 20, E5
RAIL ROAD	〃	ANKARA	485	National Rail Way
MARINE ROUTE	〃	ISTANBUL	138*	* Notical Miles

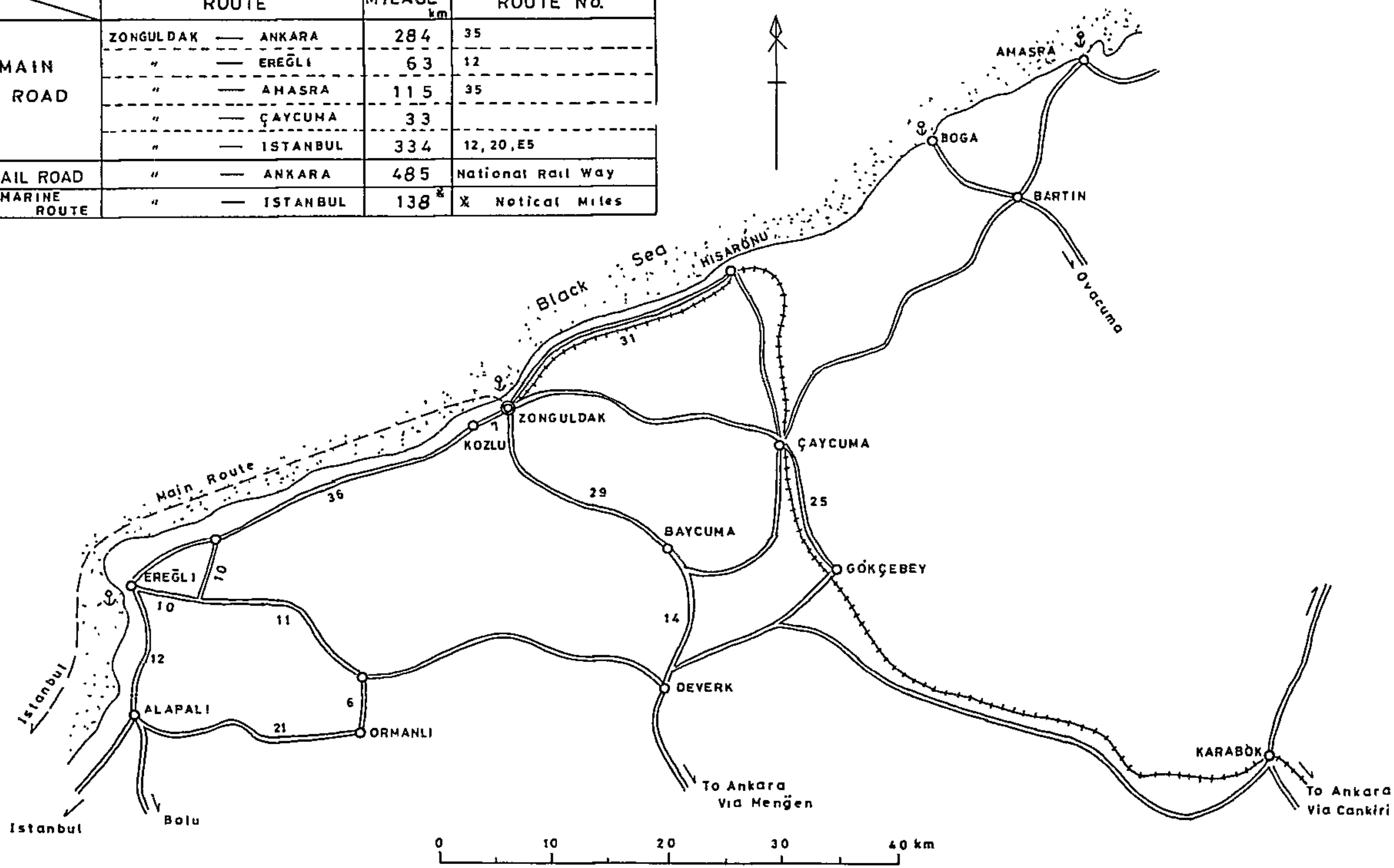

Figure 4 Main Trafic Routes in Zonguldak Coal Field

Usually the traffic between Zonguldak and the capital city Ankara is about five-hour ride by bus or a car through the route Ankara - Gerede - Mengen - Devrek - Zonguldak. The above route is paved all through, so that traffic by a large bus or truck is no problem. The traffics between E.K.I. in Zonguldak and its Arumtçuk Mine or Amasra Mine are also by roads, which are mostly blacktopped but not ideal. National Railway between Ankara and Zonguldak is used for local passenger and transportation of materials. Along the coastline of the Black Sea there are four ports, the Ereğli, Zonguldak, Boga and Amasra eastwardly. Table 15 shows the port facilities at Zonguldak and Amasra ports in relation to shipment of coal.[1]

Table 15 Port Facilities at Zonguldak and Amasra Ports

Port	Wharf	Depth	Break-Water	Main Unloading Facilities
Zonguldak[1]	500 m. long x 1 (for Coal) 290 m. long x 1 (for Goods) 200 m. long x 1 (for Timber)	(m) 10	2 at North and West	Several cranes for coal, timber, goods
Amasra	x 1 (for Coal) x 1 (for Goods)	5–10	2 at East and North	Ibid.

2-3 Coal Mining

The onland area, which corresponds to the offshore exploration area of this project, is the center of Zonguldak Coal Field in which there are five mines at Arumtçuk, Kozlu, Üzülmez, Karadon, and Amasra. The bituminous coal produced from these mines is used for iron works as mentioned before. Coal mining in this coal field started in 1848 under the supervision of the Ministry of Finance of the Ottoman Empire. Actual mining had been conducted by various institutions such as private corporations owned by foreign capitals and national capitals as well as governmental organizations. In 1957, T.K.I. (Turkish Coal Enterprise in English) was established and its subsidiary E.K.I. has been taking charge of Zonguldak coal field since.[2] Table 16 shows the production, personnel, productivity, and the operating conditions of the five mines of Zonguldak coal field in 1980. The productivity of every mine in this area is rather low with an average 8 tons/man/month, because mining has been carried out at many short working faces with the width of 100 – 140 m and under labour incentive mining method. Another thing to be noted is a low yield of average 55 %, which is also affecting the productivity.

(1) For details of the facilities, see Reference 1).
(2) For details, see Reference 2) and others.

Table 16 Current Status of Each Coal Mine in Zonguldak Coal Field (1980)

Name of Coal Mine	Production (t/year)		Personnel				Productivity (t/man/mo)	Working Face *1		Ventilation (m^3/min)	CH_4 in Return (%)	Total Drainage (m^3/day)	Remarks
	Raw Coal	Saleable	Staff	Workers				Number	Total Length(m)				
				U/G	Surface	Total							
Arumtçuk	522,786	360,241	-	2,644	1,167	3,811	7.88	96.5	11,554	6,000	0.5	12,000	*2 - 1.99m.
Kozlu	1,870,618	991,031	-	4,838	1,964	6,802	12.14	18.2	1,223	17,750	0.5	12,600	*2 - 2.33m.
Üzulmez	1,812,732	880,374	-	5,420	2,415	7,835	9.36	25.7	3,185	-	0.2-0.4	16,000	*2 - 2.20m.
Karadon	2,079,979	1,206,314	-	8,760	3,120	11,880	8.46	47.7	6,784	21,480	0.3	15,000 (35,000)*3	*2 - 1.80m.
Amasura	-	155,979	-	-	-	(6,033)	(2.15)	9	798	1,600	0.5	No Water	*2 - 1.85m.
Total	6,286,115	3,440,987	1,457	21,662	8,666	30,328 (36,361)	7.89	197.1	23,544	-	0.4	-	

Remarks: *1 - Working faces are all longwall; *2 - Average thickness of coal seam; *3 - Total dranage water in winter time.

Table 17 Coal Production from The Coal Mines in The Zonguldak Coal Field

(Unit:Metric Ton)

Years	Kind of Coal	Coal Mines					Total
		Arumtçuk	Kozlu	Üzülmez	Karadon	Amasura	
1977	Raw Coal	644,892	2,019,488	2,042,551	2,658,787	300,299	7,665,937
	Saleable	438,514	1,148,899	1,042,882	1,574,389	188,129	4,405,064
1978	Raw Coal	685,767	2,092,221	2,201,294	2,423,599	338,439	7,741,311
	Saleable	464,819	1,119,911	1,068,738	1,463,494	178,275	4,295,237
1979	Raw Coal	604,796	1,851,544	2,021,124	2,354,071	186,742	7,018,278
	Saleable	466,474	1,136,650	1,110,676	1,707,660	83,260	4,504,720
1980	Raw Coal	522,786	1,870,618	1,812,732	2,079,979	-	6,286,115
	Saleable	360,241	991,031	880,374	1,209,341	155,979	3,440,987 *1
1981	Raw Coal	494,253	1,959,350	2,055,487	2,492,113	283,881	7,285,084
	Saleable	348,745	1,015,374	1,022,147	1,388,718	146,108	3,921,092
*2 1982	Raw Coal	-	-	-	-	-	-
	Saleable	459,672	1,080,444	1,007,412	1,422,278	230,194	4,300,000
*2 1983	Raw Coal	-	-	-	-	-	8,699,000
	Saleable	-	-	-	-	-	4,540,000

Remarks: *1 - Excluding saleable coal production of Amasura Mine; *2 - Figures are all programmed ones.

Table 18 Coal Reserves and Seam Statuses in The Zonguldak Coal Field

Name of Coal Mine	Workable Coal Seams *1		Reserves *2				Remarks
	Number of Seam	Total Thickness	Positive	Probable	Possible	Total	
Arumtçuk	2	6 + 3 = 9 m.	32,899	61,283	-	94,182	
Kozlu.	22	39 m.	9,925	17,000	260,000	286,925	
Üzülmez	16	18.35 m.	73,350	101,754	79,300	254,404	
Karadon	20	29.40 m.	54,847	84,153	344,572	483,572	
Amasura	7	9.30 m.	20,946	195,550	60,665	277,161	
Cide-Kurucasile	1	2,00 m.	1,921	11,943	1,297	15,161	
Total	-	-	193,888	471,683	745,834	1,411,405	

Remarks: *1 - Restricted to only those of Westphalian A; *2 - From MTA's figures in 1981.

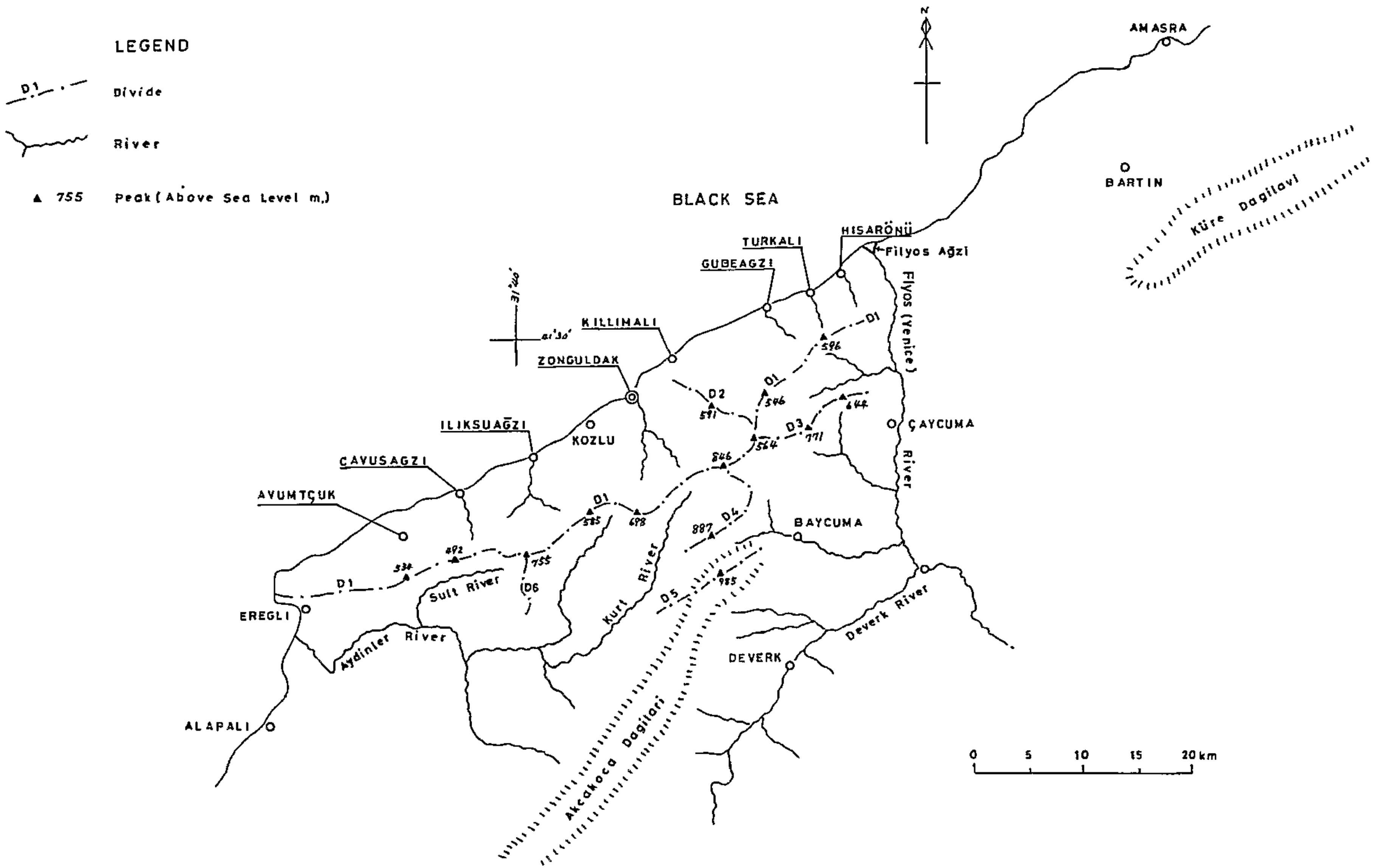

Figure 5 Main Drainage System in Zonguldak Coal Field

Table 17 shows coal production from the mines in Zonguldak Coal Field from 1977 up to the present. Production decreased sharply since 1980 and became below 4 million tons per annum in 1981. This production depression would be caused by the fact that the operating level is deepened year by year in every mine and the geological conditions are aggravated accordingly.

2-4 Topography of Zonguldak Coal Field

The coal field ranging from Arumtçuk to Zonguldak, on a broad view, corresponds to the western part of the Pontos Cordillera roughly running parallel to the coastline of the Black Sea. This area is surrounded and controlled by the Aydinler (Gülünç) River and the Akçakoca Mountain Range[(1)] a branch of the cordillera. (Fig. 5). The main part of the coal field (Arumtçuk, Kozlu Üzülmez, Karadon Mines and their vicinities) lies between the above-mentioned two rivers and on the north side of the main divide (D_1 in Fig. 5) with small drainage systems running into the Black Sea. In the north of the divide D_1, drainage systems are short and narrow, mostly running in the N-S direction generally. Among them, Gelik River which runs through the Catalagzi and Kasköy power plants near the river mouth shows the E-W direction in its tributaries (Refer to Fig. 6 and others).

On the other hand, in the south of the divide D_1, both Aydinler River and Flyos River shows extensive reaches and complex drainage patterns.

As shown in Fig. 5, the divide D_1, the main divide of the objective area, takes the direction roughly parallel to the coastline of the Black Sea. Of its branches D_2 - D_6, D_3, D_4 and D_5 show similar directions. As of the altitude distribution of the area, the highest point, the Asar Mountain (984.8 m a.s.l.), lies south of Zonguldak, or approximately 7 km southwest of Baycuma.

For analyses and interpretations of the offshore geophysical survey data under this project, geological and geophysical studies were conducted over the area about 15 km from the coastline. Topography of the area is summarized as follows from the topographical map[(2)] and others:

(1) The plain is scarce in this area except the Flyos River valley near the eastern end of the area. There are little plain-like terrains, such as narrow alluvial plains between mountains and also gentle slopes on the hills.

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(1) Yeni Turkiye Atlasi, M.S.B. Harita General Müdürlügu, 1977 (New Turkish Atlas)
(2) E.K.I. Topographical Map 1:50,000.

(2) The drainages are short and narrow, mostly in the N-S direction. V-shaped valleys are observed in some part. In the upper reaches, the drainage system shows a fairly complicated pattern.

(3) The coast has many rises of 20 – 50 m high. There is scarcely a sandy shore.

(4) The altitude distribution of the area is characterized by mountains or hills of less than 600 m above the sea level. The highs are located south and southeast of Zonguldak city. These mountains and hills are showing rugged surfaces by strong erosion caused by the small drainage systems mentioned above (1). This area has, thus, rather complex topographically.

(5) In some parts, topography and geology are closely related as to be mentioned in the following IV-2-5.

2-5 Relationship between Topography and Geology

Some relations between geology (rock facies, geological structure) and topographical elements (drainage systems, divides, altitude distribution) are observed as follows from the existing topographical map(1) and the geological map(2):

Some drainage systems obviously form transverse valley or strike valley. Some do not show any relation with geology. An example of transverse valley is observed in the tributaries of Flyos River north of Çaycuma - Baycuma which structurally cuts the Paleogene(3) and the upper Cretaceous. Another example of transverse valley is seen on the main stream of Kisla River running into Değrrmenağzi to the west of Zonguldak city, which cuts the Cretaceous to the Palaeozoic. Strike valleys are observed in many places such as those near Hisarõnỹ and Turkali in the Cretaceous (Santonian pyroclastic rocks). In the downstream of Eğir River running to the east of Çatalağzi Power Plant mentioned earlier, some wide alluvial plain of strike valley type develops among the Cretaceous (Turonian pyroclastic rocks). Some rivers change their directions from a strike valley to a transverse valley.

It was fairly difficult to read the geological structure in the pattern of the drainage systems just by the comparison between the topographical map and the geological map of 1:50,000 scale. It is a very rare case (to be mentioned later) that a structural line such as the major fault is immediately recognized as a subsequent valley. But the reflections of geological conditions are considerably well observed in the directions of the divides (D_1 and others, Fig. 5) which are developed largely between the rivers running into the Black Sea such as

(1) E.K.I. Topographical Map 1:50,000.
(2) 1:50,000. MTA Zonguldak Area Geological Map No. 30923 (1975), Reference 3).
(3) For geology, see IV-3.

the Llikus River[1] and the Açlik River[2] and also the Aydinler River which has the watershed in the southern area.

The following are the topographical highs which are considered to be reflecting the lithological character and geological structure:

(1) Those corresponding to the Palaeozoic structural highs (Refer to Fig. 6):
   - o Mountainous area around the Palaeozoic Göl mountain composed of the Devonian and the Visean where a semi-dome D_3 and an anticline (semi-dome) A-9 are developed.
   - o A kind of thrust composed of the Palaeozoic (Carboniferous Namurian and Visean) at Göbe - 6 km to the south of Göbeağzi, near Deliklimese mountain.

(2) Those corresponding to the distribution and structures of the pyroclastic rocks of the Cretaceous (Senonian - Coniasian):
   - o The pyroclastic rocks, which distribute in E-W direction at 5 – 7 km south of Alacagazi, Kileçilik and Llikusağzi, correspond to a part of the divide D_1 with E-W direction.
   - o A high around Bulat Mountain (644 m) at about 4 km west of Çaycuma.
   - o An east end of the divide D_1 near Kütücklükbaşi Mountain (516 m) at about 5 km south of Hisarönü.

(3) The distribution of andesites of the upper Campanian forms the ridge line (Fig. 5, D_5).

The above are the good examples where the topography reflects the geology well. But the structural highs of the Palaeozoic or the distribution and structure of the Santonian - Coniacian pyroclastic rocks do not always make the topographical highs or mountain ridge lines. For instance, most of the distribution of the Westphalian series and Namurian series of Palaeozoic Carboniferous, and their anticlines and dome structures exist rather in the topographically low area. On the contrary, a basin structure of the Cretaceous, composed of the Cenomanian Flysch Formation, the Turonian marl and the Santonian - Coniacian pyroclastic rocks is located at a topographical high (Fig. 6, the Western end of the syncline 58, about 5 km at the west of Osmanliköy). The influence of faults or fracture zones on the topography can not be elucidated by the data used this time and a part of the results of the field survey. Even the Midi Fault, which forms a fault zone and be known to have a remarkable influence over the Palaeozoic distribution and structure, is difficult to trace on the topographical map of 1:50,000. Some faults such as the Palaeozoic horst at Göbe

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(1) The river mouth at Llikusağzi.
(2) The river mouth at Zonguldak port.

and the Karadon Fault near Kozlu give reflections to the topography.

Some other evidences which are considered to reflect the geology to the topography in general are as follows:

(1) Marl at the lower Cenomanian and the chalky marl of the Maestrichtian often form a gentle topography or a topographical depression.

(2) The Palaeogene distributing zone mainly composed of sandstone and marl in the southeastern part of the exploration area is gentler in topography than the Cretaceous zone and tends to lower in altitude.

(3) Cuestas are observed in many places of the Cretaceous and the Paleogene zones.

(4) Karst topographies are remarkably observed in the places where the Barremian and the Aptian limestones of the lower Cretaceous are distributed (Zonguldak city, Kozlu, west of Ilkusağzi). These are well recorded on the topographical map of 1:10,000[(1)]. The limestones on the coastline bear well-developed sea caves.

(1) E.K.I. It is not attached to this report.

3. GENERAL GEOLOGY IN THE ZONGULDAK COAL FIELD AREA

IV-3 deals with the general geology mainly based on the existing literatures by M.T.A.(1), E.K.I., etc. as well as the data of the surface geological survey conducted along the coastline as a part of this project. The Zonguldak area hereafter refers to an area of approximately 60 km in the east-west direction, from the Arumtçuk Mine (on the west) in the west to the Filyos River (on the east) in the east, and of about 20 km in the north-south direction. (as shown in Fig. 6).

3-1 Palaeozoic Erathem

The Palaeozoic group in the Zonguldak area is an important geological group which contains coal-bearing formations. It has many survey and study data in the past. Especially the underground data obtained from coal mining are abundant and valuable. The distribution of the Palaeozoic group in the Zonguldak area is shown in Fig. 8. In the geological map shown as Fig. 6, the Silurian and the Permian systems are not described so far. However, as a reference of the geology in this area, these two systems and their related geological group are included in the following overall geological description of this area.

A. Silurian System

Distribution : Near Alapali (about 9 km south of Ereğli),
Near Ererci (about 21 km southwest of Devrek), etc.

Facies : Quartzite, grit, conglomerate(2), psammitic marl,

Fossils : Graptolites and brachiopods

Others : Thickness not known.
Near Alapali, the Silurian psammitic hard sandy marl overlies the Ordovician System(3).

The Silurian System near Alapali is the closest to this area. The Silurian System around Istanbul is fairly well studied, but is far from this area. As to be mentioned later, the lowest part of the Devonian System in the northwest of Bartin city at the east off this area may be the Silurian.

B. Devonian System

Outcrops of the Devonian System in this area are quite limited, but its distribution is very significant for elucidation of the basement structure of the coal-bearing formations (Carboniferous Westphalian Series, etc.) on analyzing gravity data and

(1) Maden Tetkık ue Arama Enstitüsü (Mineral Research & Exploration Institute of Turkey)
(2) Reference 4)
(3) Reference 5)

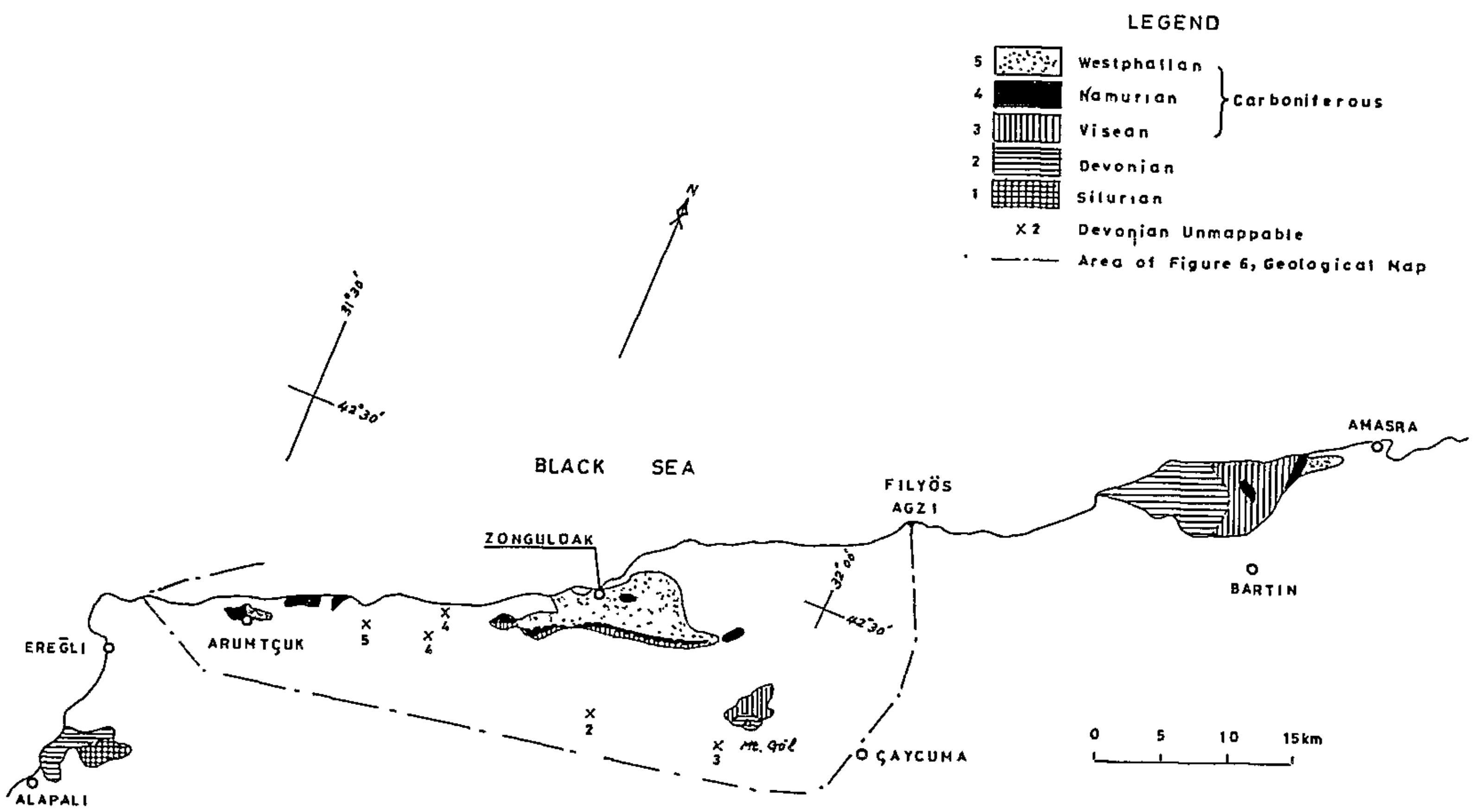


Figure 8 Distribution of Palaeozic Group

Table 19 Brief Stratigraphy of Amasra District

Geologic Age			Thickness (m)	Lithofacies
Paleogene (Paleocene, Eocene)			-	sandstone, shale, marl
Cretaceous	Maastrichtian		100-400	colored argillacious limestone
Cretaceous	Campanian-Coniacian		230-300	basaltic pyroclastics, marl, pyroclastics, andesite, & dacite, lava
Cretaceous	Turonian		30-80	argillacious limestone
Cretaceous	Cenomanian-Albian		max. 700	blue marl, sandstone (lignite bearing)
Cretaceous	Barremian		0-400	limestone
Permian (Aritdere form.)			110	alternation sandstone, marl, nonfossiliferous
Carboniferous	Stephanian (Westphalian E)		150	sandstone intercalating limestone
Carboniferous	Westphalian	D	40-180	sandstone, conglomerate, coal (coal measures)
Carboniferous	Westphalian	C	150	fine sandstone, shale, fine conglomerate, coal (coal measures)
Carboniferous	Westphalian	B	100-200	sandstone, shale, fine conglomerate, coal
Carboniferous	Westphalian	A "Kozlu form."	200-300	conglomerate, sandstone, shale, coal
Carboniferous	Namurian (Alacagazi stage)	C B A	300+	sandstone, shale, limestone with 3 coal seams
Carboniferous	Visean	D_2-Zone	250	shale with limestone, coal "Kulmfacies"
Carboniferous	Visean	D_1-Zone	1,250	marine limestone (cherty, dolomitized) Dibunophylum D_1-Zone
Devonian	Upper		325-900	Tournasian? limestone, dolomite
Devonian	Middle		360-1,200	limestone (partly cherty) dolomite
Devonian	Lower		650+	upper (400m) gray, red shale with quartzite & limestone. lower (250m+) gray, red shale*

Prepared from M.Tokay (1961)

Table 20 Devonian System in Bartin Area (Brinkmann 1976)

Geologic Age		Rock Facies
Lower Carboniferous		
Upper Devonian	Famennian	Massive dolomitic limestone
	Frasnian	
Middle Devonian	Givetian	Bedded limestone
	Eifelian	
Lower Devonian	Emsian	Glauconitic bedded lms, Conglomeratic quartzite
	Siegenian	
	Gedinnian	
Ordovician		?

in planning future drilling exploration.

(1) South of Ereğli:

In this area the lower Devonian System overlies the Silurian System, which is mainly composed of sandy shale, and is unconformably covered with the Cretaceous System. The past gravity data[(1)] indicate the local positive Bouguer anomaly near the distribution areas of the Devonian and the Silurian.

(2) Southeast of Zonguldak city:

The Devonian outcrops are observed around the Göl Mountain (771 m) about 8 km west of Çaykuma town and have an extent of about 4 km^2. It is mainly composed of the conglomerate (semi breccia of limestone & quartzite) and limestone developed in a non-stratified mass. Calcite veins intrude in network. The geological structure is not clear, but it is covered with the Visean Series and contacts the Cretaceous in the south[(2)]. In relation with the structures of the Visean Series and the Cretaceous, it is assumed that there is a dome structure with the Devonian System as a core of the Palaeozoic structural high.

(1) Reference 6)
(2) The Devonian System contacts the Cretaceous possibly by a fault on the south of the Devonian distribution area.

The Devonian System is scattered among the Velibey sandstone of the Cretaceous Aptian Series along the Dereköy River to the southeast of Zonguldak city and to the north of Basviran (with the E-W strike and dipping at 10° ± northward). The Cretaceous System surrounding the Devonian outcrops forms an anticline on the Devonian core. (Fig. 8, Anticline A-10).

At Zeytin Village about 4.5 km to the north of this anticline, M.T.A. previously conducted a test drilling (Zeytinköy Well). Its record shows that the well penetrated the Albian glauconite sandstone from the wellhead to 475 m and the Devonian (crystalline limestone) to 600 m T.D.[(1)]. M.T.A. reported that the Devonian was in unconformable relationship with the Cretaceous.

According to Brinkmann (1976, ibid.), the Devonian observed at the southeast of Zonguldak city is younger than the Devonian at the south of Ereğli.

(3) Northeast of Bartin city:

Though this location is outside of the Zonguldak area, the Devonian outcrops around this place is rather extensive (about 18 km^2), and its stratigraphy is considerably well studied. The stratigraphy in Bartin area is summarized in Tables 20 and 21 based on M. Tokay (1961)[(2)]. Tokay reports that the Devonian System in this area is divided into three, Upper, Middle and Lower, and having a submerged semi-dome in the southeast (the Inkume Anticline, Tokay, ibid.). And a part of the Lower Devonian may actually be the Silurian System. Judging from the report by Tokay, the total thickness of the Devonian System is estimated at 1,400 – 2,400 m or over[(3)]. Incidentally, the Devonian stratigraphy in Bartin area by Brinkmann (ibid.) is shown in Table 20.

C. Carboniferous System

The Carboniferous System observed in the Zonguldak area consists of the Visean, the Namurian, and the Westphalian Series.

C-1 Visean Series

The Visean outcrops distribute in a belt zone running in the E-W direction from the south of Degirmenağzi to the southeast of Zonguldak city. Another visean outcrops are observed around Göl Mountain 4 km west of Çaycuma. The relation between

(1) Reference 7)
(2) Reference 8)
(3) Tokay (1961) reports that the thickness 1,200 m of the Middle Devonian in Table 20 is the east wing of the Inkume Anticline.

the Visean exposed in the two areas is not known well.

Main components of this series are dark gray dolomitic limestone and greyish white limestone, frequently containing siliceous modules. The bedding planes are vaguely recognized, due to the development of the joints which are vertical to the bedding. The bedding planes and joint faces often have cleavages. At some places, calcite veins occur in network. The Visean Series distributed in a belt with the E-W direction is considered to correspond to the upper or middle series. It contacts the overlying Namurian Series by faults in many places and is bounded on the south by the Cretaceous in unconformity. The thickness of the Visean Series is difficult to estimate due to the complicated structure and also concealment of its lower part under the Cretaceous. However, it will be estimated over 1,400 m (1) by the existing data. This series consists of marine sediments, containing fossils of coral (Dibunophyllum), brachiopod, bryozoan and others.

C-2 Namurian Series

While the Visean Series is not exposed in the western part of this area from Arumtçuk to Kandilli, the Namurian outcrops are rather extensively distributed at Arumtçuk, Kozlu, Zonguldak, Bübe (near Delikmese Mountain) and at 6.8 km south of Degirmenağzi. Its stratigraphy and facies are the most studied in the western part from Arumtçuk to Kandilli in connection with the coal mining. The upper - middle zone of this series is called the Alacaağzi Formation. It consists of sandstone, sandy shale, shale, and intercalating coal (Fig. 9). According to Patijn (1954) (2), compared with the Westphalian Series, this series has less conglomerate, more Arkose sandstone and shale, and the black shale yielding fossil bivalves indicates lacustrine sedimentary condition. The thickness in the south of Kandilli is reported at 1,100 m (Patijn, ibid.) or 600 m (3) (Öguz, M. 1974).

The Namurian Series at Kozlu and Zonguldak are considered to be almost the same facies as that of Arumtçuk and mostly terrestrial sediment, though it is reported that some horizons yield fossil Goniatite (a kind of ammonite). There is no datum concerning the overall stratigraphy of this series in this area. It is reported to be about 850 m thick at Zonguldak (Patijn, ibid.), and also it may be 1,000 – 1,200 m thick at other places judging from the existing data.

(1) In Bartin and Amasura areas, it is about 1,500 m thick (including the upper Kulm facies). Table 19.
(2) Reference 9)
(3) This thickness refers to only the thickness of the Alacaağzi Formation. Reference 10)

The Namurian series in the eastern part of this area from Bartin to Amasra being reported by M. Tokay (ibid.) consist of sandstone and shale, intercalating two layers of limestone and three coal seams, in the total thickness of 300 m + (Fig. 6). It is reported considerably easy to distinguish this series from the Westphalian Series by the fossil pollen. (Yahsman 1961 [1], E.K.I. 1982[2] etc.)

C-3 Westphalian Series

As the major coal-bearing series, the Westphalian Series is exposed at Arumtçuk, Kozlu, Zonguldak in the west and the center and at Bartin and Amasra in the east of the objective area. Generally it is subdivided as follows:

The Westphalian Series
- D, C, B — Karadon Formation
- A — Kozlu Formation

(1) The Kozlu Formation is the major coal-bearing formation in this area (Arumtçuk, Zonguldak). The classification of A - D of the Westphalian Series can be made by fossils, especially spores. However, the classification of A from B, C and D is possible by rock facies in the Zonguldak area. As it is obvious from Fig. 9 that usually the base of basal conglomerate above the Agop Coal-Seam (Coal Seam No. 20) is a boundary between A and B of this series, and B, C and D are dealt together as the Karadon Formation. The conglomerate in the Karadon Formation has bigger size gravels than those of the Kozlu formation and reportedly contains more gravels of metamorphosed igneous rock and schist. In general, the Karadon Formation has more conglomerates and less coal seams.

On the other hand, the base of the Kozlu Formation is reported to be recognized by the existence of conglomerate in combination with the coal-seam at Kozlu and Zonguldak area. In other words, the lower boundary of the coal-seam below the lower most conglomerate is the base of the Kozlu Formation. This boundary is said to be roughly corresponding to that of fossil spore classification[3].

The Kozlu Formation is composed of sandstone, conglomerate, sandy shale and shale, intercalating considerable number of coal-seam in the predominant

(1) Reference 11)
(2) Reference 12)
(3) Boundaries between the Karadon Formation and the Kozlu Formation, and between the Kozlu Formation and the Namurian Series by rock stratigraphic classification often do not agree with those boundaries made by biofacies in a strict sense.

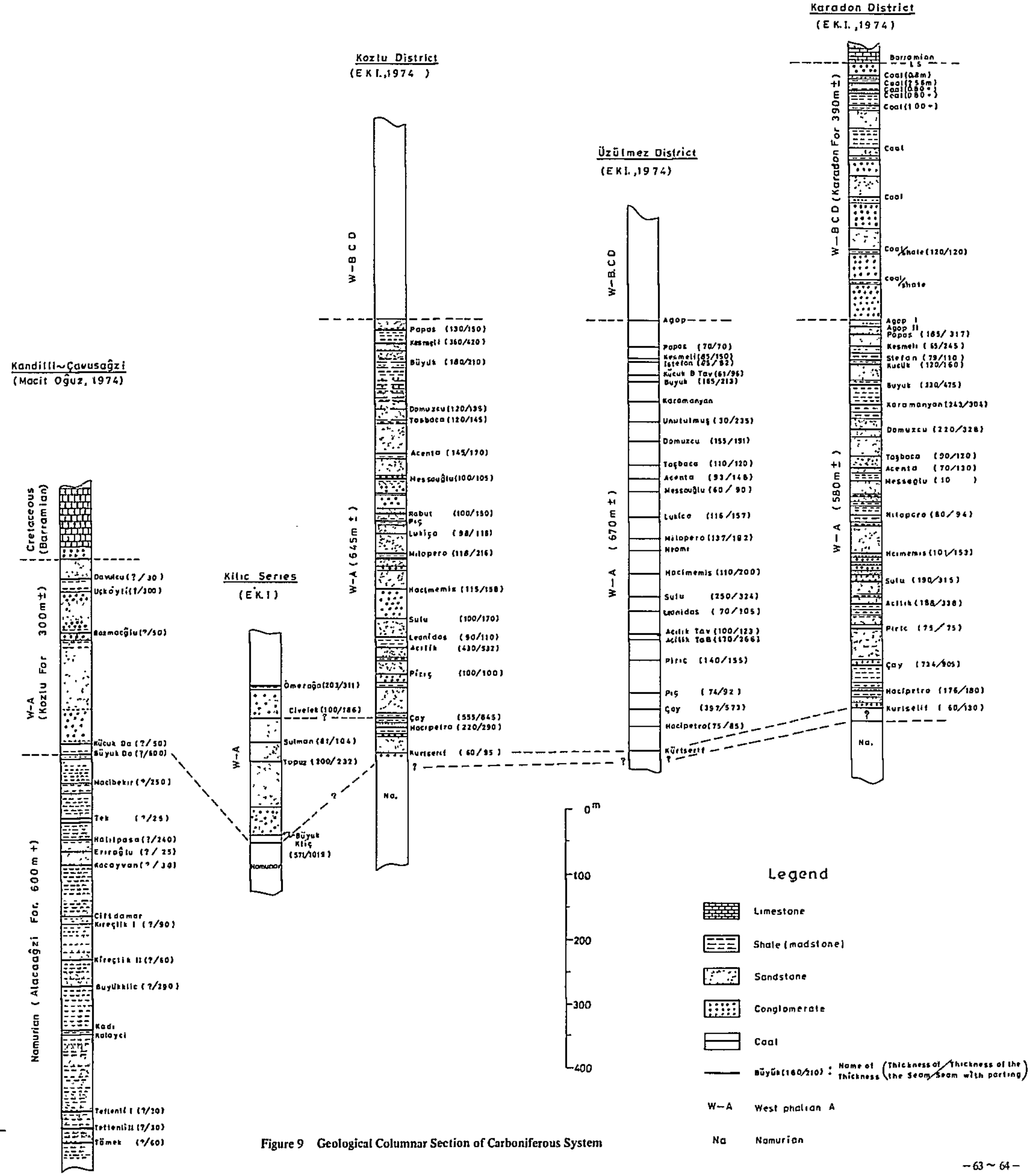


Figure 9 Geological Columnar Section of Carboniferous System

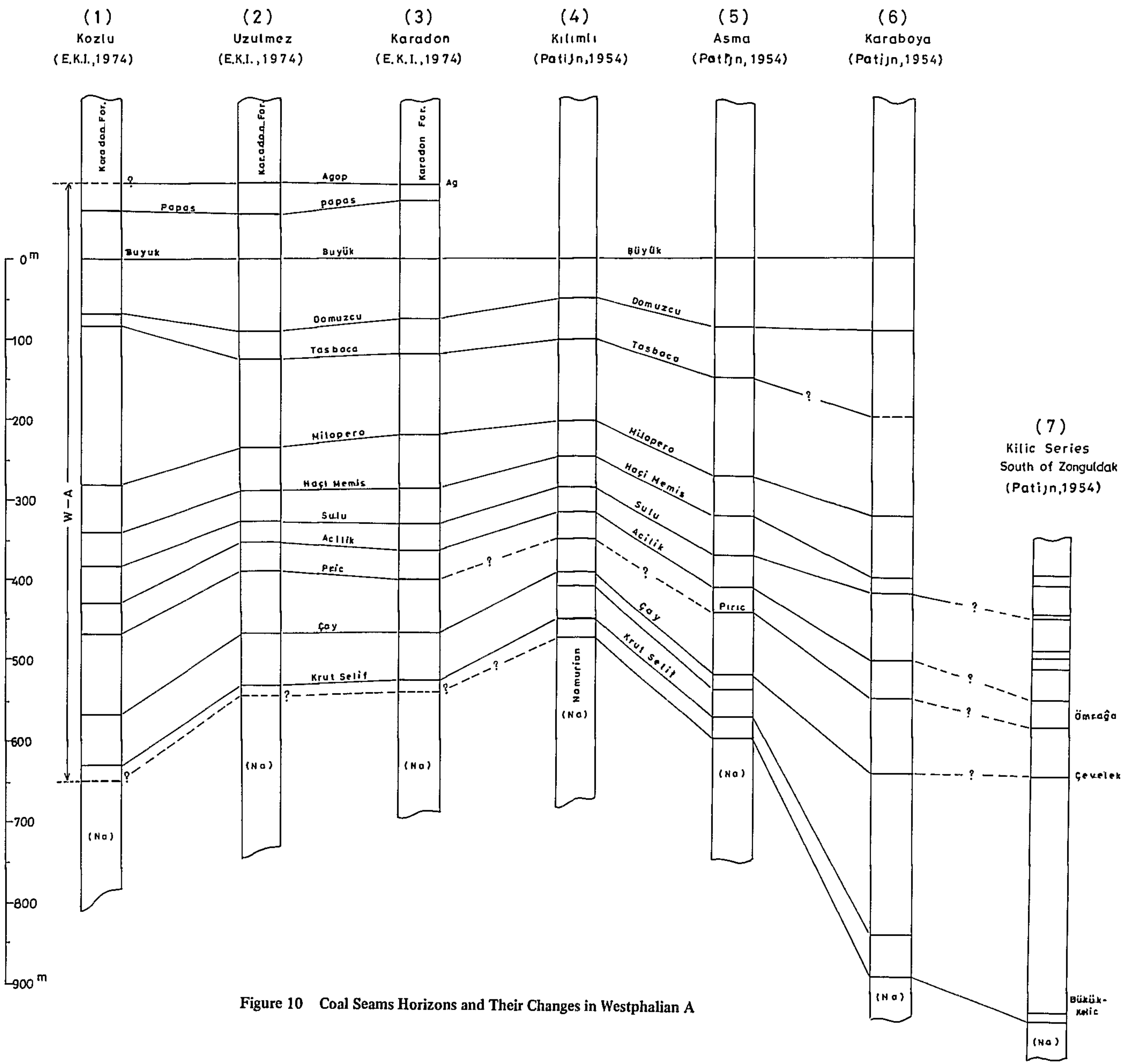
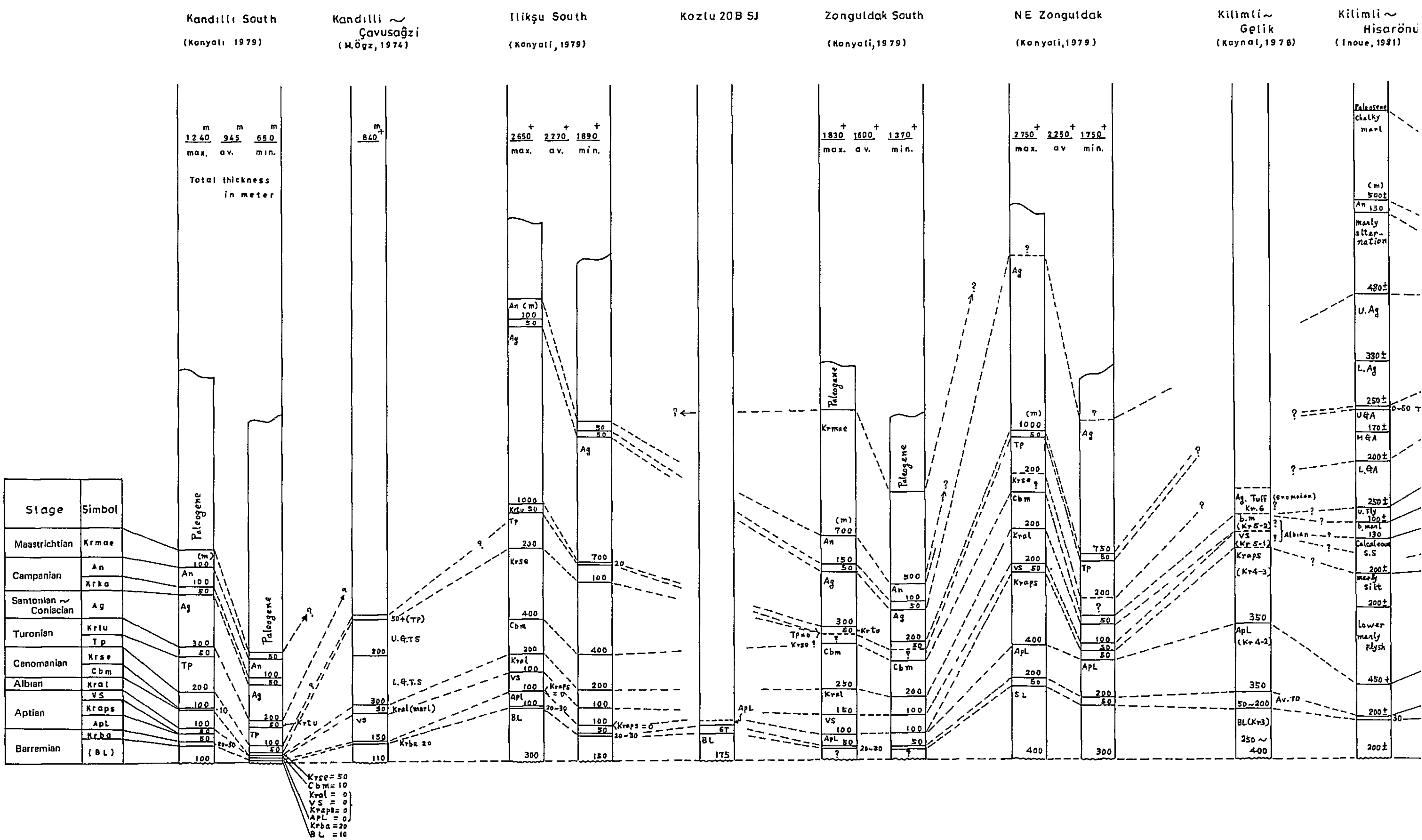
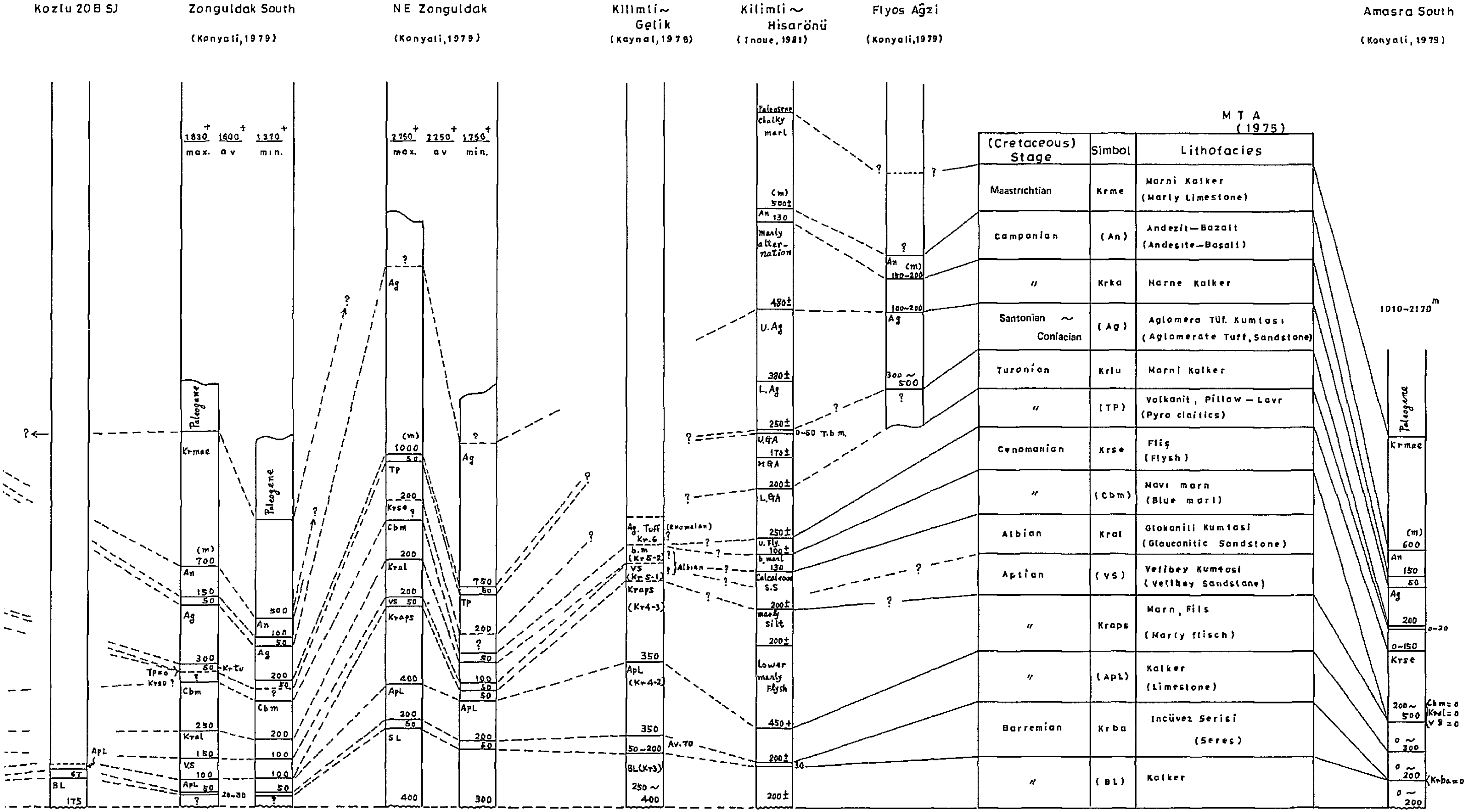


Figure 10 Coal Seams Horizons and Their Changes in Westphalian A

Figure 11 Local Variation of Thickness on Cretaceous System





(Cretaceous) Stage	Simbol	Lithofacies
Maastrichtian	Krme	Marni Kalker (Marly Limestone)
Campanian	(An)	Andezit—Bazalt (Andesite—Basalt)
"	Krka	Marne Kalker
Santonian ~ Coniacian	(Ag)	Aglomera Tüf, Kumtasi (Aglomerate Tuff, Sandstone)
Turonian	Krtu	Marni Kalker
"	(TP)	Volkanit, Pillow — Lavr (Pyro clastics)
Cenomanian	Krse	Fliş (Flysh)
"	(Cbm)	Mavi marn (Blue marl)
Albian	Kral	Glokonitli Kumtasi (Glauconitic Sandstone)
Aptian	(VS)	Velibey Kumtasi (Velibey Sandstone)
"	Kraps	Marn, Fliş (Marly flisch)
"	(ApL)	Kalker (Limestone)
Barremian	Krba	Incüvez Serisi (Seres)
"	(BL)	Kalker

order[1]. In Kozlu-Zongludak area, this conglomerate content reportedly increases toward the south (Patijn, ibid.).

On the south of the Midi Fault south of Zonguldak (Refer to Fig. 6), there is a steeply dipping area of the Visean, the Namurian and the Westphalian series, once called "Kiliç Series" (Raili, 1933)[2] (Fig. 9). The Westphalian Series in the Kiliç Series is reported to be A, but it is questionable whether the intercalated coal-seams are correlatable with those of the Westphalian A.

The Westphalian A at Arumtçuk area is considered to be correlatable with the lower half sequence of the same series A at Zonguldak, containing considerable amount of coarse materials like conglomerate, conglomeratic sandstone, etc. (Fig. 9)

The variation in thickness of the Kozlu Formation is more remarkable in N-S direction than in E-W direction. The total thickness of the Westphalian Series A in the Zonguldak Coal Field Area seems to fluctuate between 800 and 1,200 m. (Fig. 10)

(2) The Karadon Formation[3] is characterized with the predominant conglomerate and conglomeratic sandstone in its lower sequence. The thickness of a conglomerate bed reaches 10 m at places. The gravels, mainly composed of quartzite, slate, and granitic rocks, are a fist-size in general, with the maximum size of 20 cm. It intercalates abundant coal stringers, and thin coal seams. But at Zonguldak area most of the coal seams are regarded as not workable. The Westphalian Series B, C and D, in the eastern part of this area are, in view of its facies and thickness distribution, considered to be thicker toward the south and showing delta facies with rich coarse grains. The thickness of the Karadon Formation in this area is reported to be 260 – 400 m.

C-4 Stephanian Series

This series is not known to exist in this area. It exists at Amasra area to the east of this area (Table 19).

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(1) By an estimate based on the geologic column at Kozlu (Masui ? 1976), Sandstone•Conglomerate : Shale (including sandy shale•coal) = 77 : 23.
(2) Reference 13)
(3) At Amasra in the eastern part of the area, the Karadon Formation seems to be a major coal-bearing formation.

C-5 Permian System

It is not known whether this system occurs in this area. At Bartin and Amasra to the east of this area, Tokay (ibid.) reports an existence of a formation of 110 m thick composed of red sandy shale and marl (Table 19). Brinkmann (ibid.) considers that this system was probably eroded out at Ereğli and Zonguldak. Outside of this area, such as inebolo[1] and others, this system is, together with the Stephanian Series, called the Aritdere Formation, composed of thick red mudstone and sandstone without limestone.

3-2 Mesozoic Erathem

The Mesozoic group in this area lacks the Triassic System and the Jurassic System and bears only the Cretaceous System. The former two systems occur east of Amasra.

A. Cretaceous System

The Cretaceous System of this area is well studied by M.T.A. It covers the Palaeozoic Carboniferous System in a clino-unconformity and has a conformable relationship with the Palaeogene System. The rock facies and the thickness of this system which generally divided into nine stages are summarized in Table 21. The result of the field survey of the Cretaceous along the coastline will be described later.

A-1 Barremian Limestone (Thickness 100 – 400 m)

This formation is composed of generally massive limestone, a little crystalling, invariably accompanied with bedding planes and joint walls. Under a microscope, an oolitic structure is recognized and showing dark red color. In the southern part of the distribution area of the Palaeozoic inlier to the east of Kozlu, it is not known whether this limestone exists or not. It is not confirmed whether it lies under the Velibey sandstone (Upper Aptian) by overlapping or it was not deposited there at all. As there was an opinion based on the drilling results at Zytinköy that the southern area lacks this limestone through the Aptian Stage (M.T.A.), the number '0' was put in the thickness column of Table 21.

A-2 Barremian "Incuvez" Member (30 – 50 m)

This member, characterized by its color on the weathered surface, is one of the key beds. The boundary with the underlying Barremian limestone is not clear because the limestone gradually shift to an alternation of calcareous conglomerate and limestone to an alternation of mudstone, sandstone and conglomerate (matrix;

(1) About 160 km to the east of Zonguldak city.

Table 21 Summarized Stratigraphy of Cretaceous System

Stage		Rock Facies	Thickness (2)	Remarks
Maastrichtianan		White grey chalky marl, marly limestone showing banded alternation and with foraminifera fossils. (Thickening to the east)	50-700	[Krame] (3)
Campanian	Up	Augite-biotite andesite lava with visible columnar joint.	50-200	Being reported MTA as Basaltic Rock partly.
	Low	Alternation of chalky marl and tuffaceous mudstone (Possibly thickening to the east)	50-480	[Krka]
Santonian-Coniacian		Andesitic-basaltic, pyroclastic members, such as lapilli tuff, volcanic tuff breccia, tuffaceous sandstone, tuffite, etc. (Thick, Massive)	200-1,000	
Turonian	Up	Thin banded alternation of dark grey platy marl, and andesitic or dacitic tuff and tuffite	10-50	[Krtu]
	Low	Massive and bedded andesitic tuff breccia, tuffaceous sandstone, and lapilli tuff with onion structure	20-630	
Cenomanian	Up	Thin banded alternation of grey marl and marly shale	50-400	[Krse]
	Low	Blue marl, partly sandy	10-250	
Albian		MTA's glauconitic sandstone, quartzose fine-medium grained sandstone partly including block spot of rock fragment	0-200+	[Kral]
Aptian	Up	So called velibey sandstone, micaceous, quartzose fine-medium grained sandstone partly including black spot of rock fragment	50-150	
	Mid.	Alternation of marly silt, fine sandstone and marl of flysch type (With sideritic module)	0-650	[Kraps]
	Low	Grey-white limestone partly argillaceous (Fossiliferous beds of Orbitolina and Belemnite at upper most)	0-350	
Barremian	Up	Alternation of mudstone, sandstone, conglomerate (limestone pebblie), called Incuvez member (Purple color on weathered surface)	0-200	[Krba]
	Low	White-white grey limestone, partly dolomitic (Including some oolitic limestone and visible calcite veinlets)	0-400	

Remarks: (1) The classification younger than Turonian will be different by each geologist, e.g. Kanyali, 1979, designate the Campanian Andesites of this classification as of Maestrichtian's,

(2) Thickness has been taken from Figure 11.

(3) Parentheses are abbreviations derived from geological map of Figure 6.

calcareous). Accordingly, the thickness of this member varies subject to setting of boundary line against the Barremian limestone formation.

A-3 Aptian Limestone (50 – 350 m)

Similar to the Barremian Limestone, this layer is always accompanied by bedding planes and joint walls. At its uppermost part where bedding planes are well developed, there lies a fossil zone containing Orbitolina, Belemnite and bryozoan, which is reported to be useful as a key bed. Along the coastline of the Black Sea from Arumtçuk to Çavusağzi, this limestone layer and the above-mentioned Incuvez Member are not exposed. They may exist in the sea area.

A-4 Aptian "Flysh" (0 – 650 m)

On land area, the Aptian "Flysh" is slightly exposed near Zonguldak Port. Besides the above, its outcrops are solely observed in the north-eastern part of this area, Kilimli - Karadon - Gelik. As mentioned in A-1. 'Barremian Limestone,' it is not known whether this formation occurs in the southern part of the area.

Incidentally, Baykal (1971)(1) and Brinkmann (ibid.) do not distinguish and classify this "Flysh" beds into the Aptian Stage.

A-5 Aptian Velibey Sandstone (50 – 150 m)

Judging from the attached geological map (Fig. 6) and other data, this member shows considerable peculiar distribution and sedimentation. It is assumed that this sandstone deposited by filling the depressions and made a kind of overlapping sedimentation to the old rocks in the sedimentary basin.

The informations with this member in the Black Sea side of this area are scarcely available. This sandstone is reportedly called ortho-quartzite, which has frequently over 99 percent quartz content.(2)

A-6 Albian "Glauconitic Sandstone" (0 – 200 m)

This member is extensively exposed in the central - southern part of this area, namely to the south of the Palaeozoic inlier which extends from Kozlu to Zonguldak. Those classified in the category of "Glauconitic Sandstone," as a result of the field survey (mainly along the coastline of the Black Sea), are mainly composed of very fine to medium sandstone (platy), sometimes intercalating siltsone, with the sand

(1) Reference 14)
(2) Reported by E.K.I. geologist.

grains being mostly quartz. Coal stringers and fragments of black rock are frequently abundant in this sandstone. The matrix of this sandstone sometimes shows carbonate. Glauconite is hardly recognizable visually. This sandstone at Zytinköy Well is reported to have a considerable thickness (over 400 m) and unconformably overlying the Devonian System.

A-7 **Cenomanian Stage (50 – 600 m)**

The upper sequence of this stage characterized by flysh facies is regarded by Baykal (ibid.) and Brinkmann (ibid. et al.) as the "Wild flysch" frequently containing large and irregular xenolith blocks and boulders derived from the hinder land, probably originated in the Austrian tectonic movement. Occurrence of the Palaeozoic sandstone boulders at around 3.5 km to the southeast of Çavusağzi (Sebetepe Village) is considered to be an example of this xenolith blocks. (IV. 2. A) M.T.A. reports that the flysh facies of the Cenomanian Stage is widely ditributed in the southwestern part of this area and that it is thinning out to the north of Göl Mountain (about 8 km west of Çaycuma).

A-8 **Turonian Stage (150 – 620 m)**

The horizon of "igneous rocks and pillow basalts" (M.T.A.) which had been placed in the lower part of this stage was well studied by the field survey, conducted as a part of this project though restricted to the coastline zone, and its detailed stratigraphy was established.

Its result indicates that the main part of this stage is mainly composed of rhythmical, thin bedded alternation of andesitic or dacitic tuffeceous argillaceous and arenaceous rocks as the main component, sometimes intercalating thick tuff breccia or pumiceous tuff. Massive, coarse volcanic sandstone and lapilli including breccia are dominant in the lower part and showing gradual decrease of its grain size upwardly so as to be resulting in the predominant alternating beds of finely banded volcanic ash and tuffaceous siltstone in the upper part. Characteristically, the upper part looks partly greenish, which makes it appear to be containing glauconite.(1) Accordingly, the description of this facies as the "Variegated marl and Tuff" by Brinkmann based on Arni (1933) and Tokay (1952, and others) does not sound appropriate.

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(1) Of the fine-grained banded alternation in the lower part, the beds with presumably rich clastic grains show chocolate color, alternating with greenish beds.

The Geological Map of M.T.A., 1:50,000, indicates an occurrence of "Pillow Lava" in the lower part of this stage near Kizilcakoy (about 15 km to the east of Ereğli) along the main road from Zonguldak to Ereğli. As a result of the re-examination of the above map by the field survey, the actual geology in this area was found as follows;

The upper Cenomanian Flysch which shows peculiar sedimentary facies with the Palaeozoic boulders is covered with the Lower Turonian Stage composed of massive coarse volcanic sandstone of about 200 m thick, which is further covered with the Upper Turonian Stage consisting banded alternation of tuffaceous shale (partly showing green color) of about 350 m thick. Overlying it, the Coniacian lapilli is depositis very thick. The boundaries of the above strata correspond well to those shown in M.T.A.'s Geological Map. Therefore, it follows that M.T.A. calls the massive coarse volcanic sandstone above the Flysch as the 'Turonian Pillow Lava (Krtp)' and recognizes the banded alternation of tuffaceous shale above it as the 'Turonian marl (Krtu).' On a broad view, the stratigraphy of this area as a whole is presumably correlative with the stratigraphy in the east of Zonguldak, in view of occurrence of the tuffaceous banded alternation common to these two areas.

And also, the sequence corresponding to the massive coarse volcanic sandstone well observed in the western part is thinning in the eastern part, where exposures of this rock showing onion structure are confined to only about 100 m thick along the iron towers of the power cable west of Yaka Mah Village about 1 km to the north of Çatalağzi. Here, a conglomerate bed including older limestone boulders is observed between the above-mentioned massive coarse volcanic sandstone and the underlying Cenomanian Flysch beds, though it is thinner as well as smaller in boulder size compare with that in the western part. In terms of boulder size, it may hard to compare with that of the western part which contains abundant boulders of a mat size (90 cm x 180 cm), but in terms of occurrence of the older boulders, both beds may correspond well and therefore be considered to belong to the same horizon. This conglomerate is classified into the upper Flysch bed, but it is questionable whether it actually belongs to the upper Flysch or to the base of the Turonian massive coarse volcanic sandstone. Brinkmann (ibid.) and Baykal (ibid.) consider that the base of the Turonian Stage often unconformably covers the underlying strata. The above-mentioned conglomerate 3 km to the south of Çavusağzi and the conglomerate including limestone boulders at the north of Çatalağzi may be suggestive of the existence of unconformable relation mentioned above.

Furthermore, near the summit of a hill at eastern side of Gobu village along the coastline about 7 km to the west of Filyos, a thin, whitish gray, soft chalky marl with beautiful bedding of less than 1 cm thick is intercalated between the Coniacian massive lapilli and the Turonian banded volcanic ash (being exposed for about 30 m thick, and possibly thinning out easterly). This rock facies is not traceable in the western part.

In addition, in the southern part of this area (on the southern wing of the Mesozoic anticline), pyroclastic rocks of this stage do not occur, but the banded volcanic ash belonging to the upper stage seems to be recognized. Therefore, the sedimentation center of this stage is considered to have been in the north or the northwest.

A-9 Santonian - Coniacian Stage (200 – 1,000 m)

Pyroclastic sediments, such as lapilli and tuff breccia of this stage, are bigger in size than those of the Turonian Stage. The measurement result of magnetic susceptibility shows that the volcanic rocks being comprised in this stage are basic (amphibole - pyroxene, basaltic andesite and two-pyroxene andesite, etc.).

These thick volcanic breccia formations can be broadly divided into two big sedimentary cycles. In between both cycles, a massive volcanic sandstone and the intercalated banded volcanic ash deposited prior to the next major pyroclastic sedimentary cycle shows marks of the under sea landslide possibly due to big earthquakes that took place before the next major eruption, and then, extremely massive, thick agglomerate was deposited. By considering the special characteristics, such as magnetic property, seismic wave velocity (fast), topographical influence and continuity, these pyroclastic rocks are considered to be important to delineate the distribution of the Cretaceous beds exposed on the seabed.

A-10 Campanian Stage (150 – 600 m)

This stage is divided into the Lower member consisting of thin alternation of slightly tuffaceous marl and coarse marl and the overlying Upper member consisting of a gray pyroxene – biotite andesite lava with well developed columnar joint (thickness of about 150 m). The phenocrysts, i.e. – biotite, pyroxene, and plagioclase, in the andesite are big in size and therefore considered by some people to be possibly sheet. But the microscopic study shows a glassy groundmass with poor crystallization containing abundant spherulite of long-needle-like plagioclase, which suggests that the rocks were instantly solidified. Therefore, there is a strong possibility of volcanic lava. The two members of this stage can be traceable along the road on the west bank of the Flyos River to the east of this area.

A-11 Maastrichtian Stage (50 – 700 m)

Conformably overlying the Campanian andesite, this stage is composed of white – milky white, soft chalky marl with thin banded bedding, frequently intercalating hard marl bands. It yields foraminifera fossils. It is distributed on the west bank of the Filyos River and covered with the Tertiary sediments.

The Cretaceous stratigraphy of this area has been summarized in Table 21. Actually, rock facies, succession, and thickness of formations vary with the area due to the differences in Palaeotopography, tectonic movement, igneous activity and sedimentary mechanism by environment such as the direction of material supply.

Following is an outline of some specific points compiled from M.T.A.'s Geological Map and other existing data.

(1) At Arumtçuk in the western part of the area, the lower horizons of the Cretaceous, namely the uppermost of the Barremian, the Aptian limestone, the Aptian flysch are neither exposed nor distributed. The albian "Glauconitic Sandstone" does not occur, either.

(2) To the south and southwest of Iliksuağzi, the lower horizons of the Cretaceous are not traceable like (1). But the Albian Stage is distributed. Among the Upper Cenomanian Flysch facies distributed 4 – 6 km to the south and southwest of Iliksuağzi, huge derived blocks can be observed.

(3) On the south wing of the Cretaceous anticline to the south of Iliksu - Kilimli, the Lower Turonian pyroclastic rocks do not occur.

(4) The Aptian "Velibey Sandstone" shows sedimentary sequence of progressive overlapping almost all over the area. The lack of the Barremian limestone and others observed on the geological map at Arumtçuk and south of Zonguldak city may possibly be caused by such overlapping phenomenon.

(5) The drilling data at Zeytinköy Well, to the south of Zonguldak city, and others indicate a possibility that the Albian Stage and the strata below it may not have been deposited at all over an extensive part of the southern area.

(6) Distribution of the Aptian Flysch (Kraps in Fig. 6, Geological Map) is quite limited. (Refer to A-4, Aptian "Flysch")

(7) In the area from Karadon to Gelik northeasterly to Filyosağzi (Filyos River

Mouth), almost all the stratigraphic horizons of the Cretaceous System are well distributed to a considerable thickness, except the Cenomanian Flysch facies which is missing or very thin if any.

3-3 Cenozoic Erathem

A. Palaeogene System

On land, this system is distributed in the south of the area and extending to the further south and southwest to Çaycuma, Baycuma, Ormanli and Alapali, where it is reported that the Cretaceous Maastrichitian Stage to the Palaeocene Series shows continuous relation stratigraphically. In general, the rock facies are reported to gradually change from what is called the limestone – marl Flysch of the Maastrichitian Stage to the sandstone – mudstone Flysch of the Palaeocene to Eocene Series.

The Palaeogene System, which is distributed from the southern part of the area to Çaycuma, is mainly composed of an alternation of fine to medium sandstone, mudstone and marl, which shows one stratigraphic unit of a few meters thick or less in general and be frequently intercalating very densely alternated beds. In its middle to upper horizons (nearly 6 km to the east of Baycuma), the intermediate to basic tuff – hybrid tuff (5 m at the thickest) is interbedded in several horizons,(1) which are considered to be a part of the Eocene Series.

Tokay (1954, 1955) generalized the Palaeogene System of this area to Bartin on the east as shown in Table 22.

Table 22 Brief Stratigraphy of Palaeogene System

Stage	Rock Facies	Thickness
M. Eocene	Yellowish bedded sandstone	2,000 m-
L. Eocene	Glauconitic marl	150 m
Paleocene	Light colored limestone + marl	100 m*1

*1 Brinkmann, 1976, P.76

(1) For magnetic susceptibility of this rock, see Reference 15)

B. Neogene System

Occurrence of the Neogene System is not known in this area and its surrounding area up to the present. In the offshore area, off Akçakoca, about 30 km to the west of Ereğli, an existence of the Pliocene Series overlying the Eocene, is reported from the two oil drilling results (Turkey Oil Corporation).(1) It suggests that no Miocene Series are in this area.

As a result of the velocity analysis and other studies on the offshore geophysical data obtained from the northern sea area, it is assumed that the Tertiary System is distributed around the upper part of the continental slope as to be mentioned later. From the viewpoint of the geological conditions in this area and its vicinity, the stratigraphical group which is assumed to be the Tertiary may possibly consist of the Palaeogene and the overlying Pliocene Series.

C. Quaternary System

The Quaternary System is rather widely distributed along the Filyos Valley on the eastern margin of this area. Besides the above, its occurrence is only slightly observed along the coastline and in the mountain area.

Except those along the Filyos Valley, the Quaternary System is presumably composed of mostly alluvium including sand, gravel, clay which filled valleys and intramountain basins as well as talus.

3-4 Geological Structure

Fig. 7 shows a schematic structural map of the area. The geological structure of this area can be broadly divided into the Palaeozoic structure and that of the Cretaceous and Palaeogene.

A. Palaeozoic Erathem

The Palaeozoic group is scattered among the Cretaceous as its inliers. But the relationship among the inliers is not known well.

The Palaeozoic group scattered from Çamli to Çavusağzi are the Westphalian Series A and the Namurian Series from a syncline elongated roughly with E-W direction as basic structure. Near the synclinal axis the Palaeozoic formations are mostly hidden beneath the Cretaceous. From Arumtçuk westward, its southern wing is partly

(1) Akçakoca No. 1 Well: Pliocene 94 – 690 m (Eocene 691 – 1,960 m, Cretaceous – 2,280 m T.D.)
Akçakoca No. 2 Well: Pliocene 96 – 696 m (Eocene 97 – 1,634 m)

overturned, thus making the syncline asymmetrical. The axial plane at around Çamli is presumably inclined at 45° – 50° to the south. Though poorly delineated at some location, the synclinal axis in general tends to plunge gently both westwardly and eastwardly. The depth range of the base of the major working coal-seam, Gay of Westphalian Series A, will be assumed as follows: Eastwardly, near Camli – -500 to -600 m below sea level; near Kandilli – -400 to -500 m; near Arumtçuk – -300 to -350 m, south of Alacsağzi – -300 to -400 m; south of Tefleniağzi – -200 to -250 m; south of Kirecilikağzi – -300 m; south of Çavusağzi – -600 m, respectively.

The Palaeozoic group in this zone (Camli to Cavusağzi) is cut by many N-S and NNW-SSE faults, having its basic synclinal structure disturbed. All these faults that appear on the Geological Map (Fig. 6) are cutting also the Cretaceous. But actually, some faults are cutting the Palaeozoic only. Because most part of the Palaeozoic lies beneath the Cretaceous System and because there is no detailed information on the features of these faults, many questions remain unsolved concerning the ages of the faults, the faults within the Palaeozoic, etc. F_1, F_2, and F_3 in Fig. 7 are the faults that are considered to have considerably affected the Palaeozoic distribution and structure.

The Palaeozoic inlier extending from the south of Degirmeneğzi to Gobeağzi (Deliklimşe T.) is the largest exposure in the area, containing the major coal mining zone. The basic Palaeozoic structure here is the folds with E-W trend, ranging from the north anticlines (including a dome structure) A_1, A_2, D_1, syncline S_2, and a steeply dipping zone (Fig. 7). The anticline A_1 (Gelik Anticline, Patijn, 1953) plunges east,[(1)] and in the west, displacement have been taken place by a fault, it is considered that A_1 leads to A_2, and further westwardly to D_1 (Kozlu Dome).

On the west of the Karadon Fault, the Westphalian Series have been confirmed to exist below the Cretaceous System by a drilling survey, but the overall geological structure is not yet fully elucidated.

Syncline S_2 (Gelik South Field Syncline, Patijn, ibid.) extends easterly, plunging[(2)] into the Cretaceous System. To the west, cut by the Midi Fault, its existence becomes obscure. There is an opinion that the western extension of S_2 is merged into the "Steep Dip" (Patijn, ibid.).

(1) Reported to dip at 23°.
(2) Similar to A_1, it is reported to plunge at 23°. Reference 9).

The "Steep Dip" extending from Digrmennağzi to Delikilmşe Mountain, verges on the southern margin of the Palaeozoic inlier in the Zonguldak area. This "Steep Dip" roughly corresponds to the area south of the Midi Fault, being composed of the Visean, the Namurian and the Westphalian A. The dips of these strata are close to perpendicular, frequently showing overturned sequence. The Westphalian A at the "Steep Dip" is sometimes called "Kilic Series." The inlier which appears somewhat isolated near Delikilmşe Mountain close to the eastern edge of the "Steep Dip" is called the "Palaeozoic Erathem at Göbe," reportedly a kind of horst.[1]

This Palaeozoic inlier south of Digirmennağzi to Göbe is divided into many blocks by faults, while maintaining the abovementioned basic structure:

E-W trend: Midi, Karadon, Simal, Adnanbay, Boyacloğlu, Büyük, Kuzey, No. 82, No. 1, F_{11}.

Most faults show continuity, running parallel to the trend of the main axis of the folds in the area. In particular, the Midi Fault dividing the "Steep Dip" from its north is regarded as important. The Adnanbay Fault is not continuous, but is remarkable in terms of its big throw (600 – 800 m).

N-S trend: Damlar, F_5, Omertarla, F_6, F_7, etc.

These faults are not continuous, but are regarded as important in terms of big throw and their influence over the basic structure.

NNW-SSE trend: Oksne, Bastarlar, F_3, Kardislik, Taşbaca, No. 8, No. 4, etc.

These faults show continuity to some extent, cutting the folding structure diagonally. The throws are not big in general.

Of the above faults, the Midi Fault is the oldest. Some even consider that it originated in the sedimentation period of the Westphalian Series. For explanation of the phenomenon that most of the faults which had affected the Palaeozoic structure also cut the Cretaceous System, it would be convincing to assume that the faults once caused displacement and deformation to the Palaeozoic strata owing to the Bariscan orogeny and be revived in the Alpine orogenic phase, resulting in the strengthening of displacement and deformation of the Palaeozoic. As to be mentioned later, it is difficult to make a distinction between the major trends of folds resulting from the above two orogenic movements.

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(1) Reference 16).

In addition to the Palaeozoic inliers mentioned above, there are also those near the Göl Mountain and near Osmanli Köy in the southeastern part, and those near Ilikusağzi, near Sandaciarmk T. and near Başviran in the western to southern part.(1) These are composed of the Devonian System, the Visean Series or the Namurian Series, but due to insufficiency of detailed data, their features and their relationship with those inliers observed in Arumtçuk and Zonguldak mentioned above remain uncertain.

B. Creatceous System

On a broad view, there lies one megaanticline with the NEE-SWW axis running parallel to the coastline of the Black Sea, of which the axis roughly corresponds to the distribution of the Palaeozoic inliers. On closer observation, it is found that this anticline comprises two lines of anticlinal series where the anticlinal axes repeat dipping and rising.(2)

The northern series consists of an anticline Arumtçuk - Cavusağzi (A_3) and the one Gelik - Kutükluk Basi T. (A_8), while the southern series comprises A_7, D_2, A_{10}, A_9, D_3, etc. The northern series is the major anticline.

A_3 of the northern series is displaced southward at around the south of Alacaağzi, and its western part is obscure but considered to pass over the Palaeozoic inlier at Arumtçuk and then to plunge westward (In Fig. 7, the denuded part is not illustrated). A_4 has been regarded as a by-product. Eastwardly, A_3 becomes obscure east of F_3. Whether it leads to A_5 (presumed) or to A_6 would need further investigation.

From Degirmennağzi eastward to Gelik, the Cretaceous System is not observed due to present erosion. In view of the Cretaceous structure around the Palaeozoic inlier, it looks certain that the anticlinal axis had been above the Palaeozoic inlier. Then it reaches to A_8 and plunges east afterwards.

The southern anticlinal series is intermittent and order in its arrangement compared with the northern one. Then, it might be a little controversial to treat these anticlines as a line of anticlinal series. As shown in Fig. 11, the Geological Section, the southern anticlinal series may be the secondary product of the northern anticlinal series at its southern wing. Many synclines and semi-basin structures are observed along the southern line, but they are mostly gentle in shape, except S_7 and S_8 which show

(1) The Namurian Series distributed near Acagicayer is likely to be the allogenic rocks among the Cenomanian Flysh.

(2) It may be called 'anticlinorium.'

continuity and S_9 which remarkably plunges east.

In the west, from Arumtçuk to Çavusağzi (F_1, F_3 for example), the faults which have the trends of N-S to NNW-SSE appear to affect in a considerable degree to the distribution and the structure of the Cretaceous System. F_3, in particular, seemingly dipping east, is disturbing the basic structures of both the Cretaceous and the Palaeozoic.

In the central to eastern part along the coastal zone of the Black Sea there are many faults with the N-S to NNW-SSE strikes, having caused the displacement to the Cretaceous system. However, the faults that look more continuous and that have caused larger displacement are in the E-W to EEN-WWS directions, such as Karadon, Büyük, No. 1 North Fay[(1)], etc.

In the eastern inland zone, the faults with NNE-SSW trend, such as F_{11} that is marking off "Göbe Horst" (mentioned earlier) and F_{23} which is traceable from west of Osmanli Köy to Dere Köy, have to be noticed. F_{23}, in particular, is affecting the overall structure of the anticlinorium in the eastern half of the area, and also markedly reflected on the gravity record.[(2)]

The faults F_{20}, F_{19}, F_{15}, and F_4 observed in the central to western part of the area have the E-W direction and is continuous. But the throws and displacements by these faults are considered not so large.

The Cretaceous System overlies the Palaeozoic groups in clinounconformable relation. On the north wing of the northern Cretaceous anticlinal series the basal conglomerate of the Barremian limestone covers the Palaeozoic group unconformably. Currently, exploratory drilling and electric prospecting (resistivity method) programs are underway to investigate the depth and feature of the basal plane of the Cretaceous System in the coal-mining area of Zonguldak and its adjacent area.

C. **Tertiary System**

The Tertiary System exposed in the southeastern part conformably overlies the Cretaceous and forms the south wing of the mega-anticline lying to its northwest of the area.[(3)] Gentle anticlines and synclines with the NE-SW direction are observed.

(1) Termed by M.T.A., meaning north fault.
(2) Reference 17).
(3) The basic structure of the Palaeozoic System in the south and southeast of the area is a syncline with the EEN-WWS trend extending from around Osmanli south of Ereğli northeasterly to Baycuma to the south of Bartin. (Reference 15).

In addition, intra-formational folding is frequently found inside the marl in the Flysh facies. Near F_{23} along the boundary with the Cretaceous System, an overturned sequence is observed.

3-5 Coal Seams

In Arumtçuk area, there exist about twenty coal seams in the Alacaağzi Formation at the upper Namurian Series and its overlying Westphalian A. Major working coal seams are the Büyük Damar (working thickness of coal seam: about 6 m) and the Üç Köylü about 250 m above the Büyük Damar (working thickness of coal seam: about 3 m).

In the western half of the area – Arumtçuk, Kandilli and Camli – it is reported that the Kücük Damr (1.5 m) and the Bozmağlu (1.7 m) are considered partly workable.

In the eastern part, Kireçlik and Alacaağzi, coal seams among the Namurian Series have been once mined.

At the eastern mines like Kozlu, Üzülmez and Karadon, fifty or more coal seams have been confirmed in the Westphalian Series. The workable coal seams are all in the Westphalian A (the Kozlu Formation) where there are 16 – 22 working coal seams at present. Especially important are, in ascending order, the Çay, the Acilik, the Sulu, and the Büyük. Also important among the Kiliç Series at what is called the "Steep Dip" is the Büyük kiliç (coal thickness: 5.71 m, seam thickness: 10.19 m).

The coal seams among the Karadon Formation at B, C, D of the Westphalian Series and those among the Namurian Series have only slight records(1) of mining at very limited parts, and they are considered to be scarcely worth mining.

In general, the coal seams in the area abound with thickening and thinning generally and be usually accompanied with disturbed fine coaly partings (2), such as "Hoya" or "Gambai" in Japanese coal mine nickname, in their main body. Therefore it seems to be difficult to correlate the coal seams only by their columnar sections.

The number and the thickness of workable coal seams and coal reserves, etc. are given in Tables 16, 17, and 18. Also the seam thickness, the coal thickness, the interval between coal seams are shown in Figs. 9 and 10.

(1) For example, the coal mining at the Namurian Series in the "Göbe Horst" area was conducted before the World War II.

As having been pointed out in the existing data (Reference 4), etc.), the physical and chemical properties of coals from Zonguldak are not able to be described exactly by Japan's Coal Classification Standard, but rather they seem to be classified well by the International Classification Standards. The results of proximate analysis of coal are listed in Table 23, 24, and 25.

Based on all these data, the coal properties in this area are summarized as follows:

(1) Properties considerably differ by individual area, coal seam and, even in the same seam, by some other causes.

(2) Compared with those from the Zonguldak area, such as Kozlu and Üzülmez. The coals from Arumtçuk area, show tendencies of a little lower pure coal calorific values, lower coking properties (swelling index), higher volatile matter contents. The ultimate analysis reveals that the coal from Arumtçuk[1] has more oxygen and less carbon contents and be indicating a difference in the coal petrographical constituent. The Arumtçuk coal is classified into No. 611 of the International Classification Standard.

(3) Even in Zonguldak area, the coal properties vary from Kozlu to Üzülmez, and to Karadon (Gelik) eastward. Eastwardly, the coals show higher pure coal volatile matter content, higher diratometer index. The coals from Kozlu and Üzülmez are reportedly classified into Nos. 532, 533, 534[2] and the coals from Karadon fall under Nos. 634 and 635 of the International Classification Standard.

(4) In general, from the viewpoint of various analyses of properties as shown in the above-mentioned tables, the run of mine coals tend to show a remarkably higher ash contents, and the coals after washing tend to have a lower volatile matter content and a higher fixed carbon content compared with those of the Japanese coals.

As being clear from the above, the coals produced in this area are high quality bituminous coals, showing from low to high coking property. In terms of the coking property, the coals from Kozlu and Üzülmez are regarded as important.

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(1) Coal from Kandilli.
(2) Analyzed by ASTM.

Table 23 Main Qualities of Coals from Zonguldak Coal Field, Turkey

Area	Coal Seam	Moist %	Ash %	Vola. %	F.C. %	Heat' V. kcal/kg	H.V(M.A.F) kcal/kg	Sulfur	Swell' Ind. No.	Diratometer Index %	A.F.T. C°	No. of Int. Classif.	Remarks
Arumtçuk	Üç Köyli	2.80	34.10	23.28	38.65	4,882-5,152		1.17	week				Özkal,K.(1962)
"	Büyük Damar	2.60	4.37	31.58	60.28	7,491-7,761		1.23	"				Özkal,K.(1962)
"	-	5.74	6.20			7,390		1.50					T.K.I. Laboratory(1981?)
" (Kandilli)	-	2.40	10-40 *1	35.50			7,980-8,080	-	1 1/2	31	1,180	611	Bayki,F.(1961)
Kozlu	Çay	2.00	37.27	25.36	35.37	7,662	8,447	-	3 1/2			(422)*2	Japan(1970), originally from E.K.I.
"	Messooğlu	2.20	48.33	24.46	25.01	7,612	8,381	-	5 1/2			(433)*2	"
"	Acilik	2.15	37.88	24.50	35.52	7,511	8,199	-	3 1/2			(422)*2	"
"	-	2.25	8.30			7,720		1.50					T.K.I. Laboratory(1981?) Washed coal?
" (Koradon)	-	3.16	7.50			7,900		1.00					"
Kozlu	-	1.10	42.00	22.00	34.90	5,040-5,220		0.61	strong				T.K.I.(1962) Raw coal
"	-	1.50	14.00	30.50	54.00	7,000-7,250		0.85			1,450		T.K.I.(1962) Saleable coal
" (Kozlu)	-								4 1/2-6 1/2	+8-+76		533, 534	Bayri,F.(1961)
" (Ozülmez -Gelik)	-								7 1/2	+134-+169		534, 535 (Ozülmez) 634, 635 (Gelik)	"
Kozlu	Sulu		6.08	27.52	66.40	7,897	8,418		1			(411)*2	Hosono, et all(1970) dried after wash
"	Büyük		8.42	24.32	67.27	7,589	8,183		1 1/2			(511)*2	"
"	Dirıç		8.28	28.01	63.71	7,914	8,268		7			534	"
"	Leonidos		7.45	28.20	64.35	7,982	8,628		9			535	"

Note: *1 Ash content of washed sample - 6-8 %
*2 Analised by German Code.

Table 24 Ultimate Analysis of Arumtçuk Coal

Coal Seam	C	H	N	S	O	Remarks
Kandilli Seam	84.0	5.1	1.2	0.6	9.0	
Other Seams	86.2-87.5	5.1-5.7	0.9-1.1	0.4-0.9	5.6-6.3	

Table 25 Petrographical Constituent of Kandilli Coal

Petrographic constituent		Kandilli coal	Others*	Remarks
		(%)	(%)	
Lithotype	Vitrain	32.0	7.0	*Average except Kandilli, Kozlu coals.
	Clarain	20.0	10.0	
	Clarain-Durain Transition	4.5	59.0	
	Durain	3.5	6.0	
	Fusnin	5.0	15.0	
	Carbonaceous shale	3.5	15.0	
Maceral	Vitrinite	68.0	39.0	
	Exinite	17.0	18.0	
	Inertinite	15.0	43.0	

4. GEOPHYSICAL EXPLORATION

There is not much accumulation of past geophysical data on Zonguldak Coal Field and its adjacent area. However, there are some gravity, magnetic, and electrical prospecting data on land area, and some recent seismic survey results on the sea area.

4-1 Geophysical Surveys Until 1978

The past survey data summarized by Bojo and Tsu are as follows:

A. Offshore Seismic Surveys

In 1977 and 1978, offshore seismic reflection surveys were conducted by M.T.A.'s survey boat SISMIC-1 with multi-channel air-gun and others.

Examination of the data of oil exploration in 1977 (Eres K. et al.) in the light of coal field exploration revealed the following: The formations of possibly the Pliocene and Eocene are considered to be deposited considerably thick in the offshore area. These Tertiary formations are dipping northward, with the upper sequences gradually denuding toward the shore. The nearshore very close to this coalfield seems to lack Tertiary formations. This distribution status of the Tertiary in the offshore area has reportedly been inferred by applying the well geologic data obtained from the two oil drilling wells off Akçakoca west of this coalfield (about 33 km to the west of Ereğli). The record sections obtained from the above seismic surveys show several reflection planes with considerable continuity. According to the Turkish geophysicists of M.T.A. and others, of these reflection planes the following two are remarkable:

A specific horizon among the Eocene Series

The top of the Cretaceous System

The former is reported to be traceable throughout most of the exploration area. The seismic lines of 1977 are running at a distance of over 3 km from the coastline with the exception of an area off Amasra and others, and the intervals between the lines are sparse. From the viewpoint of the coalfield exploration, most area of the major offshore exploration lacks seismic lines. However, judging from the above survey records, it seems that the distribution of the lower strata gradually rises closer to the sea bottom from offshore toward the land area, and that in the considerable part of the nearshore up to a few kilometers from the coastline lie the Cretaceous System or the Palaeozoic group at a rather shallow depth beneath the sea bottom. Diffracted waves, possibly due to faults and other causes, are found in most part of the record section of the seismic lines running adjacent to the coastline.

Among those waves, intermittent reflection planes (segments) can be observed, though it is difficult to correlate them. A part of these reflection waves are considered to include information from the base plane of the Cretaceous. Also, it is reported that the offshore record sections, where presumably the Tertiary strata are deposited considerably thick, frequently include the reflections perhaps from the base plane of the Cretaceous (the top of the Palaeozoic).

Another offshore seismic survey was a test run performed in 1978, aiming at establishing the techniques adaptable for this coalfield. Of eight seismic lines at the test run (EZ1, Z1, Z2, Z4, Z5, ZB1, A2, A6), most covered the offshore Zonguldak area. Airguns and sparkers were used as the energy source. Special attention was paid to obtain records of good quality by varying the source energy of the sparker and the frequency. Compared with the conventional method of the above-mentioned oil exploration, the records of test run with reduced source energy showed fairly clear information of the shallow zone (less than one second in travel time).

Data of the above-mentioned offshore exploration were processed by M.T.A. with the computer "TIMAP 980-B" and the software package "MATE-5000." Offshore magnetic and gravity surveys were not conducted.

B. Onland Geophysical Surveys

The existing geophysical survey data on land area were considered to provide efficient information for the planning and performance of offshore exploration. Air-borne magnetic survey was conducted by M.T.A. covering an extensive area including the Zonguldak Coal Field. The direction of major flight course was roughly N45°W, at right angles to the trend of the major geological structure. The interval between lines was approximately 500 m. The mean flying altitude was about 150 m above ground. The survey results were compiled into the Magnetic Maps of 1/25,000 and 1/10,000. Comparison between the distribution of magnetic anomalies obtained through qualitative interpretation and the geologic data revealed that the high magnetic anomalies closely correspond to the distribution and exposures of volcanic rocks, basic to ultrabasic rocks. In this coalfield, the volcanic rocks among the upper strata of the Mesozoic and the igneous rock complex to the south of this coalfield (north of Bolu - Kaynarçan - Çeltik) were considered to be related to the magnetic anomalies.

Bojo and Tsu measured magnetic susceptibility of rocks along some routes in this coalfield with K-meter (Kappameter UGF-KT3, mfd. by ABEM Co.). Its results and the previous data by Hosono et al. (ibid.) showed remarkable difference in magnetic susceptibility between volcanic rocks from upper strata of the Mesozoic and other Mesozoic and Paleozoic sedimentary rocks in this coal field. Noteworthy was the Palaeogene basic tuff at about 6.5 km east-north-east of Bayçuma, which indicated high magnetic susceptibility.

The volcanic rocks of upper horizon of the Mesozoic group exhibit, on the whole stratification and regional variation in thickness, but are regarded to constitute one stratigraphic unit. So it was considered necessary to obtain further information on this rock in the future offshore exploration. Hosono et al. (ibid.) observed, in the result of the magnetic survey off Kozlu, a high magnetic anomaly extending for about 4.5 km in the NEE-SWW direction around 2 km off the coast. As a result of the vertical secondary derivative analysis, they correlated this magnetic anomaly to the distribution of an intense magnetic body in the upper strata of the Mesozoic group (the Turonian Stage or thereabout). From the viewpoint of the overall geological conditions in this coalfield, the above inference sounds acceptable and will be examined of its adaptability in future exploration.

The above-mentioned airborne magnetic survey records were processed by the M.T.A. computer (INTERDATA-8/32) and its interpretation program is now under preparation.

The gravity survey on land was, like the magnetic survey, conducted over an extensive area covering the Zonguldak Coal Field and was compiled into the Bouguer Anomaly Map (M.T.A. 1975). Qualitatively observed, this map suggests that the low gravity area which extends to the northeast from Devrek (about 25 km to the south of Zonguldak) through Kayabaşi to Kozçağzi roughly corresponds to the exposures and distribution status of the Eocene Series and others of the Palaeogene System. The high gravity area in almost the same direction with that of the above-mentioned low gravity area (EEN-WWS) extends from around Ereğli through south of Zonguldak city to Filyosağzi. Further to the east, its extension is partly presumed to lie in the sea area and reaches through land area to around Kuracasile. For interpretation of this high gravity area, comprehensive examination would be required of gravity, magnetic, and geological data. Following is a rough interpretation of this high gravity area. Except for some western parts of this coalfield such as Ereğli and Kandiri, this high gravity area is apparently connecting the structural highs. The structure of the

Palaeozoic in this coalfield is, as mentioned earlier, considered to be basically composed of a synclinorium, which, however, cannot be picked up on this gravity map. This gravity anomaly is probably affected by the distribution and structure of the Visean Series and the lower Carboniferous System mainly composed of high density limestone as well as the subsequent lower strata, the Palaeozoic.

The zone of dense gravity contour lines to the south of the high gravity area extending from east of Çayçuma to southwest, near Kirazly, is presumably an extension of a fault. This is shown on the gravity profile of the Zonguldak geological map. This fault was assumed to reach the deeper strata, with a large stratigraphic throw. For interpretation of the gravity anomaly, the Mesozoic limestone (the Barremian Stage and others, density 2.68 – 2.69) should be taken into consideration.
be taken into consideration.

The electrical prospecting on land is currently underway as a part of the coalfield exploration mainly by E.K.I. engineers. Mostly, vertical electric sounding by Wenner electrod array and Schlumberger's electrode array are being applied and the following areas have been covered already.

(1) Iliksu-ağzi – Digirmen-ağzi
(2) Oksma-ağzi – Kozlu
(3) Northeast of Zonguldak city – Kilimli
(The first three are all on the coastal zone of the Zonguldak area.)
(4) Kilimli – Karadon – west of Ĝöbü
(Zonguldak area)
(5) Southwest of Amasra

The area (4) is the most extensive, covering about 2.5 km x 12 km. From these electrical prospectings, attempted at elucidating the unconformable planes between the Cretaceous and the Palaeozoic beneath the Cretaceous system, fairly good results have been acquired. The survey lines, therefore, were plotted principally over the Cretaceous exposures.

4-2 Geophysical Prospecting During 1979 – 1980

In June, 1979, M.T.A. carried out an experimental operation of four seismic reflection survey lines, a total of 37.6 km long, off Zonguldak. The Preliminary Survey Mission dispatched from Japan in February to March of 1980 examined the results of this experimental operation such as the field technique, data processing, and analysis reached a conclusion that reprocessing and reanalysis of those data would be required to improve their quality. And, in accordance with the provisions of S/W, those data were re-examined in Japan. Its results are summarized as follows:

A. Reprocessing of Offshore Seismic Reflection Data

Results from this data processing indicated that the data obtained by using the long streamer cable (length of active section: 1.2 km) are better than the data by short streamer cable (length of active section: 0.6 km). (Hereafter called 'long spread' and 'short spread' respectively.)

The long spread data are:

(1) More reliable in terms of their velocity information,

(2) Showing their lineups more characteristically, based on the better stacking velocity resolution, with larger NMO (normal moveout) correction for a given velocity function.

Especially the stacking velocities having been designed based on the velocity information from the long spread, the velocity analysis of the long spread showed excellent velocity resolution. The clear events considered to be true reflection waves are in general dipping seawards. This phenomenon is consistent with the sparker data off Kozlu (1970). A terrace and a small culmination (possibly a local reverse dip associated with a fault) were observed, but a perfect anticlinal structure by folding could not be recognized.

B. Refraction Analysis of the Offshore Seismic Data

(1) The maximum applicable water depths for the refraction method is 200 m and 100 m for the long spread cable (1,200 m) and for the short spread cable (600 m).

(2) Comparison of velocity distribution and other geophysical data shows:

(a) The high Bouguer anomaly zone corresponds to the high velocity zone, where the existence of high density rocks such as limestone was assumed. And the low velocity zone was observed on the zone of dense gravity counter lines, suggesting an existence of fault or fault zone.

(b) The magnetic anomalies occur at a velocity zone of certain range, which made it possible to associate the magnetic anomaly zone with a certain kind of rock facies.

(c) Around the seemingly intrusive rocks inferred from the seismic records, a low velocity zone was observed.

(3) The result of velocity measurement of rock samples by means of Ultra-sonic wave method shows a distinct velocity difference between limestone and other rocks.

(4) The low velocity zones of 3.0 km/sec or less may be correlated with a fault or fractured zone. Additional seismic surveys on a more detailed grid were recommended to trace the onland faults extending seawards as well as to estimate their scale or dimension.

(5) The velocity distribution of the seabottom along the test lines did not show a good correlation with the rock facies. It was suggested to accumulate data on velocity measurement of rock samples in laboratory by Ultra-sonic wave method, to carry out the onland seismic refraction analysis and to conduct sonic log in some drill holes of the area for better correlation between velocities and geology or rock facies, thus making the refraction method an efficient means of elucidating the geology and the geological structure at the sea bottom.

C. Examination of Gravity and Magnetic Data

(1) Gravity/magnetic survey can serve as an effective method in helping elucidation of the geological structure of a coalfield, when enough data are accumulated, as a reconnaissance or preliminary survey.

(2) The gravity anomaly map is considered to reflect greatly the geology of deeper sequence. To eliminate these regional gravitational slopes, qualitative analysis was conducted based on the residual gravity calculation by band-pass filtering procedure in an attempt to extract information of the shallower sequence. As a result, there arose a possibility that the structure of the lower Palaeozoic system and the distribution status of the coal-bearing formations surrounded by the Palaeozoic System may be elucidated. In the Zonguldak area, no sharp density contrast was observed between rocks of the Cretaceous and the Palaeozoic. It was even expected that the Cretaceous rocks might show higher density. Therefore the relation between the gravity data and the geological data on land need to be clarified before interpreting the offshore area. It was pointed out that the quantitative analysis by a horizontal plate model would be efficient to a certain extent for the geological interpretation, if conducted on the basis of the above consideration. (For example, the fault with NE-SW trend approximately 20 km to the east of Zonguldak shows a steep gravitational dip.)

(3) Magnetic survey has long been considered as effective in detecting tuff and igneous rocks. Actually, the magnetic anomalies obtained from the 1980 data processing showed a possibility of corresponding with the distribution of tuff and igneous rocks surrounding the Zonguldak Kozlu mine.

In this area some correspondability was observed between the magnetic survey result and the gravity data and also between the magnetic data and the result of the refraction analysis. This method was believed to be effective, when used in combination with the measurement of physical properties of rocks, exploratory drilling survey, and the offshore gravity survey on appropriate grid lines.

D. The Adaptability of Geophysical Survey Methods in the Offshore Zonguldak Coal Field and Their Problems

Until 1980, a definite evaluation of adaptability of the geophysical methods as a means of studying the offshore geology and geological structure for coalfield exploration was somewhat difficult due to sufficient data. However, since then, the 1980 processing and analysis results yielded various basic data which suggest the effectiveness of the geophysical methods.

Successful result can be expected if further efforts are made to collect measurement results of rock properties, to improve the quality of the survey records, to combine other necessary exploration methods and to increase the survey volume.

Table 1 shows the adaptability of the geophysical methods and their problems involved.

Table 26 : The Adaptability of Geophysical Exploration for The Development of The Offshore Zonguldak Coal Field and Its Problems to be Solved

Geophysical Methods	Adaptability	Problems	Countermeasures
Seismic Reflection Method	1) To be able to infer the tendency of reflection plane (For example: As same as results of Speaker survey at offshore Kozlu in 1970 and also that of gravity survey 2) To be able to recognize a terrace and a small anticlinal structure in the reflection profile	1) Detection of the primary reflection is insufficient at the moment due to a) geological structure does not have visible primary reflection, b) amplitude of refracted wave, multiples and primary reflection is too big 2) Processing capacity of M.T.A. computer and details of software are unknown 3) On acquiring back data for velocity assumption	1) To improve quality of data on acquisition stage: a) Control of source spectrum, b) Control of source energy, c) Review of airgun array: d) Review of length of streamer cable, etc 2) Review of data processing 3) Acquisition of seismic velocity data of rocks (P-velocity measurement of the core and sonic survey in the boring hole if possible)
Seismic Refraction Method	1) There is a possibility to assume rock facies at seafloor by estimating seismic velocity from the reflection seismogram. 2) Refraction analysis will be conducted as a two layers structure of sea water and seafloor within a depth range less than 150 or 200 m. 3) It will be able to obtain a sufficient velocity data to judge the rock facies and also a low velocity zone possibly caused by fault or disturved zone when the dip of seafloor is less than several degrees	1) There is a possibility of errors in the velocity analysis data due to the one way transit time analysis 2) As the basic data on correlating seismic velocity and corresponding rock facies, the interpretation of velocity analysis is not clear	1) To improve the accuracy on positioning 2) To develop the new method for recording corresponding opposite seismic records 3) For correlation data between velocity and rocks: a) P-velocity measurement of rock samples b) Well shooting; c) Test operation of refraction method on land area.
Gravity Survey	1) It is effective for general geological structure survey as a reconnaissance or preliminary survey. 2) It will be a fundamental data to estimate the geological structure of Lower Palaeozoic System and the coal bearing formations surrounded by the Lower Palaeozoic System based on the residual gravity analysis. 3) There are good correspondence both between the high gravity area and the high seismic velocity area of refraction analysis and between the low seismic velocity zone and the steep dipping area on gravity contour. 4) The gravitational steep dipping area may correspond to the fault zone.	1) A caution will be required for analysis and interpretation of data because no visible gravitational difference between rocks of Cretaceous and Palaeozoic. 2) To review the correspondence between the coal mine locations and the gravitational basin by residual gravity	1) It is necessary to establish a mutual relation between geology and gravitational survey results 2) To utilize the results of qualitative analysis obtained from the running average method to the interpretation of geological structure. 3) Physical property measurement of rock samples study of boring data, increase of quantity on exploration 4) Increase of positioning accuracy. (Use of trsponder together)
Magnetic Survey	1) There is a good correspondence between the magnetic anomaly of the magnetic total intencity and the estimated distrubution of the cretaceous volcanic and tuffeceous formations 2) It will be possible to estimate the existence of the magnetic body by adopting magnetic quantitative method 3) The magnetic anomaly appears to correspond to the area having the seismic velocity of 3.6 ~ 4.0 km/sec.	1) Correspondability for the other geophysical exploration is uncertain 2) There is a few data for interpretation of correspondability between gravitical anomaly, low seismic velocity area and relative low density area	1) Study and measurement of physical properties of rocks 2) Increase of quantity on exploration 3) Study of correspondability to the other survey results.

V. ANALYSES OF GEOLOGICAL AND GEOPHYSICAL DATA

[illegible]

V. ANALYSES OF GEOLOGICAL AND GEOPHYSICAL DATA

1. SURFACE GEOLOGICAL SURVEY

The result of the surface geological survey mostly described in III-3. General Geology. Here, the necessity of surface geological survey and some important aspects of its results will be discussed.

In the 1980 Preliminary Survey, as a means to clucidate the geological formation or tectonic lines under the sea bottom, it was attempted to assume the rock facies from the elastic velocity data computed by the refraction analysis using the first arrivals indicated on the seismic reflection survey records. Furthermore, the distribution of geological formations on the sea floor was attempted to assume in combination with this velocity data and the magnetic or gravity anomaly data. This method has been quite effective to interpret the geological structure of this offshore area where the seismic reflection method is insufficient because of the existence of a thick limestone layer covering the coal-bearing formation.

To verify the assumptions for the interpretation of the offshore geology, the following onland surveys were conducted:

(1) Concerning the stratigraphy of Zonguldak area, the detailed data were available with the coal-bearing formations, but not available with the Cretaceous formations. In August 1981 during the second survey period of this project study, the surface geological survey was conducted along the main road of about 25 km long, from geological structure is relatively stable and the natural outcrops are well exposed. By this survey, it was confirmed that MTA's geological map of 1:50,000 is almost perfect except a few points which need correction and it was attempted to establish the Cretaceous stratigraphy. Its outcome is shown in Fig. 13, a compiled columnar section.

Furthermore, in November 1981 during the fourth survey period, a supplementary geological survey was conducted again to the west of Zonguldak city to Kandilli village along the main road to check if the stratigraphy established on the eastern side of Zonguldak city is applicable to the western side.

As a result of these surface geological surveys, some important aspects have been obtained as follows;

(a) According to MTA's geological map, the lower part of the Turonian Stage is mainly composed of pillow lava. But no lava was observed in the area designated to the lower Turonian during this survey. Instead, there lies volcanic blocks or the massive coarse lapilli tuffs in the lower Turonian Stage. But these pyroclastic rocks, especially the massive volcanic sandstones, are showing onion structure through weathering so as to be described as "pillow lave" (Refer to III-3. General Geology).

(b) It was found that the thick massive pyrodastic sediments of the Santonian – Coniacian Stage were divided into two sedimentary in cycles macrosopic view of stratigraphy.

(c) The velibey quartzose sandstone of the Albian stage was observed all over the surveyed area, but the glauconite sandstone above it was observed only in the western area.

(2) While surface geological survey was conducted, the magnetic susceptibilities were measured simultaneously on major rock facies by Kappermeter Model KT-5 of Geafyzika Brno Co., Czechoslovakia, for correlation with the magnetic survey results in the offshore area. The Kappermeter calibrated its gradation with the two standard samples of granite in possession of Dr. Shunzo Ishihara of Geological Survey of Japan. The results are as follows:

Rock sample	No.	Standard value	Measured value by KT-5
Granite	KY 218	62 x 10^{-6} emu/gr	1.60, 1.58, 1.58 x 10^{-3} SI unit
Fine grain granite	HK 21	118 x 10^{-6} emu/gr	3.55, 3.56, 3.57

The results of the field measurements of the magnetic susceptibilities of the Cretaceous and Polaeozoic rocks by Kappermeter KT-5 are shown in Table 13.

As the results of the measurements, rocks or rock facies show the following tendencies (measured value: 10^{-3} SI unit):

(a) Limestones (limestones in the Aptian, Barremian, and Visean stages) show quite low magnetic susceptibilities in the range of 0.00 – 0.02. Even with the argillaceous limestones, the values are ±0.02.

(b) Marls (including chalk or chalky stones) show the magnetic susceptibilities of

0.05 – 0.15. Included in this group are the flysch and marly siltstone in the Aptian stage, the blue marl and flysch in the Cenomanian stage, the alternation of mudstone and limestone in the Campanian stage, and the chalky marl in the Maestrichtian stage.

(c) Quartzose sandstones (the Velibey sandstone in the Aptian Stage, and the sandstone in the Namurian Series) show 0.07 – 0.1.

(d) Conglomerates (B and C stages plus the Karadon conglomerate formation of D Stage in the Westphalian series) show 0.1 – 0.18.

(e) Of the drilling cores from the Kozlu coal-bearing formation, sandstones show 0.13 0.13 – 0.17 (NQ size), coal seams 0.09 (NQ size) and siltsones 0.26 – 0.30 (BQ size). (Shales in the Namurian series show 0.17 ±).

(f) The alternation of green-tuff and mudstone in the Turonian stage shows average magnetic susceptibilities of 1.70 in the lower part and 3.5 in the upper part.

(g) Of the tuffs and tuff breccias in the Santonian – Coniacian stages, the basic andesite tuffs show the magnetic susceptibilities of 35.0 – 38.0, and the intermediate andesites show 27.0 – 35.0.

(h) Biotite andesites of the Campanian stage are 12.5 – 16.4.

To sum up, the rock that shows high magnetic susceptibility regionally is the tuff breccia in the Santonian – Coniacian stage, of which the value is more than ten times as high as the upper value of the green tuff (3.5) in the Turonian Stage which is the second highest magnetic susceptibility in the surveyed area. Therefore, it (tuff breccia) shows a strong magnetic contrast to its surrounding formations. The magnetic anomalies observed on the offshore magnetic survey results are considered to be derived from the high magnetic susceptibility of the tuff breccia.

On the other hand, the limestone shows nearly zero value. It can be also marked to its surrounding rocks relatively.

2. EXPLORATORY DRILLING IN THE GALLERIES OF THE KOZLU MINE

2-1 Brief History of the Drilling Program

According to S/W, the drilling program in galleries of the Kozlu Mine, Zonguldak Coal Field, was to be started in Gallery No. 22926 at –425 m level from the driving face round 100 m after penetrating the Simal fault and in Gallery No. 22925 at the same level from the heading immediately after penetrating the fault. But Gallery No. 22925 had encountered the fractured zone of the Simal Fault at 45 m back from the heading of this gallery and the driving was terminated finally.

Then, in the intermediate prefeasibility study in March 1981, the original drilling program had to be greatly changed due to the following reasons:

(a) In Gallery No. 22925, the interval from the heading to about 35 m front collapsed due to an extraordinary earth pressure under the fractured zone of the Simal fault about 45 m from the heading, which made it impossible to drill from the heading. Therefore, the original plan was altered so that the drilling machine may be installed at a stable position about 60 m back from the heading and that guide pipes may be run into the collapsed gallery, through which a guide pipe was to be inserted.

(b) In Gallery No. 22926, the drilling proceeded about 100 m past the presumed location of the Simal fault, but the Simal fault was not encountered due to a possible change in the geological structure. Judging that if drilling proceeded further into a geologically aggravated area, it would be very difficult to find the appropriate stable area to be able to install the drilling machine, and that from the experience in Gallery No. 22925, it would be impossible to penetrate the Simal Fault through gallery, it was decided to conduct the drilling from the present heading and penetrate the Simal fault by horizontal boring.

Upon consulting with the EKI staff and the TKI managers, S/W was revised as follows:

(a) Firstly, horizontal drilling No. 1 (+5°) shall be conducted as long as possible in the Gallery No. 22926 at –425 m level in the direction of the gallery in order to have informations of the geological structure beyond the Simal fault.

(b) Then, Hole No. 2 shall be drilled in the Gallery No. 22925 in the same way as hole No. 1 in the direction of the gallery, horizontal drilling +5°) with the same purpose as hole No. 1. (This plan was further revised because of severe collapse of Gallery No. 22925 occurred later, and well No. 2 was also obliged to be drilled in Gallery No. 22926.)

2-2 Transportation of the Drilling Machine and the Preparatory Work for Drilling

The drilling machine and its auxiliary equipments were shipped out from Japan on Jan. 14, 1981 by sea (Verbena-Maru) and arrived at Istanbul Port on April 6, the same year. They were immediately transported by train to Zonguldak Station (April 17), then hauled into the Kozlu Mine on April 18 by trucks and went through the custom formalities in the Kozlu Mine.

The machine and equipment were stored in the Kozlu Mine warehouse by May 4 and the list of machine and equipment was prepared at the same time.

The main machines and equipment are indicated below:

Major machines	No. of equipment	Type	Capacity
Drilling machine	1	KOKEN EP-1W	1,200 m (BQ)
Wire line hoist	1	KOKEN WLH-4S-4	3.7 KW
Drilling pump	1	KOKEN WL-MG-15h	ϕ68, 11 KW
Mixer	1	KOKEN HM-250	1.5 KW
Blowout Preventer	1	TSUKAMOTO H.N.B.	4", 50 kg/cm^2
Instrument to measure the hole deviation	1	MURATA SINGLE SHOT-A	–
Other tools		1 unit	–

Before the drilling exploration in Gallery No. 22926, the following preparatory works were conducted:

a) To enlarge the gallery.

b) To prepare sumps for drilling mud.

c) To install the power-source switch boards.

d) To set the safety devices (piping for gas extraction, installation of gas detector/alarm and automatic power breaker, preparation of drainage ditch for abnormal water seepage).

Meanwhile, the drilling machine was assembled outside the gallery, then a trial drilling was performed.

The trial drilling was carried out in the vertical hole. To start with, a hole of 116 mm in diameter was drilled for 11 m, and NW casing pipe was inserted. Then drilling proceeded to 49.95 m by NQ wireline drilling method. During the drilling operation, coal-seam was encountered at the depth of 24.55 – 25.80 m. The coring of the cool seam was conducted.

Following is the preparatory work prior to the commencement of the drilling hole No. 1 in Gallery No. 22926:

- To April 13, '81 Lay out of the Gallery for installing the drilling machine in the Gallery.
- To April 21, Draw & order of the necessary materials and machine parts.
- To April 25, Preparation of the drilling site in the Gallery.
- To April 27, Start unpacking the drilling machine parts which had been stored in the warehouse.
- To May 2, Unpacking containers and putting materials in order.
- To may 4, Start trial assembling of the drilling machine.
- May 5 – 14, Assemble the auxiliary equipment of the drilling machine and operation testing.
- May 15, Start trial drilling on the ground (Vertical hole of 116 ϕ, NWC.P. 11 m)
- To May 30, Complete trial drilling on the ground (Drilling proceeded to 49.95 m deep by NQ wireline).
- June 5 – 6, Haul the drilling machine and equipment into the gallery.
- June 8 – 12, Install drilling machine and equipment.
- June 11 – 19, Set main power cables.
- June 15 – 26, Install the safety devices (laying of 2" gas drainage pipe, ditching for drainage, installation of gas separator, compressed air pipe, gas alarm, automatic power breaker).
- June 24 – 29, Supply electric power (wiring and installation of five switch boards).

The preparatory work process is shown in Table 27. The layout of the drilling machine and auxiliary equipments is shown in Fig. 14.

2-3 No. 1 Hole Drilling at –425m Level in Gallery No. 22926

Gallery No. 22926, the hole No. 1, started on June 30, 1981, drilled mainly by wireline method through the quartzose greywacke and the underlying coal-bearing shale of the Kozlu Formation. On Aug. 17, while cleaning out the drill hole with BQ diamond bit, the bit was stuck at the depth of 61.89 m due to blow out of gas and collapse of hole. Tap was used to fish the bit, but unfortunately it was judged impossible to recover the bit because it was stuck persistently. Upon consultation with the staff of E.K.I. and T.K.I., decision was made to give up further drilling and the well was abandoned. (Total drilling depth was 62.42 m.)

Table 27 Preparation of Underground Drilling at Kozlu Mine

(Equipment Transportation, Storage, Test Drilling, Etc.)

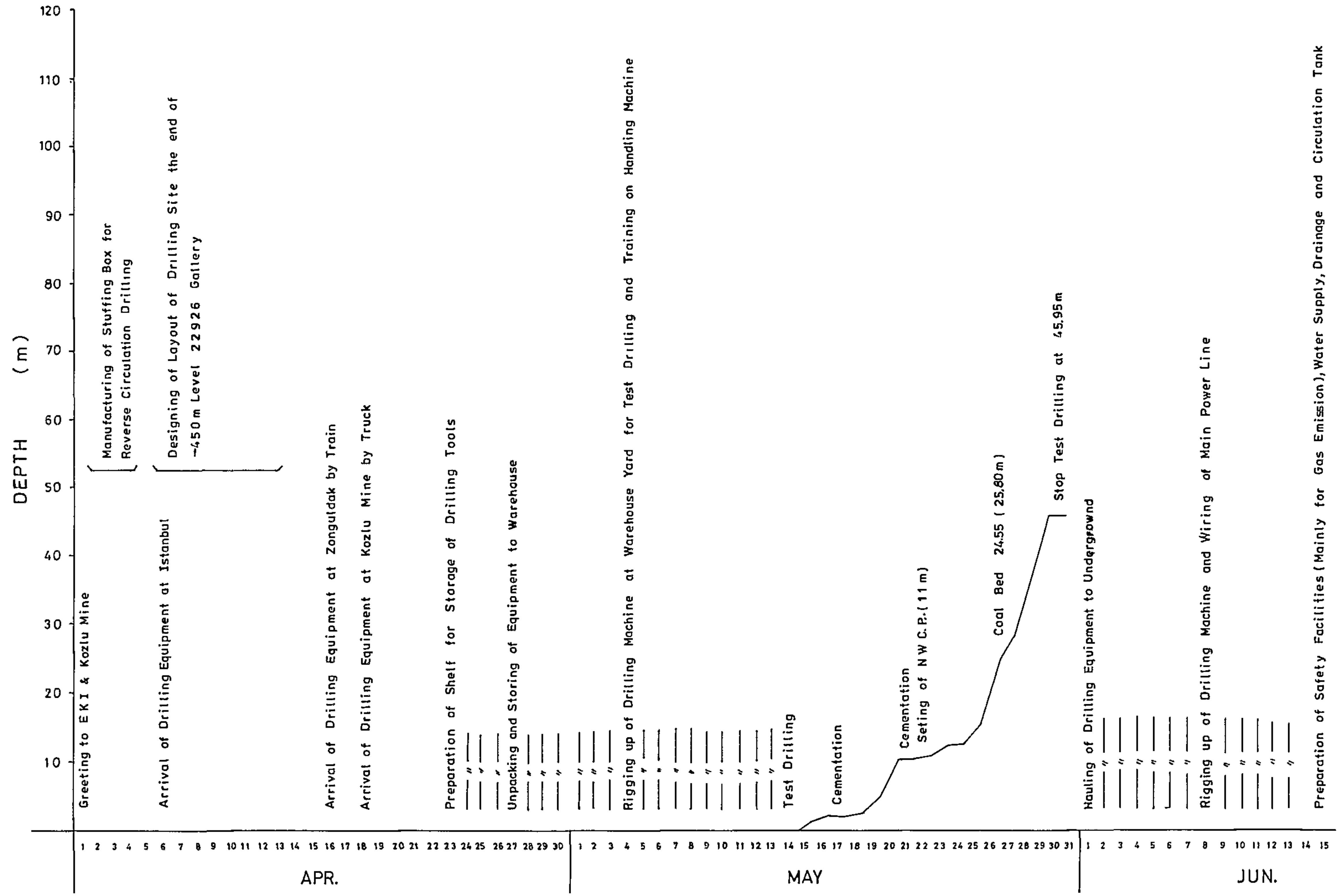
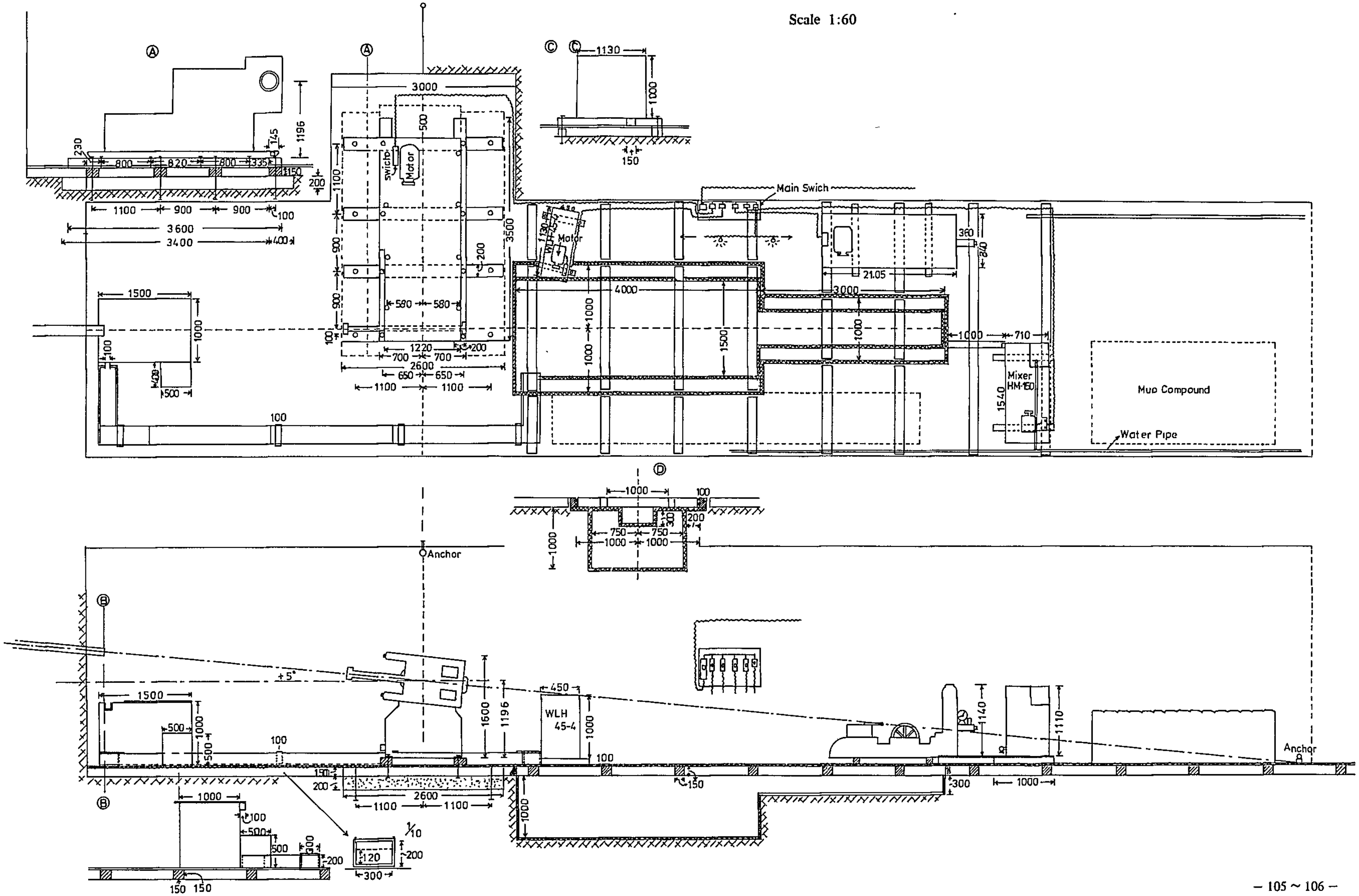


Figure 14 Schematic Layout of Drilling Machine and Equipment at 22926 Gallery, Kozlu Mine



Following is the outline of drilling progress (Refer to Table 28):

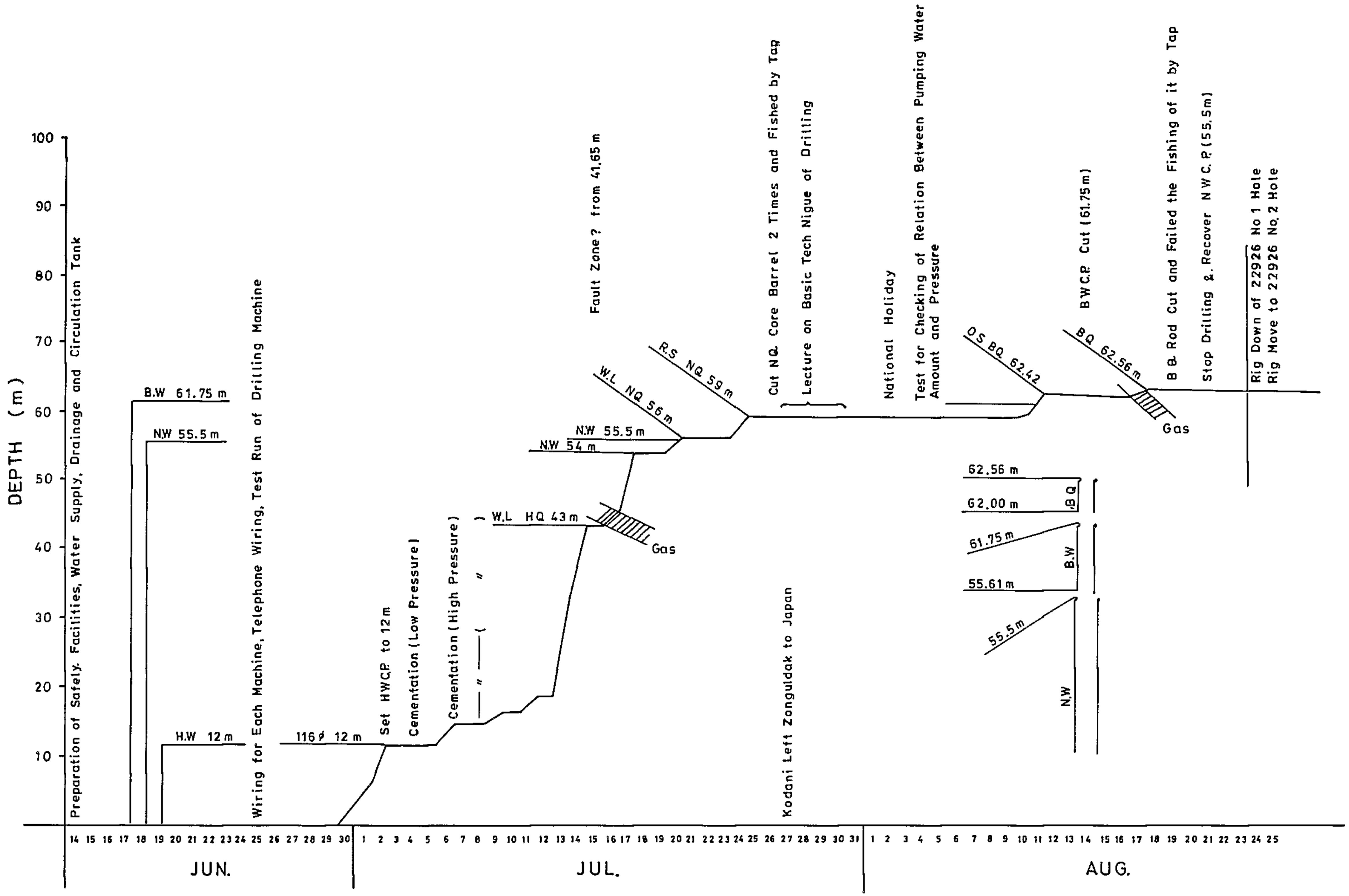
June 30, 1981	Start of drilling with 116 m/m diamond bit.
June 2,	After drilling 12 m, HW casing was set.
July 4,	Cementing HW casing (200 ℓ of cement milk was squeezed in).
July 6,	Cleaning out excess cement and drilled 3 m, then 200 ℓ of cement milk was pumped in.
July 8,	At the first water injection test, there was a water leakage of 10 ℓ at 20 kg/cm^2. An additional Cement milk was again squeezed in. (250 ℓ)
July 10,	Water injection test was conducted with success. Preventer was installed for further drilling.
July 11 – 14,	After mud conditioning, drilling proceeded to 43.65 m by HQ wireline and the insert of NW casing was started.
July 15 – 17,	After NW casing was run to 43.65 m, drilling by NQ wireline was tried but there was a severe gas blow (5 – 6 % at the rod end and 1% in the gallery), to which the gas alarm reacted. Therefore, the power source was shut temporarily. A preventer for NW casing was set to HW casing and the drilling with NW casing attached with diamond shoe was carried out under reverse circulation method up to 54 m.
July 18 – 23,	Drilling by NQ wireline was conducted up to 56 m where pressure rose. Then, NW casing was pulled out again and the drilling was continued down to 55.5 m under reverse circulation by using the same casing.
July 24 – 25,	While drilling under NQ reverse circulation, core barrel was cut off at 59.0 m. After the core barrel was fished up by a tap, drilling resumed, but again the core barrel was cut off. The recovery of the core barrel succeeded.
July 27 – 30,	The accidents of cutting of core barrels seemed to be due to partly the operation mistake. Operators/engineers were called in and lectures were given on overall drilling techniques.
Aug. 4,	After long holidays of Ramadan, Bayram, machines, and equipment were checked if they are ready to be operated. (Pressure of feed water, condition of thrust bearing, etc.
Aug. 5,	NQ rod was inserted, but encountered resistance from 55.6 m. With slower rotation, drilling proceeded to 59.0 m, but the core barrel was cut off.

Aug. 6,	The core barrel was fished up by NQ tap. After mud conditioning, NQ rod was inserted, but, encountered resistance at 56.6 m again, and was pulled out.
Aug. 7,	Measurements of drill hole deviation were conducted. (25 m +5°, 50 m + 5° 30', 58 m + 6° 20').
Aug. 8 – 10,	BW casing was inserted but did not run below 56 m. Then it was pulled out.
Aug. 11 – 14	To run BW casing, there was repeated attempt to clean out the hole by oversized BQ, but due to the rising water pressure, drilling could not proceed beyond 58 m. Through reverse circulation, BW casing was pushed down to 61.75 m, where the casing seemed to be cut off. Then the further drilling was given up.
Aug. 15,	BQ rod was inserted to 55.61 m but it was pulled out because it could not go through this depth. At that time, BW casing had been loosened from 55.61 m.
Aug. 17,	Drilling proceeded to 61.8 m after cleaning the hole by BQ reverse circulation. It encountered gas blow and the rising water pressure at 62.56 m, then the drill string was pulled out.
Aug. 18,	Drilling by BQ reverse circulation was tried again, but was unsuccessful. Then BQ rod was cut off while being pulled out. Tap was lowered to fish it, but could not pull it out because the locking-coupling at the tip of the road was stuck at the end of BW casing. By pulling out the rod corcibly (Thrust 6 t), the locking-coupling was again cut off at the head and BQ tap could be recovered, but BQ diamond bit and sub of 0.59 m were left in the hole. As there was no hope of recovery, the drilling was terminated.
Aug. 19 – 21,	NW casing pipes (3 m x 19 pipes) were pulled out. A part of D.B. shoe was damaged.
Aug. 22 – 23,	After clearing the drilling site, the whole drilling operation of this hole was completed.

2-4 No. 2 Hole at –425 m Level in Gallery No. 22926

Hole No. 2 was planned, at the stage of prefeasibility study in March 1981, to run 8″ pipes in Gallery No. 22925 at –425 m level through the collapsed fractured zone of the Simal Fault, and to explore the area beyond the fault. However, it became impossible later to run

Table 28 Drilling Progress of Drill Hole 22926 – No. 1



the 8″ pipes because of the severe collapse thus drilling could not be done in gallery No. 22925. Therefore, the drilling plan had to be revised again.

The experience at hole No. 1 indicated that drilling through a fractured zone, especially where gas blows, is extremely difficult and dangerous, it was considered imperative to start from a drill hole as large as possible in diameter to penetrate such a difficult zone. In other words, it was considered almost impossible to penetrate such a big disturbed zone as the Simal Fault by drilling.

In the meantime, as a result of the drilling at hole No. 1 it was found that the sandstone of the Kozlu Formation continuously exists for 60 m from the heading of the gallery No. 22926 at –425 m level. From this geological evidence, there derived three different assumptions as follows: (a) that the Simal Fault has an unexpectedly smaller throw than previously assumed, (b) that the Simal Fault changes its strike suddenly at the west of Gallery No. 22925 to NNW, or (c) that the Incirharman Fault, lying between the galleries No. 22926, cuts the Simal Fault, having caused displacement of the Simal Fault to the north on its west side.

These assumptions were to be elucidated by changing the direction of a horizontal drilling in Gallery No. 22926 at an angle as wide as possible with hole No. 1 to the right. Upon consultation with the staff of E.K.I. and of the Kozlu Mine, it was decided to locate hole No. 2 at the same place with hole No. 1 in Gallery No. 22926, aimed at horizontal drilling (+5°) to the direction at an angle of 15° with hole No. 1 to the right.

This plan is considered to have the following advantage:

(1) Since the preparation works of the gallery No. 22926 will be done with the minimum effort, the technical deterioration of drilling operators and other engineers who had been freshly trained in a short period while engaged in hole No. 1 operation would be avoided to a minimum and thus, one of the most important objects of this project – technical transfer – will be realized most efficiently. (All but one engineer were inexperienced at the start of this drilling operation, and they had just learned operating machines and begun to acquire the techniques of drilling through hole No. 1 operation. So it was considered to loose their skills by suspending operation for a long period.)

(2) With the result of hole No. 1 only, there might be a little difficulty to assume the geological structure in the direction of Gallery No. 22926 at –425 m level. But by conducting the drilling operation of hole No. 2 in the same plane, it will be possible to clarify the strike and the dip of the formations encountered. Besides, if a fault can be

penetrated, its strike will be estimated to a certain extent. Thus, more reliable informations will be obtained to elucidate the geological structure.

Gallery No. 22926 – No. 2 hole at -425 m level was started. onAug. 28 at the location of No. 1 hole to the direction at a 15° angle to the right. This hole encountered a fault at about 45 m (presumably the Incirharman Fault) and got out of the fractured zone at about 65 m. From 69.15 m to 80.3 m it encountered the Karadon conglomerate formation containing fist-sized older round pebbles (guartzite, chert, red ingneous rock, green silt, etc.). After drilling about 51 m through the conglomerate formation, it reached the drillable limit by BQ size equipments (in the disturbance zone), and as it was judged that enough data were obtained necessary for elucidation of the geological structure, the drilling of hole No. 2 was terminated at 120.6 m on Nov. 13.

Following is the outline of drilling progress at No. 2 hole (Refer to Table 29):

a) Sept. 3, To make the well-head pipe as large as possible, drilling started with a 6½" hole, inserting a 5½" casing pipe for 3.6 m, and grouted with cement.

b) Sept.16 – 17, Drilling proceeded for 48 m with a HQ oversized diamond bit (O.S.DMB). At 30 m, the hole deviations were measured: wellhead +4°, 15 m + 5°, 29 m + 5°.

c) Sept. 19, At 40 m encountered a strong gas blow. To shut it down, HW casing pipe was run to 38.62 m.

d) Sept. 26, While cleaning out the inside of HW casing to 39.7 m by NW casing, a gas blow accompanied with abundant slime was encountered. In spite of the efforts, HW casing could not be extended and grouted with cement.

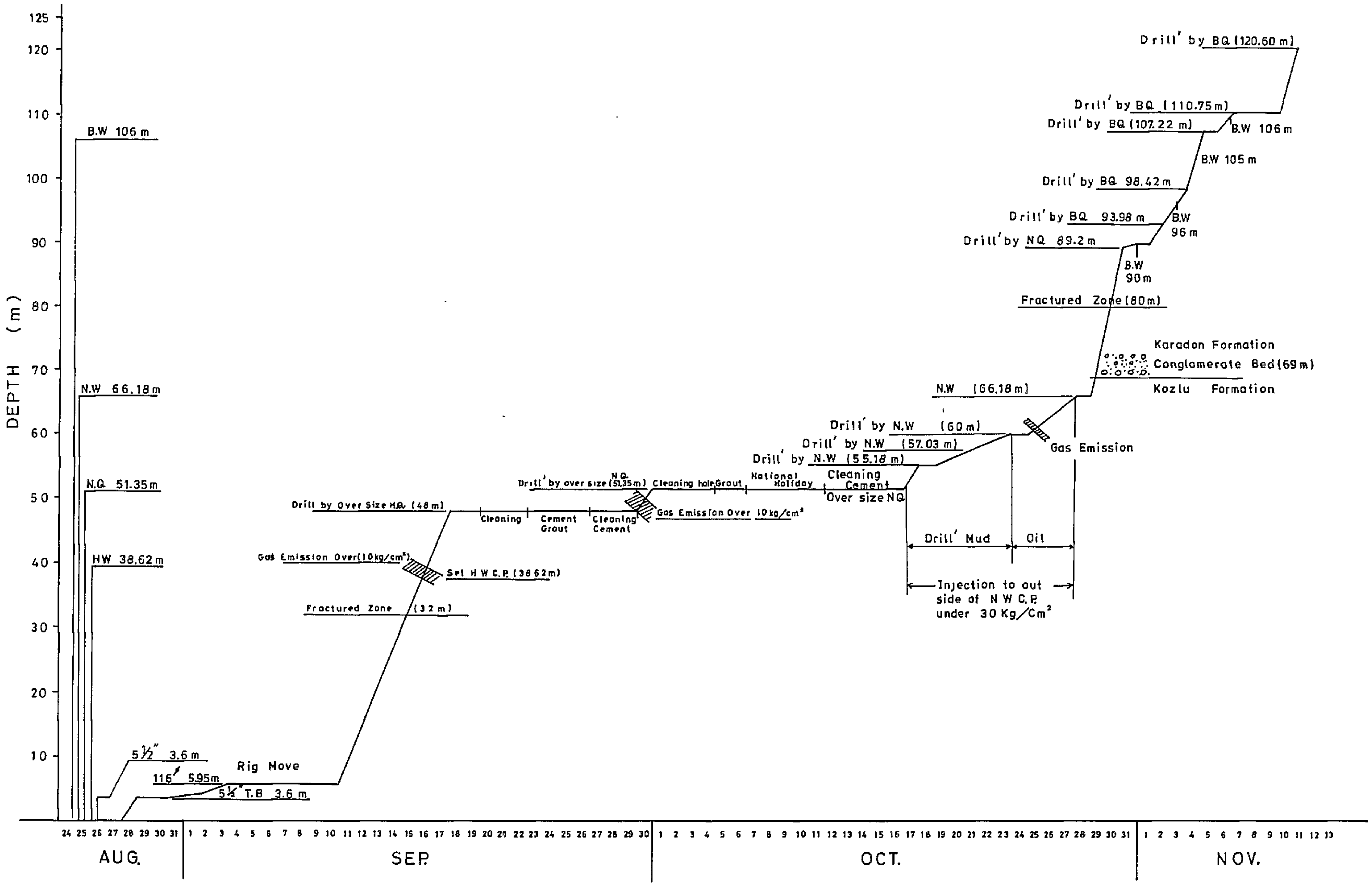
e) Sept. 30, After cleaning out the hole with NQ oversized DMB, drilling proceeded to 51.35 m, where a strong gas blow with abundant slime was encountered. This was assumed to come from the fractured bad coal or coaly shale at the interval 49.5 – 51.0 m.

f) Oct. 6, It took four days to clean out the hole with NW casing up to 51.35 and to grout the hole with cement at the maximum pressure of 40 kg/cm².

g) Oct. 15, While cleaning out the hole with NQ oversized DMB, a strong gas blow was encountered at 49.0 m.

Oct. 20, Drilling continued to 57.03 m with NW casing attached with a

Table 29 Drilling Progress of Drill Hole 22926 No. 2



diamond shoe under reverse circulation.

h) Oct. 21, Drilling continued up to 57.62 m after cleaning out NW casing with BW casing under reverse circulation.

i) Oct. 22, Drilling proceeded with NQ DMB to 59.03 m, where the bit was stuck. Drill strings were recovered after injecting hydraulic oil into the circulating mud.

j) Oct. 23, NW casing was run to 59.93 m. After drilling with NQ DMB to 61.25 m, NW casing was further extended to 60 m.

k) Oct. 27, The inside NW casing was cleaned by BW casing and when drilling proceeded to 67.29 m NW casing was run but stuck at 66.18 m Maximum torque 700 kg-m).

l) Oct. 31, Drilling proceeded to 89.20 m with NQ DMB under reverse circulation, using the circulating mud mixed with Astex and heavy oil. Then BW casing was run to 90.15 m.

m) Nov. 3, After drilling further with BQ DMB to 96.08 m BW casing was run to 96.08m.

n) Nov. 5, In the same method, drilling proceeded to 107.22 m with BQ DMB and BW casing was extended to 105.14 m.

o) Nov. 6, Drilling continued to 110.75 m with BQ DMB and BW casing was run to 106 m and set.

p) Nov. 10, Drilling by BQ DMB wireline method failed due to a sudden rising of water pressure and strong rotation resistance. But drilling resumed and proceeded to 120.60 m by reverse circulation method with BQ DMB.

q) After that, the same method was applied repeatedly in the interval of 117 – 120 m in an attempt of breaking through the once-attained depth (120.60 m). But the rapid rise in pump pressure and strong resistance made it impossible to drill further. Therefore, drilling was terminated on Nov. 13.

The sudden rise in pump pressure and the high torque seemed to be caused by the jammings of hard rocks (hard pebble from the Karadon conglomerate formation) at the back side of BQ DMB and of the drill strings by swelling of wall.

r) Drill hole deviations were measured at 65 m and 45 m:

65 m	+ 5°
45 m	+ 4°

2-5 Geological Interpretation of the Drilling Results

2-5-A Geological interpretation of No. 1 hole and No. 2 hole

Both holes No. 1 and No. 2 had drilled into a very large scale fault or the fractured zone affected by the fault and also encountered high pressure gas zone such as coal seams or faults several times so that the casing pipes had to be run each time. Thus, both wells could not gain great drilling length, but they provide quite a great effect on the geological interpretation.

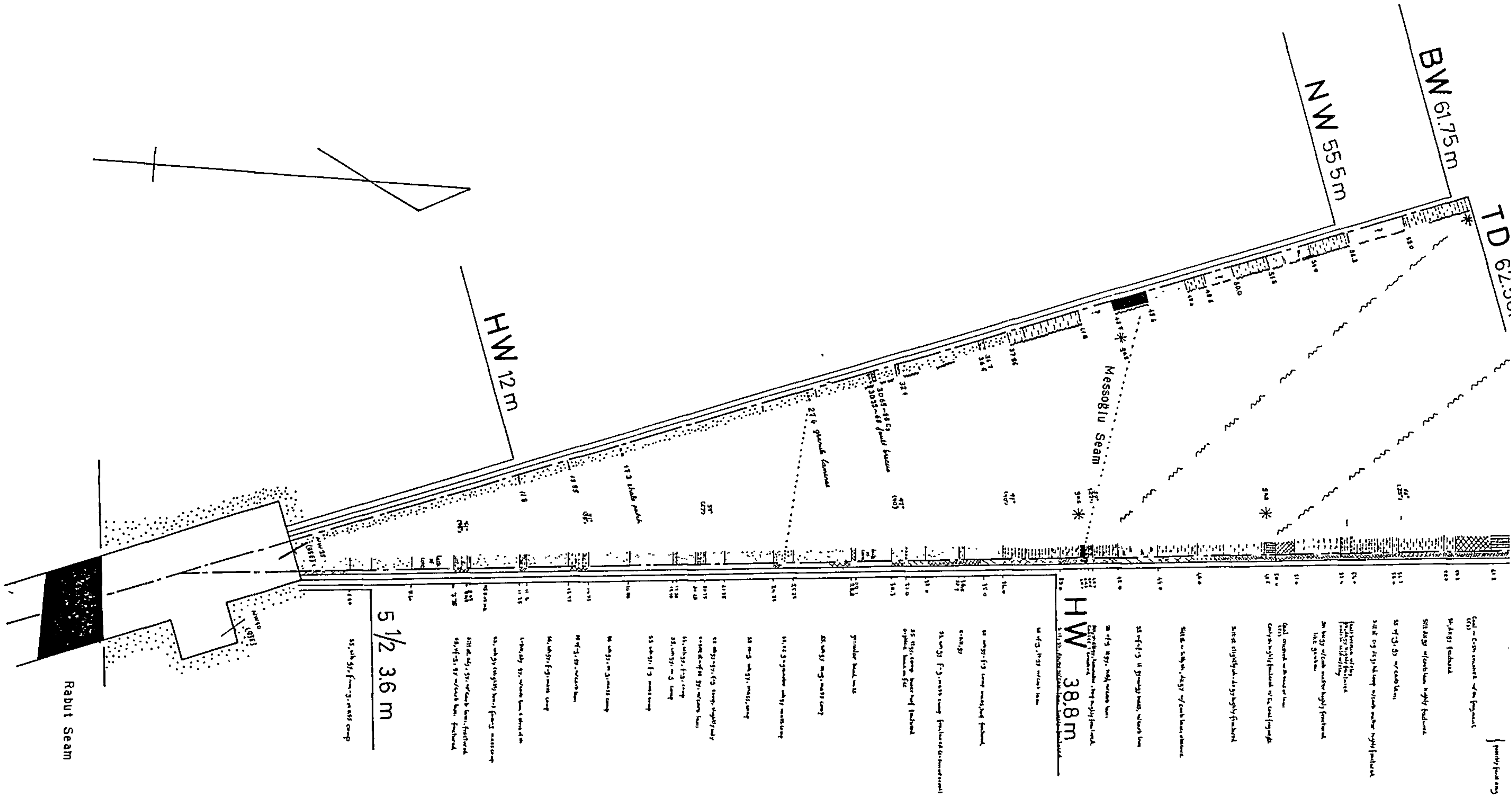
The success in penetrating such a big fault like the Simal Fault by drilling deserves special attention and was highly appreciated by the Turkish participants. In other words, the established fact that a big fault can be penetrated by drilling made it possible to sound the geological conditions beyond the fault by drilling prior to the driving of a gallery (the cost of which is very high), thus saving unnecessary expenses, as well as to foresee gas blow or water flow which might greatly affect mine safety. Following is the geological data obtained from the holes No. 1 and No. 2 and their interpretations (Refer to Figs. 15, 16 & 17):

(1) Horizontal drilling (+5°) was conducted at both holes No. 1 and No. 2. The drilling direction of hole No. 1 was parallel to Gallery No. 22926 and that of hole No. 2 was at a 15° angle with the first one to the right. In view of the facts that just before the fault encountered by hole No. 2, both holes penetrated the Messoğlu Seam and that the rock facies inserting the seam are well correlated between holes No. 1 and No. 2, the formation before the Fault was identified as the Kozlu Formation, having the strike of E-W direction and the dip of 50° ± 10°.

(2) The fractured zone observed in the interval about 45 – 65 m at hole No. 2 bears coal seams or coal streaks at two horizons.
As mentioned before (IV-2-4), there are three assumptions on its interpretation. Of the above, (b) or (c) is the possible assumption. Since well No. 1 did not penetrate this fault zone, the strike of the fault is, as shown in Fig. 15, considered to be running NNW-SSE. Whether it is the Incirharman Fault or the Simal Fault, the formation encountered beyond 69.15 m of hole No. 2 corresponds to the Karadon Conglomerate Formation. The geological structure east of hole No. 2 is the same in either case

Figure 15

SCHEMATIC PLANE SKETCH OF DRILL HOLES NO



H OF DRILL HOLES NO 1,2 AT 22926 GALLERY

SCALE: 1/200

Drawn by M INOUE, JICA &
ERKAN TERHAN, E.K.I

Nov 13, 1981