UNDERGROUND COAL GASIFICATION FIRST TRIAL IN THE FRAMEWORK OF A COMMUNITY COLLABORATION

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SUMMARY

The European Economic Interest Grouping "UNDERGROUND GASIFICATION EUROPE (UGE), A.E.I.E." is conducting the first field trial of a European Underground Coal Gasification programme formulated by the European Working Group on UCG in 1989. The members of the Grouping are:

- The Instituto Tecnológico GeoMinero de España (Spain).
- The Institution pour le Développement de la Gazéification Souterraine (Belgium).
- The United Kingdom Atomic Energy Authority (United Kingdom)

The overall aim of the programme is to demonstrate the technical feasibility and commercial viability of underground gasification of European coals. The European Community is providing financial support to the first trial under the THERMIE programme. The trial is being conducted in a coal seam in the North-East of Spain at a site near to the town of Alcorisa in the province of Teruel.

The coal selected for the trial is known as "El Tremedal", a deposit of relatively young sub-bituminous coal or black lignite for which some information was available from previous exploratory drilling and seismic investigation. At a depth of 600 metres - the target depth for the first trial - two coal seams were expected, each of 3-6 metres thickness.

Site selection was carried out by analysis of existing exploration information, by assessment of the probability of coal continuity (absence of faulting) and consideration of the costs of land acquisition, site access and preparation.

Agreements to purchase or rent 5 parcels of land required for the trial were negotiated with the owners, and applications for permissions to drill the first exploratory well of the trial were submitted to the relevant Authorities.

Civil engineering works for access and preparation of the site for the first exploratory well took place in March/April 1992 and the well was drilled in April/May 1992. The results confirm that the coal is present at the expected depth, although the upper seam is thicker than expected and the lower thinner.

A full analysis of the results of the first exploratory well was conducted in June 1992. Because of the variations in seam thickness from those expected, and the importance of seam regularity and continuity for subsequent drilling operations, it was decided to reschedule the drilling programme, bringing forward the drilling of a monitoring well to obtain additional information on seam location and conditions in the vicinity of the product well.

In order to minimise civil engineering work, it has been decided to carry out works for the complete trial site before the monitoring well is drilled. Design of the civil works is complete and these works together with the drilling of the monitoring well will be the main activities in the second half of 1992. The design and planning of the deviated in-seam injection well will be conducted in parallel with these activities to avoid delay in the drilling programme.

1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The project is the first field trial in the European UCG development programme proposed to the CEC in April 1989 by the European Working Group on UCG. The trial is located at a site near to the town of Alcorisa in Teruel, Spain. The estimated cost of the project is 2,470 Mpta over a duration of 4 years.

The main objective of the project is to demonstrate the technical feasibility of UCG at an intermediate depth of about 600 metres - a significant increase in depth over that of previous successful USA trials of UCG by in-seam drilling. The trial has several technical objectives including the demonstration of drilling long in-seam holes at this depth via deviated drilling from the surface, the construction of a competent gas flow circuit between injection and product wells, and the demonstration of adequate coal conversion.

The planned programme of the project comprises three main stages: preparation, gasification and postburn activities. The operations in the stages are as follows:

- *Preparatory Stage*. During this stage, the geology and hydrology of the selected site will be subject to detailed evaluations, and an analysis of the coal and the adjacent strata will be obtained. The major activities of this phase - drilling, linking, completion of the boreholes and installation of the surface equipment, will only be carried out if the initial investigations confirm expectations.

- *Gasification Activities*. The gasification stage will enable the influence of different well configurations to be determined, and different gasification scenarios (channel and filtration gasification) to be compared. During a test of long duration, parameters such as reactor lifetime, cavity growth mechanisms, sweep efficiency and gas quality will be determined.

- *Postburn Activities*. The activities during the postburn phase consist primarily of analysis of the data obtained to validate and, if necessary, modify gasification models. These activities will be supported by postburn drilling to verify the cavity shape. Finally, reporting and site restoration will conclude the activities of the field test.

The wells to be drilled for the trial include wells for exploration, process operation and monitoring. The well arrangement will allow the successive realisation of two gasification scenarios mentioned previously:

- a first test along an in-seam channel,

- a second test by filtration, between the lateral injection well and the previously gasified zone.

1.2 PHASES OF THE PROJECT

The operational phases of the project include the following:

- *Final linking.* Final connection over the few metres between the in-seam deviated injection well and the vertical production well is planned by hydrofraccing and/or reverse combustion. In hydrofraccing, high pressure water injection would be used in the in-seam well. In reverse combustion, a combustion zone would be initiated at the base of the production well and drawn to the in-seam well by the injection of air to sustain the reaction.

- *CRIP operations.* The Controlled Retraction of Injection Point technique will be used in the in-seam injection well to widen the injection channel by ensuring growth of burn zones in an upstream direction and relocating ignition/injection points along the in-seam well. Coiled tubing will be installed along the whole length of the injection well for this purpose.

- *Channel gasification.* The aim of this operation will be to produce a medium C.V. gas by high pressure oxygen/water gasification. Maximum thermal power will be 10-15 MW at an oxygen consumption of 1000-1500 m^3/hour. Molar ratio of injected H_2O/O_2 will be low, perhaps 1-1.5/1, because of the high water content of the coal. At normal conditions, operating pressure in the production well will be maintained close to the effective hydrostatic pressure and below the minimum stress within the strata.

- *Reverse pyrolysis/combustion.* The aim of this operation is to form a zone of high permeability by reverse pyrolysis/combustion between the transverse vertical injection well and the zone created previously by channel gasification. The injection of gasification reactants will be transferred progressively from the deviated injection well to the second (vertical) injection well. If a large semi-carbonised zone can be formed, then the concept of filtration gasification will be tested.

- *Filtration gasification.* The aim of this phase is to gasify coal in the zone created during the previous reverse pyrolysis/combustion operation. Reactor life, cavity growth mechanisms, efficiency and gas quality will be evaluated if this phase proves to be successful.

- *Fire extinction.* Reactions will be stopped and the test terminated by the circulation of nitrogen through the gasifier. After a few days, all underground cavities will be filled with water.

- *Environmental monitoring.* An environmental monitoring programme will be developed to cover conditions before, during and after the test. The underground system will be vented continuously to minimise the potential transport of contaminants into adjacent strata and to enhance groundwater influx for additional cooling.

2. SITE SELECTION AND CHARACTERIZATION

2.1 GENERAL GEOLOGY

2.1.1 Stratigraphy

The three Teruel coal basins, Andorra - Foz Calanda, Castellote and Utrillas - Aliaga, were formed between the Upper Aptian and the Middle Albian periods. The coal bearing zones lay within the Escucha formation defined in the 1960's by Oriol Riba et al. who divided the formation into three Members, subsequently given the classification M1, M2 and M3.

M1: Mainly deposited in a "Paralic" environment, the coal seams in this Member appear between shallow marine limestones. The coal seams Nºs 3, 4, 5 and 6 in Utrillas and seams P, Q, R and S in the Ariño valley belong to this Member.

M2: Lagoon environment, coal seams between fossiliferous clay and outstanding rooted sands, "linsen" very frequent. Coal seams Nºs 1 and 2 in Utrillas and 0 in the Ariño valley are good examples.

M3: Fluvial environment, coal between clay and sand. No coal occurrence in Utrillas, coal seam N in Ariño valley.

Finally, above Member M3, the Utrillas Formation appears, a continental fluvial deposit that can be found over the whole Iberica Range. Typical multicolour clay and sand bodies (paleochannels) constitute this geological marker. The sand can have eroded the underlying strata.

2.1.2 Tectonic

The Jurassic movement had an important role in the Cretaceous sedimentation period. Neokimmeric phase uplifts caused by faults, and subsequent erosion, managed to divide the zone into different Cretaceous subbasins that led to a large range in thickness.

Early phases of the Pirinic movement played a big role in the base of the Albian (Escucha Formation), being responsible for many of the coal bearing disturbances. During the coal sedimentation stage, small movements took place in many places so that sedimentation and/or erosion led to the disappearance of some coals seams. Sometimes these weak movements were reactivated following old Jurassic fault patterns. This effect has been detected clearly in the Ariño-Andorra and Castellote coal basins.

2.2 TREMEDAL GEOLOGY

In the Tremedal area, as in nearby Foz Calanda, the three Members M1, M2 and M3 are not clearly evident, and a new Formation, the "Val de la Piedra" Formation was defined. This Formation is widespread over the whole Tremedal area with an average thickness of 16-20 m.

The "Val de la Piedra" Formation (Aptian-Albian) lays unconformably over the Jurassic down to the Utrillas Formation. In general two coal seams are present, separated by some metres of fossiliferous clay and/or limestone. The upper seam can disappear, having been eroded by the overlying sand, wheareas the lower seam can be found practically over the whole Tremedal. One or both of these two seams can be found over the whole Tremedal area.

The Utrillas Formation attains a thickness of about 100 m, and is composed mainly of sand bodies and clay. At the bottom, just over the upper seam, a sandy level appears (erosive paleochannel?), which ranges from 2 to 30 m thickness, and which could be the cause of the variation in thickness of the upper coal seam.

2.3 SITE SELECTION

ENDESA's offer of the 'El Tremedal' as a possible location for the field trial was found acceptable by the European Working Group on Underground Coal Gasification in November 1990.

Within the Tremedal, the site area was selected taking into account the following:

- Confidence that the coal would be in place.
- Confidence about the tectonic setting.
- Coal thickness, depth and quality.
- Appropriate topography.
- Minimization of the number of owners for land occupation.

The site area is shown in Figure 1. The potential of the Tremedal for conventional deep mining had been examined previously to some extent by ENDESA and existing exploration information comprised some seismic lines, 1979, and exploratory wells, 1974. From this information, it was apparent that the upper seam was thickest (7.4 m) at the exploratory well T7 and that the lower seam comprised about 2m thickness of good quality coal in the area of the exploratory wells T6 and T7.

After studying the information provided by ENDESA, a zone located between the previous exploratory wells T6 and T7 was selected for the trial site on the basis of the following considerations:

- A high level of confidence of the presence of at least 1 good seam for gasification. (Based on information from exploratory wells T4bis, T6, T7, T9, 24E and 27E, all within 1 km).
- Good probability of freedom from faulting.
- Suitable thickness, depth and quality.
- Topography not excessively difficult for access and site preparation.
- Low number of owners of land involved for access and occupation.

Three different site options within the zone of interest, identified in July 1991, were evaluated in greater detail in December 1991 in order to finalise site selection.

The coal seams could be expected to be located at the preferred depth of 600 m along an East-West line 100 m North of exploratory well T7. Coal thickness decreases to the West, the thickest coal being observed in T7 (upper seam 7.4 m). The thinnest sand layer over the upper seam is also observed in T7 (2 m), and sand thickness increases in all directions (well 27E appears to be an exception - no upper seam and no sand?).

According to the seismic interpretation, the area selected was located between two transverse faults, F12(A) a very clear fault, and F6 not quite so clear, at a separation of approx. 400 m. On this basis, the most likely fault-free location could be mid-way between the two possible faults, at a location of some 200 metres from each. Two drawbacks to this location were apparent; firstly, that extensive civil engineering works would be required for site preparation due to difficult terrain (strong Tertiary sandstone and conglomerate) and secondly, a lack of clarity in seismic reflection.

In these circumstances, it appeared prudent to consider alternative locations either a) to the East, in the direction of T7 or b) to the West, further from T7.

Alternative a) had advantages of possibly thicker coal and a thinner sand layer above over the upper seam. Alternative b) had the drawbacks of a weaker seismic reflection (from the limestones) than a) and of being closer to fault F12(A), potentially more significant than fault F6. In view of these factors, the easterly location was selected as the first choice for the trial site.

3. EXPLORATORY WELL (ET1)

3.1 STRATEGY AND DESIGN

The exact location of the site was finalised in December 1991 and the design specification of the exploratory well ET1 was formulated during January 1992.

The objective of the exploratory well was to drill vertically by conventional methods to provide information on the nature, thickness and depth of the two coal seams, and the composition and sequence of the overburden strata.

The coal seams themselves, their rooves and floors, and selected sections of overburden were to be cored. An extensive logging programme would also be carried out in order to obtain more information on the nature of the coal and adjacent strata for:

- Drilling the subsequent deviated/in-seam wells.
- UCG process control parameters.
- Performance analysis and modelling.

The exploratory well was located to obtain precise information on the seam entry point of the subsequent deviated injection well. A vertical cross-section of the process well layout is shown in Figure 2. To obtain information on the hydrogeological behaviour of the coal and adjacent strata, hydrogeological tests would also be conducted such as Drill Stem Testing (DST), build-up and injection fall-off.

Based on this strategy, the following sequence of operations were presented to different companies for tendering in February/March 1992:

- Civil works.
  - Rural road widening and improvement
  - New road access to well site
  - Site/rig platform preparation
  - Cellar/guide tube installation
- Drilling and coring operations.
  - 12 1/4" drilling
  - 9 5/8" drilling and reaming
  - 8 1/2" drilling and reaming
  - 4" coring
  - 7" casing setting
  - rig operations for logging/testing
- Logging and perforation operations.
  - Geophysical combination log
  - Dipmeter/geometric log
  - Cement bond log
  - 1 m window perforations at coal and sand levels
- Cementing operations.
  - Cementing of 7" casing
  - Supply of cementing equipment/accessories
- Drill Stem Testworks.
  - Coal seam production tests
  - Sand layer production tests
- Supply of well equipment.
  - 9 5/8" casing
  - 7" casing
  - Other (cap, pup-joints, ...)
- Site mapping and benchmark construction.

On the basis of tenders received, 8 contractors were selected for the exploratory well operations, and civil works began on 23 March 1992.

3.2 OPERATIONS

3.2.1 Access and site preparation (COMERCIAL DE SONDEOS)

Civil works took place between 23 March and 10 April 1992.

Access to the trial site is via a 2.6 km long rural road from the main Andorra-Alcorisa highway. The road was in very poor condition, of insufficient width for access by rig and heavy supply trucks, and considerable improvements were necessary to ensure trouble-free access for all traffic during the drilling of the exploratory well and subsequent trial stages. The works comprised removal of the existing top 10-40 cm clay layer, the laying of new foundations to a width of 3.5 m, and 2 stages of gravel setting, surfacing and compaction.

A new 200 m long access road was constructed from the rural road to the wellsite and approx. 2500 m^2 of agricultural land were prepared for wellsite operations. Part of the exploratory wellsite will subsequently be used for the future installation of injection facilities for gasification and a good quality surface was therefore considered essential. Extensive works were required to stabilize the heavy clay soil and to prepare if for heavy traffic. In some areas over 50 cm of the top clay layer had to be removed and replaced by an equal depth of compacted gravel.

The exact location of the exploratory hole was finalized taking account of site boundaries and levels to minimise the extent of civil works whilst meeting the operational requirements of the drilling and service contractors. A concrete platform was constructed to receive the rig structure and a small cellar was formed to receive the pre-drilling guide tube. The excavation of a 300-400 m^3 mudpit and site perimeter fencing completed the civil pre-drilling works.

3.2.2 Site map, benchmarks and grid reference (TASA, CADIC)

First, a stereoscopic aerial survey at 1/3500 scale was flown. Secondly, from the photographs, a 1/500 scale topographic map of the field trial area was produced with a height contour interval of 0.5 m. Finally, 5 benchmarks for survey referencing in subsequent drilling and surface plant construction were set. One of these is set in the surface of the exploratory well concrete platform, the others at high points in the vicinity from which the whole field trial area can be sighted. The exploratory well (ET1) is located 164.5 m from the previous T7 exploratory well (UTM co-ordinates X = 4532524.81 m; Y = 718653.57 m; Elevation = 666.2 m) drilled in 1974. The UTM co-ordinates of the new exploratory well ET1 are:

- X : 4532660.39 m
- Y : 718560.38 m
- Elevation : 653.3 m

3.2.3 Rig operations (IBERICA DE SONDEOS)

The Mayhew 2500 rig (see Figure 3) was mobilized and arrived on site on 20 April 1992. Rig equipment, mud pump mixer/tanks, shaker, desander, etc... were installed and drilling (12 1/4") began on 26 April 1992. A protakabin for temporary UGE office use and a container for core storage were rented and installed shortly after drilling began.

From 26 April to 24 May 1992, the following operations were realized:

• Drilling	12 1/4"	0 - 39 m	26 April-27 April
Casing and cementing	9 5/8"	0 - 38 m	
• Drilling	8 1/2"	39 - 450 m	28 April- 8 May
• Coring	4"	450 - 557.5 m	9 May - 16 May

• Reaming	8 1/2"	total depth	17 May - 23 May
Open-hole logging		38 - 555 m	
Casing and cementing	7"	450 - 550 m	
Cement Bond Log		70 - 528.9 m	
Perforation Upper Coal		529.4- 530.4 m	
Perforation Sand Layer		516.5- 517.5 m	
• Production Testworks			22 May - 24 May

A summary of the operating time distribution is presented in Table I.

The mud used for the 8 1/2" drilling phase was Bentonite with CMC, caustic soda and Spersene at density 1.11 - 1.15 kg/l, viscosity 34-36 cP, filtrate loss 10-13 cm^3/30 min, pH 9-9.5. The desander was used continuously to take out the important sand content. The mud velocity was always below 200 ft/min.

At intervals, the deviation of the well was measured by TOTCO inclination surveys and found to be less than 1° from vertical over the majority of the well, increasing to 2° over the final section.

Two cementing jobs were realized:

- 9 5/8" - 40 lb/ft - N80 casing (0-38 m)
- 7" - 29 lb/ft - N80 casing (0-550.4 m)

The first cementing job was realized with the standard rig equipment and used 1,300 l of slurry at a density of 1.65 kg/l. The second cementing job was realized by a specialist cementing company (HALLIBURTON). The cementing programme was:

- Class "G" cement : 15 tons
- Microsilica for slurry integrity : 800 l
- Halad-361A for gas control : 750 l
- NF-3 defoamer : 15 l
- Water (360 l/ton) : 5,400 l
- Density : 1.9 kg/l
- Free water : 1%
- Cement injection time : 25 min
- Mud displacement time : 35 min

No major difficulties were experienced during the drilling, coring and reaming phases; only some small problems with the principal pump and the drilling head. The only significant problem encountered was the inability to drill out a cement setting plug following cementing of the 7" casing. Although the top of this plug (530.9 m) was near to the floor of the upper seam (532.05 m), it did not prevent perforation at the upper coal seam level and an alternative arrangement was able to be adopted for production testworks in the coal and sand. The presence of the plug could however affect the ability to utilize the exploratory well for subsequent monitoring purposes, particularly if the lower coal seam is selected for gasification.

Table II shows the 7" casing composition and Figure 4 gives a schematic view of the present situation of the exploratory well ET1.

3.2.4 Logging, perforation operations (SCHLUMBERGER)

The following logs were run (38 - 555 m) open-hole prior to casing:

- *Litho-Density log.* The principal functions are porosity analysis and lithology determination.

- *Compensated Neutron log.* The principal functions are porosity analysis, lithology identification, clay analysis and gas detection.

- *Microlog.* The principal functions are identification of permeable zones, definition of bed boundaries, detailed sand count and indication of mudcake thickness.

- *Gamma Ray log.* The principal functions are depth control, shale indicator, base log for correlation with cased hole and detection of radioactive minerals.

- *Caliper log.* The principal functions are hole volume calculation and definition of bed boundaries.

- *Stratigraphic High-Resolution Dipmeter tool.* The principal functions are determination of structural dip, computation of stratigraphic dip, stratigraphic analysis, fracture identification, and borehole geometry and trajectory.

The first 5 tools (LD, CNL, ML, GR, Cal.) were incorporated in a combination sonde and run in a single trip to save time and money. The main drawback of this combined tool is that, due to the vertical stacking of sensors, the upper sensors may not cover an appreciable section (± 14 m) of the well at the bottom of the hole.

Once the 7" casing setting and cementing were realized, the following logging and perforating tools were run:

- *Cement Bond tool (70 - 528.9 m).* The principal functions are evaluation of cement seal in the casing-formation annulus, casing location and depth correlation with previous open-hole logs.

- *High Shot Density gun.* The gun was designed for double window shots in a single wireline trip. The gun characteristics were two 1m-windows, 5" O.D., 12 SPF density and a phasing angle of 120°. The first window was shot in front of the upper coal seam (529.4 - 530.4 m), the second window in front of a sand layer situated above the coal seam (515.5 - 516.5 m). The sand layer window was selected on the basis of the coring and log analysis.

3.3 INTERPRETATION

3.3.1 Lithology (from drilling cuttings, coring and logging)

The lithology of the exploratory well ET1 (see Figure 5) can be divided as follows:

- *Terciary (0-368 m)*. This zone is composed of clay, conglomerate, marls and some high porosity sands. The sands were crossed at the levels 115-126 m, 192-213 m and 248-262 m. The caliper log in this zone indicates hole sizes generally greater than the drill bit diameter of 8 1/2". Diameters up to 11" were measured in clay zones. The zones of sand presented caliper measurements of 8 1/2"- 9" with reduced mudcake.

- *Cretaceous-Cenomanian (368-418 m)*. This zone comprises impermeable brown/red marls with minor layers (± 1 m) of limestones. The rate of penetration during drilling was very slow (4-5 times less than the drilling rate in the Terciary). The logging characteristics of this zone were low resistivity and low natural gamma emission, porosity near to zero were low resistivity and density nearly constant around 2.4 g/cc. The zones with limestones show an increase in gamma emission and apparent porosity, and a decrease in density. No cavities were observed in this zone and the caliper measurements indicated a diameter similar to the drilling diameter.

- *Cretaceous - Albian/Aptian (418-544.1 m)*. In the upper section, this zone comprises a succession of various clay and sand layers (Utrillas Formation from 418 m to 528.3 m, the roof of the upper coal seam). The lower section - the "Val de la Piedra" Formation comprises two coal seams separated by a layer of strong limestones. The clay parts of the upper section are impermeable and separate the sand layers into independent aquifers. The total zone can be divided into the following sub-zones for more detailed analysis:

  - *Sub-zone A (422-433 m)*. This zone is composed of the cleanest sands within the Cretaceous zone with high permeability and low gamma emission.

  - *Sub-zone B (433-457 m)*. This zone is composed mainly of multicolored plastic clay/sand and clay of very low permeability.

  - *Sub-zone C (457-488 m)*. This zone is composed mainly of grey sand/clayey sand with insertions of white mica and pyrite. Fragments of coal (± 10 cm) with high pyrite content (>20%) appear at 472.5 m depth and the sands have high porosity and very fine grain.

  - *Sub-zone D (488-514 m)*. This zone is mainly composed of black/grey clay (sometimes multicoloured). Some appearances of coal, pyrite and white mica can be observed.

  - *Sub-zone E (514-528 m)*. This zone is composed mainly of sand/clayey sand which constitutes the roof of the upper coal seam. In general, this zone did not appear as permeable as zones A and C. A sand layer at 516-518 m depth was identified as suitable for subsequent casing perforation and production testwork.

- *Sub-zone F (528.3-532.2 m).* This zone corresponds to the upper coal seam of the "Val de la Piedra" Formation. The coal seam is 4.8 m thinner than in the previous exploratory well T7. The presence of carbon fragments inside the immediate sand roof of the coal suggests that the upper coal seam has been eroded. The coal is well-consolidated with no presence of faults, and is of good quality (low ash content). The coal density is in the range of 1.2-1.6 g/cc and the porosity over 50% (see Table III). It was also decided to perforate a window at the level of the upper coal seam to realize subsequent production testwork.

- *Sub-zone G (532.2-539.3 m).* This zone is constituted of compact limestones without apparent fissuration. The parts with "characeas" present higher porosity, but the microlog did not indicate the existence of a high permeability zone. The porosity estimates from logging indicate higher values than apparent visually.

- *Sub-zone H (539.3-544.1 m).* This zone corresponds to the lower coal seam of the "Val de la Piedra" Formation. The coal seam is approx. 1.6 m thicker than in the previous exploratory well T7. The upper part (±1.2 m) of the seam is composed of low quality carboniferous mudstone, the lower part (±3.6 m) of good quality, low ash content, consolidated coal with no sign of fissuration. The lower part also indicates very high gamma emission (up to 300 API) which could be a good marker for subsequent geological correlation (see Table IV).

• *Jurassic (544.1-557.45 m).* The Jurassic begins at the floor of the lower coal seam and is composed of grey limestones with strong fracturation. The fractures are filled with black clay and, although their orientation is vertical or subvertical, no coal intrusion is observed. In the upper part of the zone, the fractures within the limestones have undergone little displacement. In the lower part of the zone, the fracturation is less intense and the strata more compact with many ooliths. Different open permeability areas are observed over the length of this zone.

3.3.2 **Coal Analysis**

To obtain information on the nature of the coal for subsequent UCG interpretation, cores of the 2 coal seams have been sent to the Instituto de Carboquímica, Zaragoza, for proximate and ultimate analysis to identify the rank, sulphur, ash and moisture content, and calorific value. Additional tests such as swelling index, C^{13} determination and petrographic analysis will also be carried out on selected samples.

3.3.3 **Dipmeter**

The primary function of the dipmeter is to measure the magnitude and direction of the dip of the sedimentary features crossed by the well i.e. structural dip, stratigraphic dip and fault/fracture identification. The device also provides measurements of borehole geometry, including drift (inclination from the vertical) and azimuth.

The SHDT log was processed in SCHLUMBERGER's Paris computer centre with a basic correlation programme 'Mean Square Dip' (MSD), which finds the "best fit" satisfying all possible cross-correlations.

These results were utilized to detect structural and/or stratigraphical anomalies in the formations crossed: Terciary, Cretaceous and Jurassic.

The structural dip of the Terciary is almost constant from 60m to 370m at 32-36° to the South.

The interpretation of the structural dip of the Cretaceous is less clear due to the importance of cross-bedded strata:

Depth (m)	Dip	
465	28°	South
520	35°	South
535	30	South

Some abrupt changes in the sedimentation of sand bodies were also observed in the Cretaceous below 460 m depth - from pure clay to sand and the reverse. This type of sedimentation could be explained by paleochannel and lagoon sedimentation inducing important cross-bedded strata. Some strata dip to the S-SW and SE and have no relation to the structural dip. Some strata dip at higher or lower angles than the structural dip (±30-35°) within the Cretaceous cross-bedded sand units, generally over lengths less than 5 metres.

Two possible small normal faults can be located from the analysis of the dip profile:

- In the Tertiary at 365 m depth
- In the Cretaceous at 544 m depth, corresponding to the floor of the lower coal seam.

3.3.4 **Cement Bond Log**

The log indicates good quality cementation of the 7" casing over the lower section of the well (460 m to total depth).

Cementation is of lower quality over the upper section of the well, mainly within the Tertiary. The reason for this could be channelling during cementation in zones of oversize annulus diameter (up to 11").

3.4 PRODUCTION TESTWORK

Due to the time and difficulty experienced in attempting to drill out the top cementing plug located at approx. 530.9 metres depth, it was decided to modify the programme as follows:

- CBL to Total Depth to check cement integrity and to confirm the depth measurement by the drilling company.
- perforation of two 1-metre windows at the level of the upper coal seam (529.4 - 530.4 m) and at a sand layer located approx. 11 m above the upper coal seam (516.5 - 517.5 m).
- production testwork at the level of the coal seam with a single packer (instead of a straddle packer) to isolate the coal seam.
- production testwork at the level of the sand layer with a straddle packer assembly to isolate the sand layer.

The production testwork was realized jointly by BAKER HUGHES (DST tool) and GEOSERVICES (downhole Memory Quartz Gauge - MQG and Wireless Transmitted Data - WTD system).

3.4.1 Coal Seam Testwork

The production testwork began at 21h 36min on 22 May 1992. The time involved in tool installation was quite long because of the need to assemble the many components involved. The composition of the DST assembly is listed in Table V.

The sequence of operations was:

22/5/92	21h 36min	Run DST in hole with MQG + WTD
23/5/92	1h 07min	Set packer
	1h 43min	Open valve - First production (cleaning)
	2h 11min	Shut-in valve - First build-up
	3h 21min	Open valve - Second production
	12h 33min	Shut-in valve - Second build-up
24/5/92	8h 17min	Unset packer
	8h 51min	Run-out
	10h 36min	Tools at surface - End of production testwork

The second build-up period was interpreted by means of the GEOSERVICES WISE validation software.

The production period prior to second build-up lasted 10h 41min with a production flow of approx. 5 l/h.

The main results from the Horner Interpretation (Figure 6) and the Derivative Plot Interpretation (Figure 7) are:

Permeability	:	2 mD
Skin effect	:	38
P* (roof of coal)	:	48.4 bar

3.4.2 **Sand Layer Testwork**

The production testwork began at 15h 35min on 24 May 1992. The composition of the DST assembly is listed in Table VI.

The sequence of operations was:

24/5/92	15h 35min	Run DST in hole with MQG + WTD
	17h 30min	Set Sraddle Packers
	18h 06min	Open valve - First production (cleaning)
	18h 12min	Shut-in valve - First build-up
	18h 59min	Open valve - Second production
	19h 09min	Shut-in valve - Second build-up
	20h 41min	Upset packers
	21h 08min	Run-out
	22h 32min	Tools at surface - End of production testwork

For this test, the second production period was short (9 min) compared to the build-up period (92 min). In this condition, special care was taken to define production with the pressure history recorded by the gauge. Finally, six flowrate periods were defined: clean-up period, first build-up, and four decreasing flowrates prior to main build-up.

Validation by GEOSERVICES WISE software was made with the data of the second build-up period. Figure 8 shows the derivative and pressure plots. It can be observed that the logs of pressure and derivative follow a straight line of slope 0.5 at the beginning of the build-up with a ratio of 2:1 between both. This behaviour is not consistent with a wellbore storage effect at an early stage of build-up; more probably it relates to the behaviour of fractured strata, the effect being further supported by the significant quantity of sand found in the drill string after pull-out (± 20 l of sand inside the first drill collar). After a little less than 1 hour, the derivative curve is horizontal and can be interpreted as stabilised radial flow. A better interpretation of this period is via Superposition Plots, Figure 9; a straight line fit to the final points gives values of:

Permeability	:	18 md
Skin effect	:	-5

The skin is negative, of opposite sign to the skin of the coal, indicative of a fractured well - in accordance with the observation during the early stage of build-up.

4. PROJECT DIRECTION

4.1 ADMINISTRATION

The deed of formation of the Underground Gasification Europe AEIE was signed on 1 October 1991 in Madrid in front of a Spanish notary, managers of the UGE were appointed, and the first members of the project team occupied relatively small, temporary office space provided by ENDESA on 30 October 1991. The period to end-December 1991 was spent in the acquisition of temporary offices, the installation of furniture, telephone and fax facilities, and in general administration to get the project up-and-running. The Commission agreed that the first reports on the project could cover the period to end-June 1992.

Larger office accommodation is now required to cater for the planned growth in personnel during the second half of 1992. Suitable, ready-to-occupy office accommodation is scarce in the area and it will be necessary to acquire floor space which can be converted. Negotiations are in progress to rent such accommodation and to realise the necessary conversion.

The team presently comprises 5 full-time staff including a secretary. Advertisements for the additional engineering and technical staff required by the programme were placed in the press in June 1992. Some difficulty is anticipated in recruiting appropriate staff because the relatively isolated location is unattractive for experienced/qualified staff.

4.2 CONFERENCES, PUBLICATIONS AND REPORTS

A paper "Joint European Underground Coal gasification Project in Spain" was presented to the XVth World Mining Congress in Madrid in May 1992. The paper covered the background, objectives and planning of the project, together with a status report.

A report on project status was presented to the THERMIE Contractor's meeting in Saarbrucken on 10-11 June 1992.

A publicity handout on the project was prepared by UKAEA and this has been translated into Spanish for publicity/information purposes in Spain.

Reports prepared by contractors include a drilling/geology analysis of the Exploratory well ET1 by ADARO, and an interpretation by GEOSERVICES of the permeabilities in coal and sand formations by analysis of DST tests.

4.3 PROBLEMS/DIFFICULTIES

The only significant problem to date was encountered during the drilling of the exploratory well ET1 when a cement setting plug was unable to be removed by drilling following cementing of the 7" casing. Although the top of this plug was close to the floor of the upper seam, it did not prevent perforation at seam level and an alternative arrangement was able to be adopted for DST production testing in the coal. The presence of the plug could however affect the ability to utilize the exploratory well for subsequent monitoring purposes, particularly if the lower seam is selected for gasification.

4.4 CHANGES IN TECHNICAL STRATEGY

Although the coal in the exploratory well ET1 is present at the expected depth, the thicknesses of the seams deviate from those anticipated in the prognosis, the upper seam being less than expected and the lower seam greater than expected. Because information on seam regularity/continuity is important for subsequent operations, particularly the drilling of the deviated injection well, it has been decided to reschedule the drilling programme slightly, bringing forward the drilling of a monitoring well to obtain confirmation of seam location and conditions in the vicinity of the product well (the end of the in-seam section of the injection well). The design of the in-seam injection well will be conducted in parallel with this activity in order to avoid a delay in the drilling programme.

4.5 FUTURE WORK

The work to be conducted in the next six months will include the drilling of a second exploratory/monitoring well, the civil works for almost the whole of the trial site, and the design of the deviated in-seam injection well. Contacts will be established with directional drilling contractors to establish their technical credentials for the provision of services involved in this well, and with engineering contractors for detailed design of the surface plant, prior to the issue of tenders for these services.

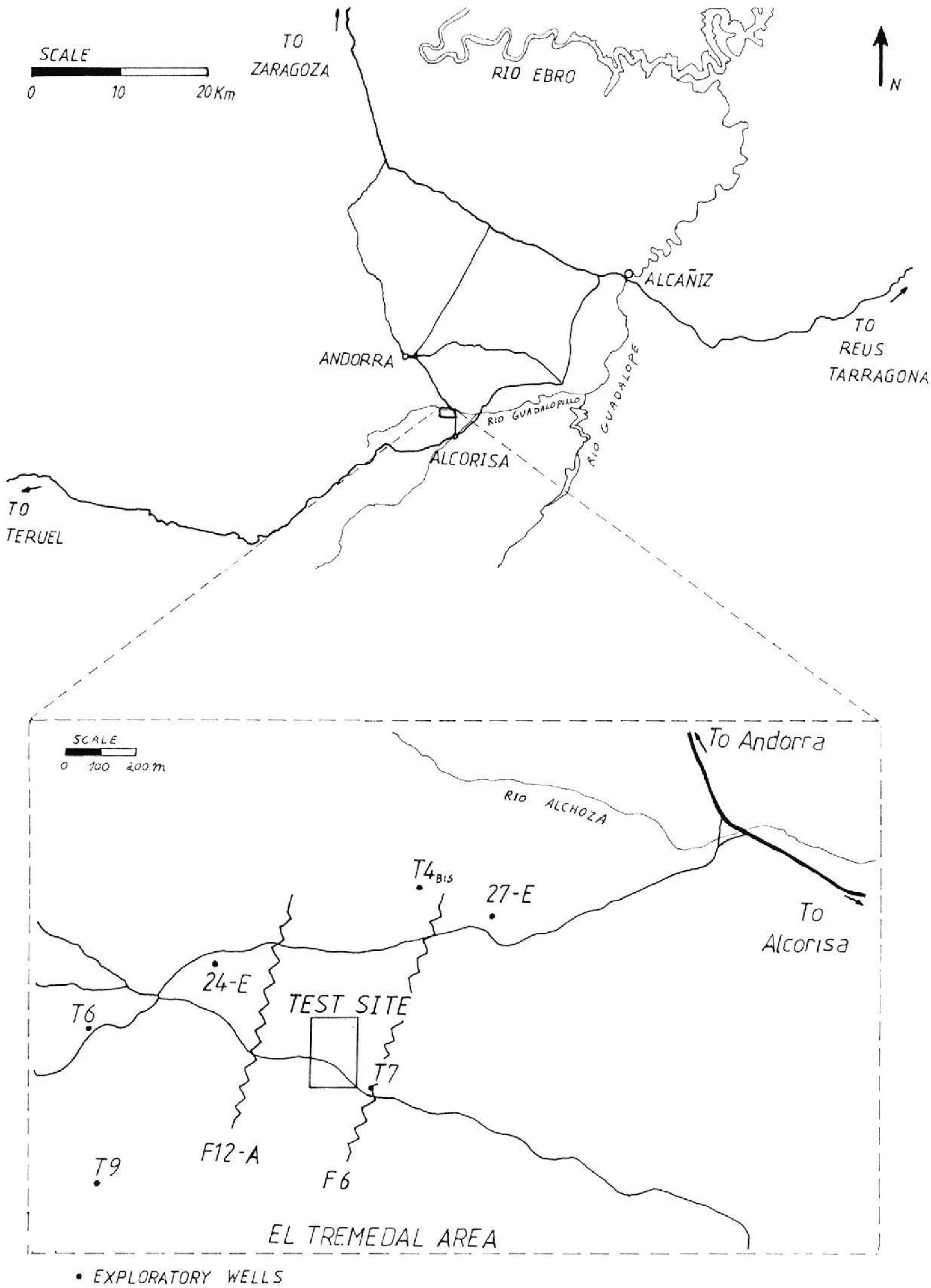

FIGURE 1 . SITE LOCATION

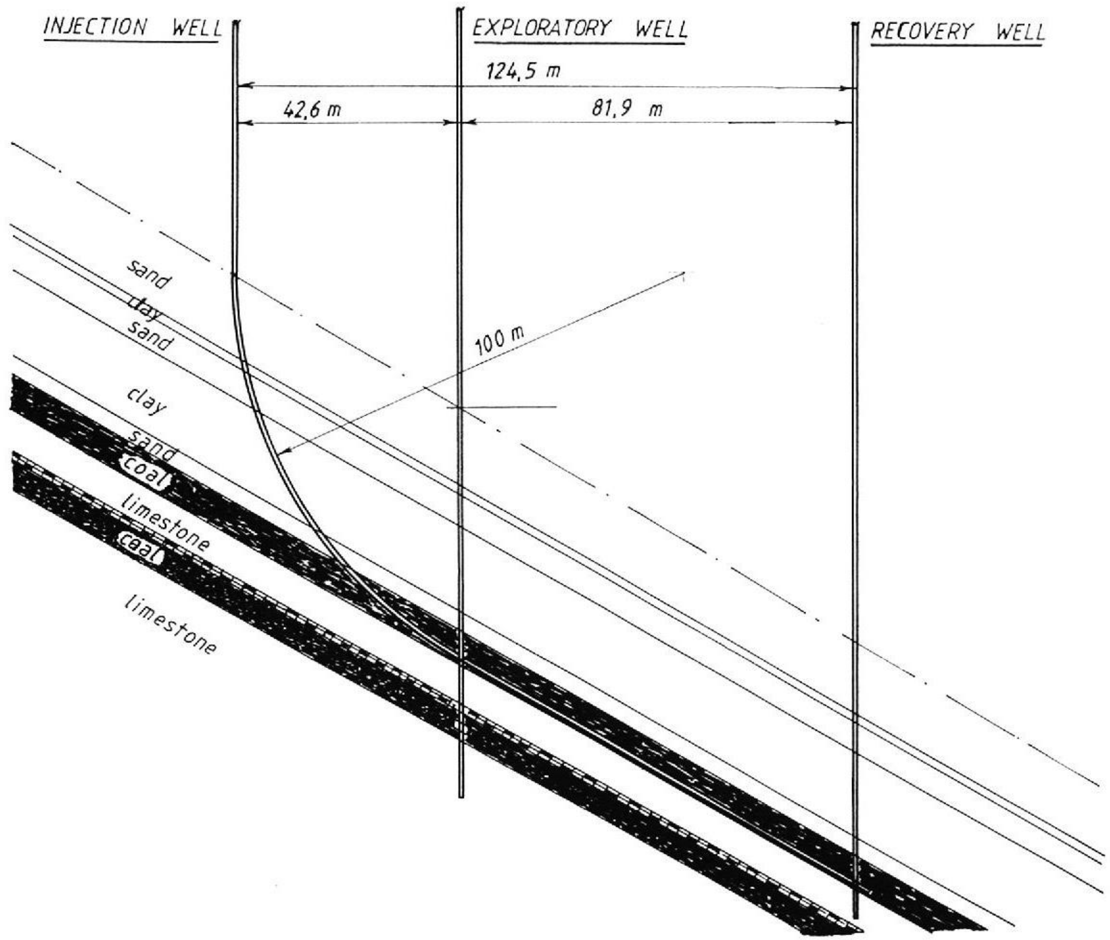

FIGURE 2 . VERTICAL CROSS - SECTION OF PROCESS WELL LAYOUT
(ESTIMATED DIP ANGLE 35 º)

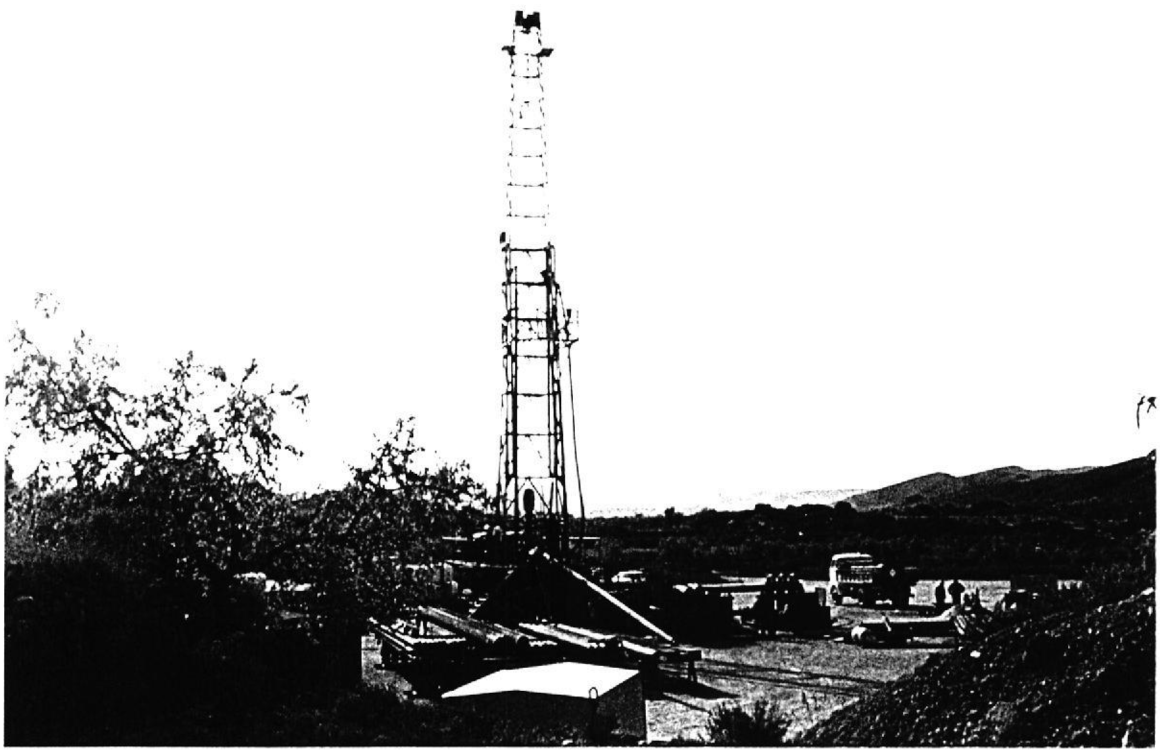

FIGURE 3 . RIG VIEW(MAYHEW 2500)

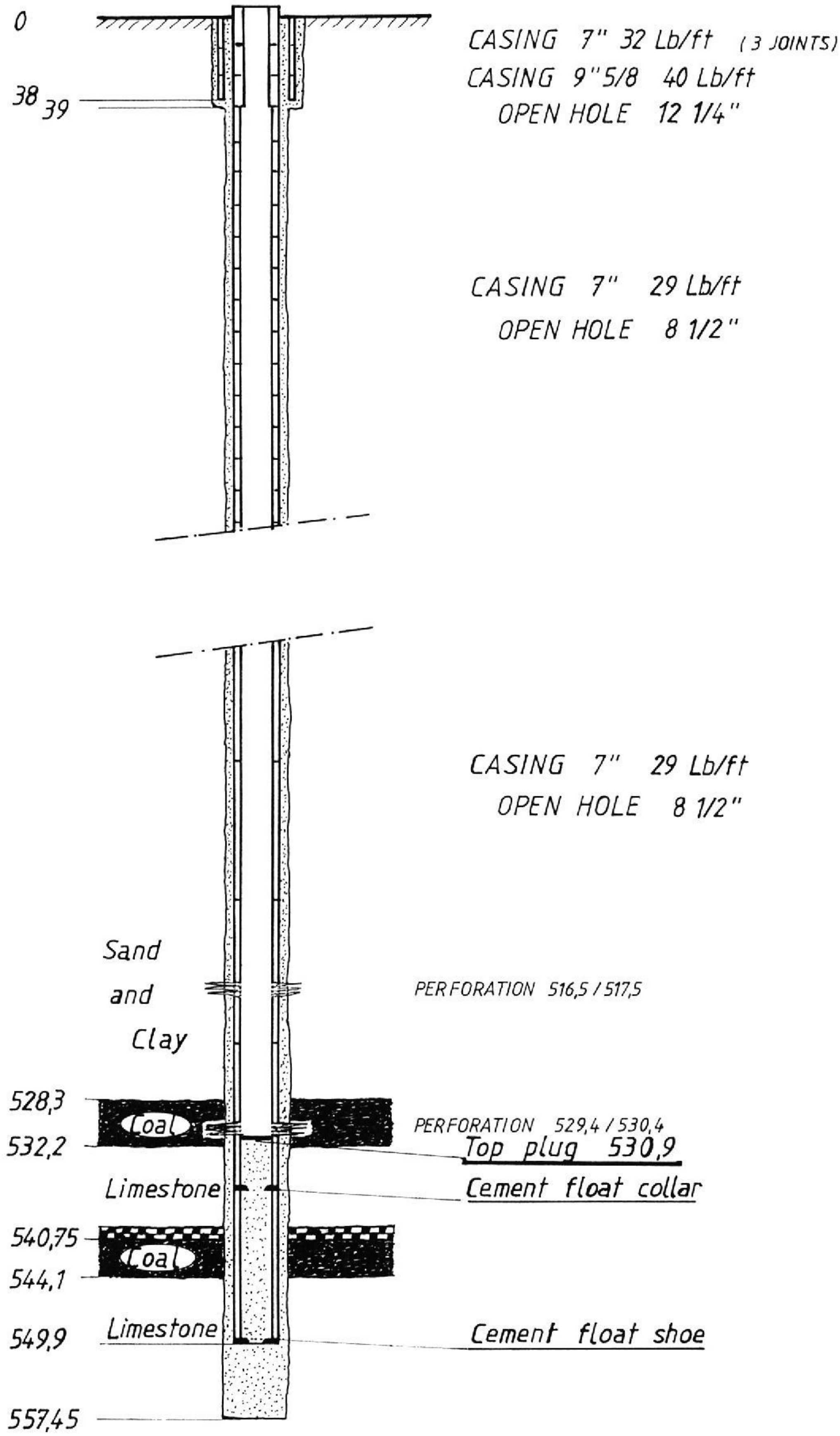

FIGURE 4 . EXPLORATORY WELL ET1 COMPLETION
(DEPTH IN METRES BELOW PLATFORM LEVEL)

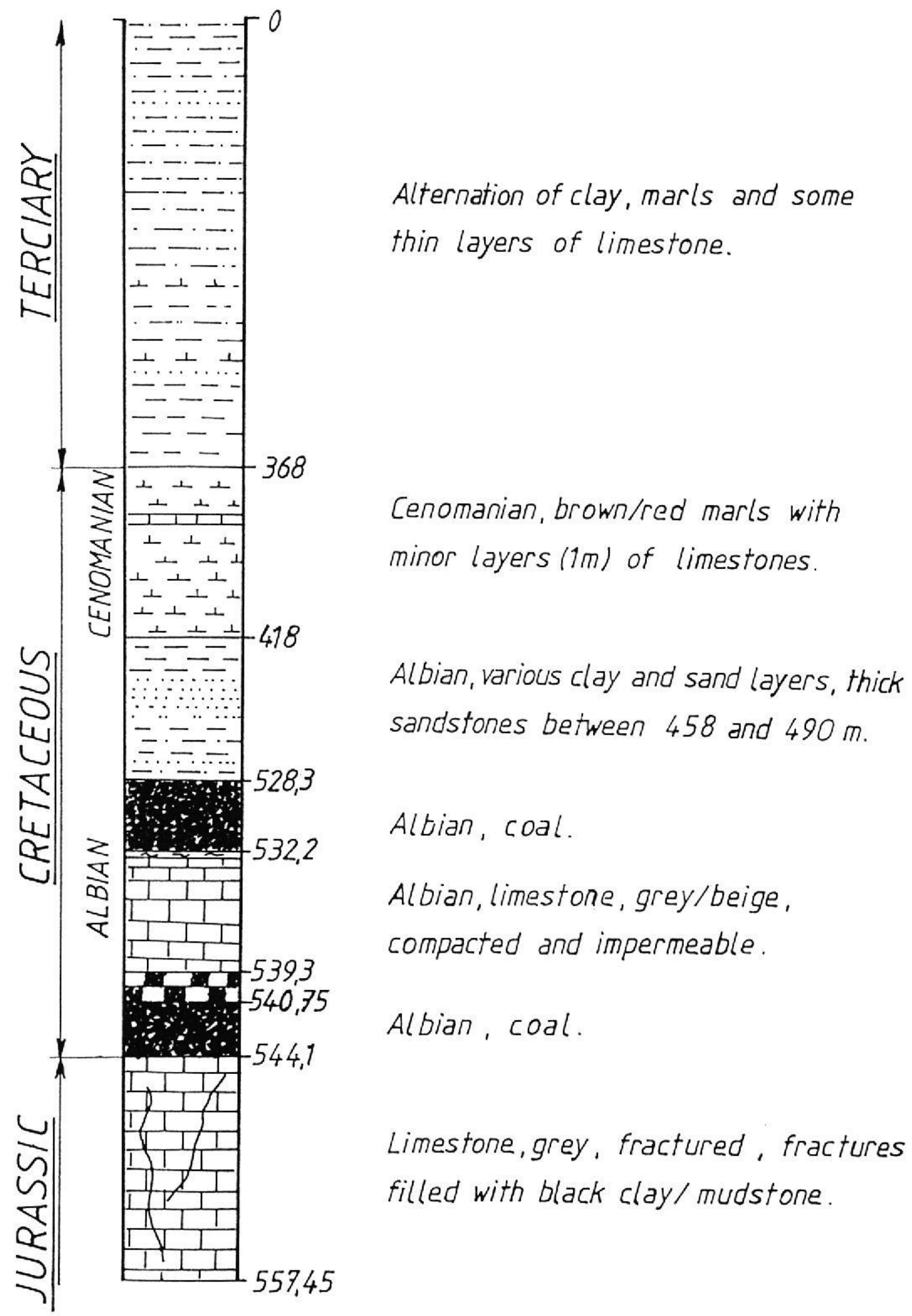

FIGURE 5 . EXPLORATORY WELL ET1 LITHOLOGY
(DEPTH IN METRES BELOW PLATFORM LEVEL)

GEOSERVICES PRODUCTION	WISE REPORT	W.I.S.E. SYSTEM

HORNER INTERPRETATION

CLIENT : U.G.E.	OPERATORS NAME : DAUTREME
FIELD : EL TREMEDAL	REPORT DATE : 22/05/92
WELL : TRL1 DST#1	PAGE : 1

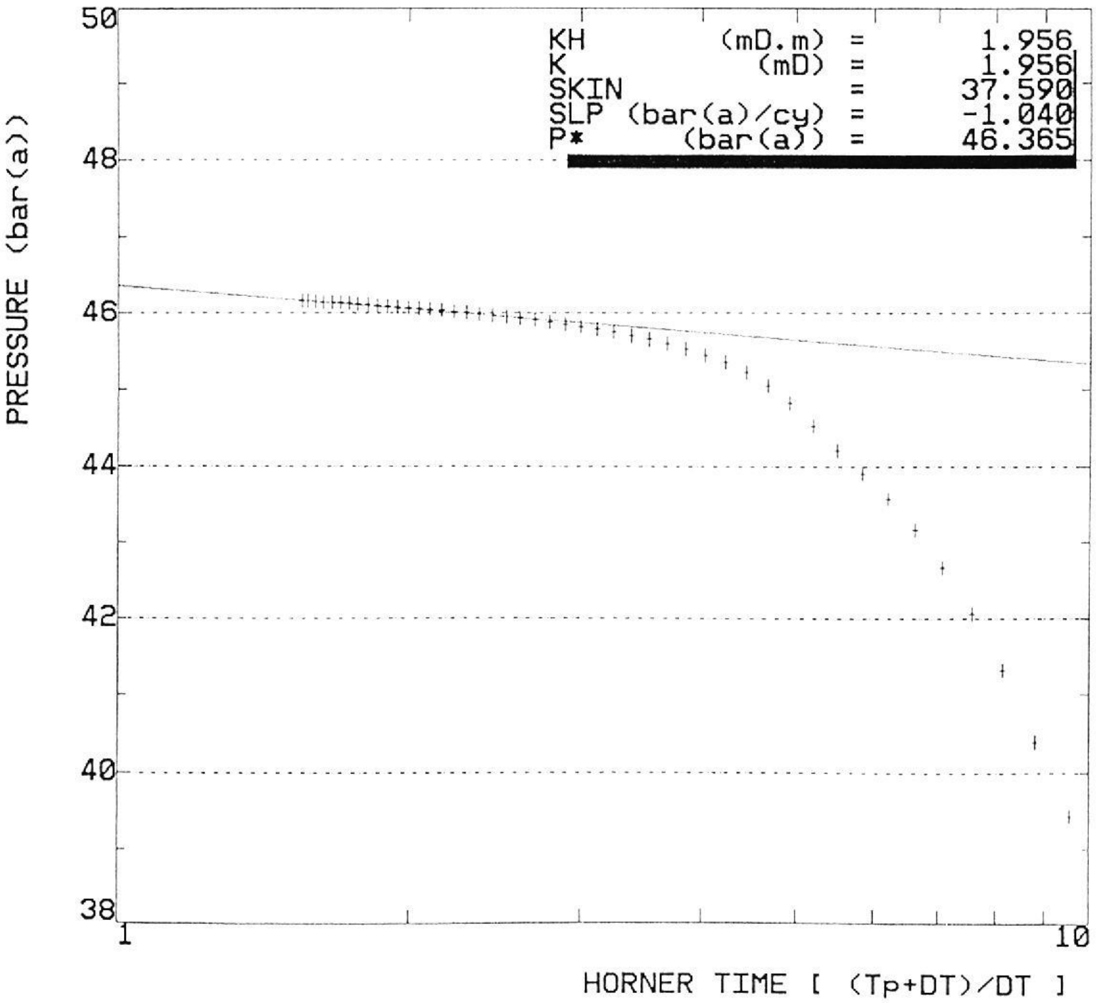

FIGURE 6 . COAL SEAM PRODUCTION TESTWORK
HORNER PLOT INTERPRETATION

GEOSERVICES PRODUCTION	WISE REPORT	W.I.S.E. SYSTEM

DERIVATIVE PLOT INTERPRETATION

CLIENT : U.G.E.	OPERATORS NAME : DAUTREME
FIELD : EL TREMEDAL	REPORT DATE : 22/05/92
WELL : TRL1 DST#1	PAGE : 2

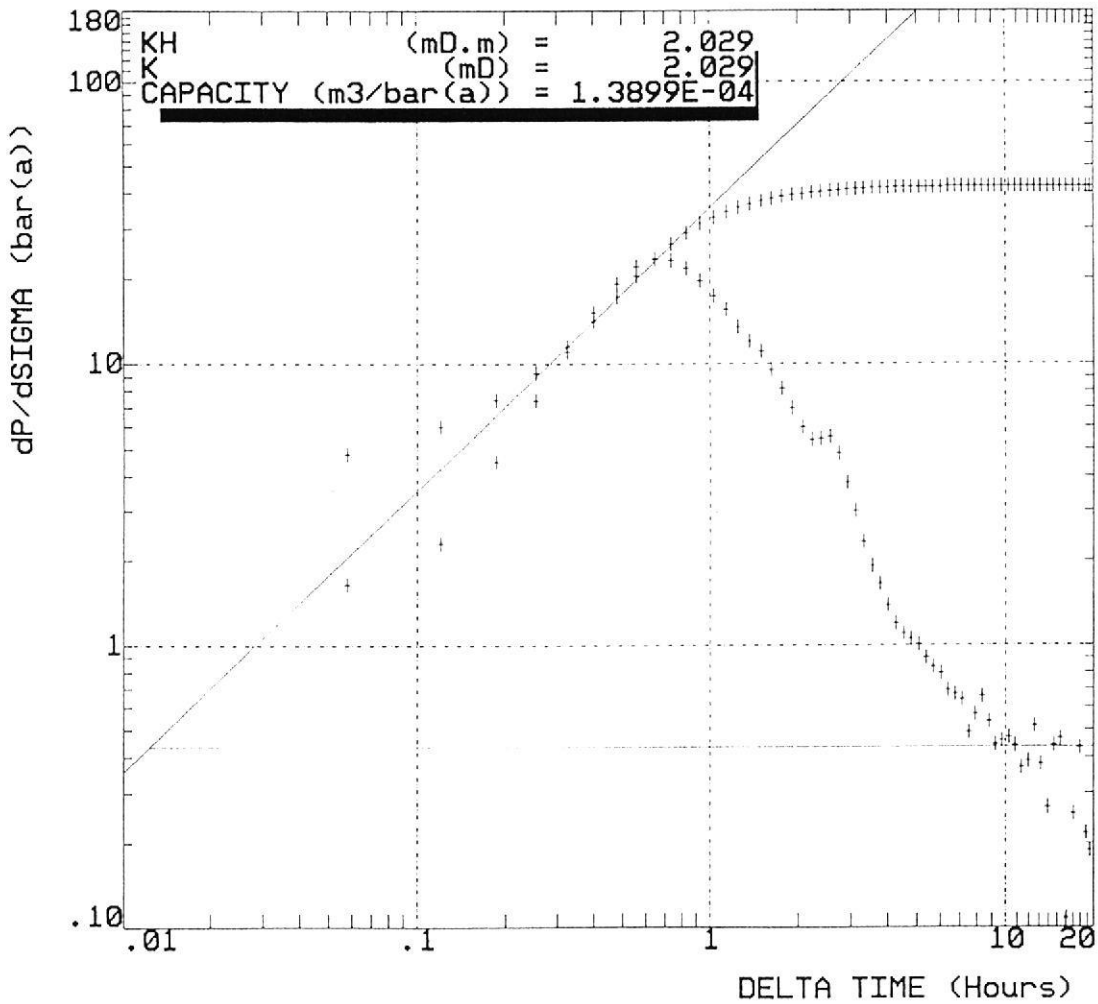

FIGURE 7 . COAL SEAM PRODUCTION TESTWORK
DERIVATIVE PLOT INTERPRETATION

GEOSERVICES PRODUCTION	WISE REPORT	W.I.S.E. SYSTEM

DERIVATIVE PLOT

CLIENT : U.G.E.	OPERATORS NAME : DAUTREME
FIELD : TREMEDAL	REPORT DATE : 24/05/92
WELL : TRL1	PAGE : 6

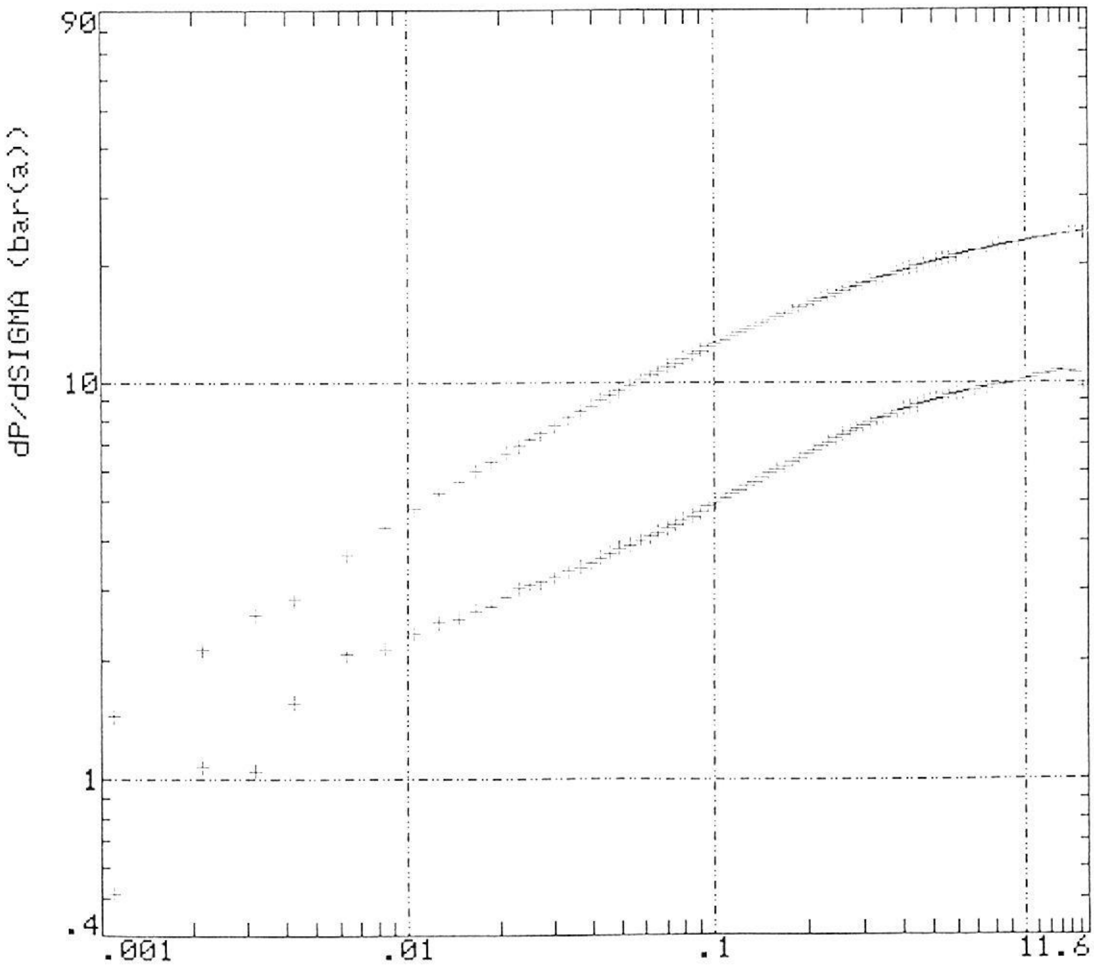

FIGURE 8 . SAND LAYER PRODUCTION TESTWORK
DERIVATIVE AND PRESSURE PLOTS

GEOSERVICES PRODUCTION	WISE REPORT	W.I.S.E. SYSTEM

SUPERPOSITION INTERPRETATION

CLIENT : U.G.E.	OPERATORS NAME : DAUTREME
FIELD : TREMEDAL	REPORT DATE : 24/05/92
WELL : TRL1	PAGE : 8

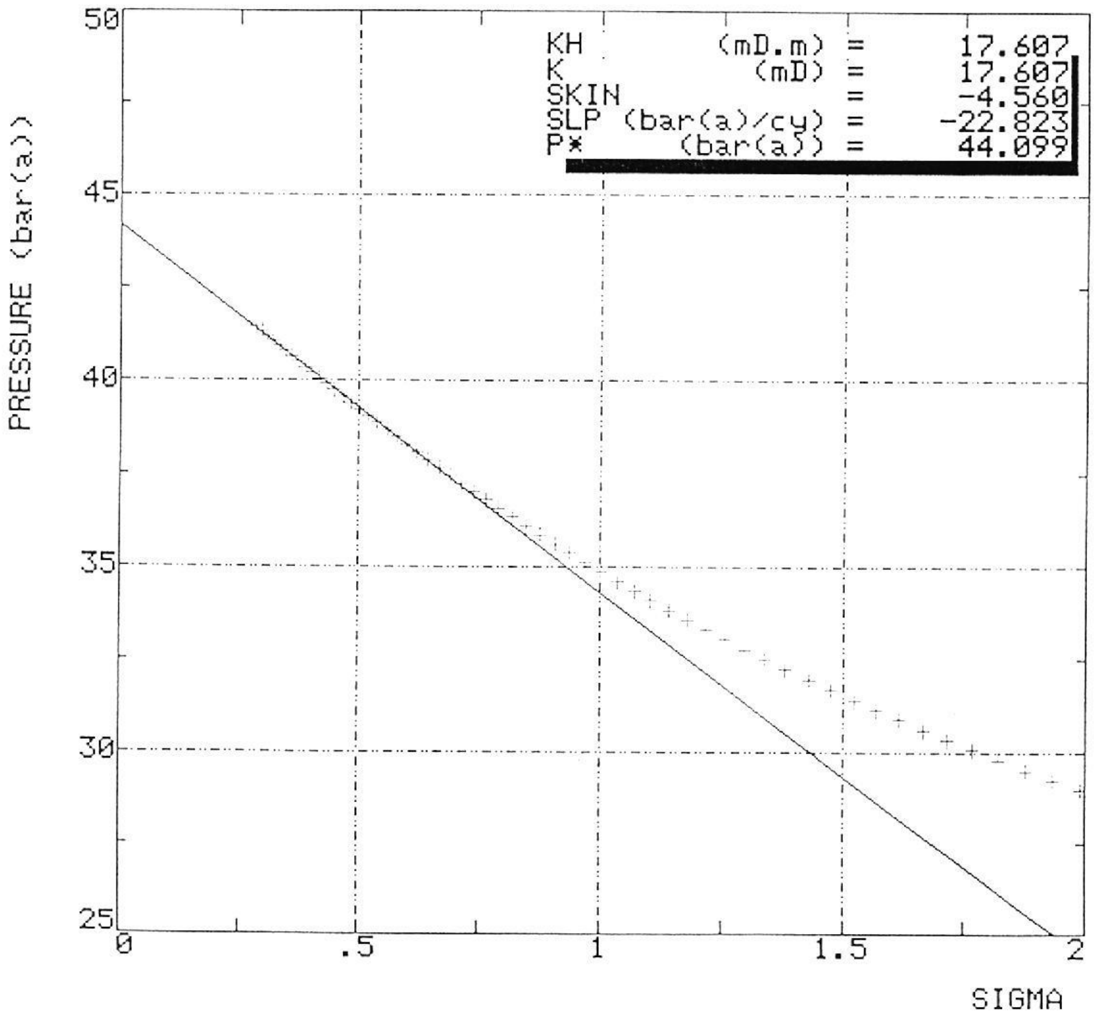

FIGURE 9 . SAND LAYER PRODUCTION TESTWORK
SUPERPOSITION PLOT INTERPRETATION

Day	Drilling	Stop/ Main- tenance	Rig Manoeuvre	Mud Prep./ Circul.	Casing Setting	Cementing	Coring	Reaming	Logging	Production tests
1	19.00	4.00	1.00							
2	1.50		0.40	0.30	3.00	18.00				
3	13.15		0.45	1.00		9.00				
4	22.15			1.45						
5	15.00	4.45	2.00	2.15						
6	22.45			1.15						
7	19.15		3.15	1.30						
8	23.15			0.45						
9	18.45	2.00	3.15							
10	9.05	11.30	3.25							
11	21.40		2.20							
12	22.00		2.00							
13	0.20	0.30	6.30	2.45			13.55			
14			18.00	0.15			5.45			
15		1.00	13.20	0.15			9.25			
16		0.15	8.15	1.00			5.00	5.00	4.30	
17			16.15	0.15			7.30			
18			19.45				4.15			
19			19.15				4.45			
20		1.00	8.45				9.45	4.30		
21			2.30	0.45				16.15	4.30	
22			2.30	1.00	4.30			11.00	5.00	
23					9.00	15.00				
24			2.00			22.00				
25			10.30					13.30		
26			10.15					13.45		
27			3.00						7.00	14.00
28										24.00
29		2.00	4.00							18.00
Total	208.25	27.00	163.30	15.15	16.30	64.00	60.20	64.00	21.00	56.00

TABLE I . EXPLORATORY WELL ET1 OPERATING TIME DISTRIBUTION (HOUR.MIN)

Nº	Element Description	Element Length(m)	Bottom Element Depth(m)
45	7 in. Casing(32 lb/ft)	12.03	-11.53
44	7 in. Casing(32 lb/ft)	12.08	-23.61
43	7 in. Casing(32 lb/ft)	12.08	-35.69
42	7 in. Casing(29 lb/ft)	12.49	-48.18
41	7 in. Casing(29 lb/ft)	13.08	-61.26
40	7 in. Casing(29 lb/ft)	12.86	-74.12
39	7 in. Casing(29 lb/ft)	13.08	-87.20
38	7 in. Casing(29 lb/ft)	13.32	-100.52
37	7 in. Casing(29 lb/ft)	12.97	-113.49
36	7 in. Casing(29 lb/ft)	12.60	-126.09
35	7 in. Casing(29 lb/ft)	12.80	-138.89
34	7 in. Casing(29 lb/ft)	13.20	-152.09
33	7 in. Casing(29 lb/ft)	13.10	-165.19
32	7 in. Casing(29 lb/ft)	12.97	-178.16
31	7 in. Casing(29 lb/ft)	12.45	-190.61
30	7 in. Casing(29 lb/ft)	13.05	-203.66
29	7 in. Casing(29 lb/ft)	13.15	-216.81
28	7 in. Casing(29 lb/ft)	12.90	-229.71
27	7 in. Casing(29 lb/ft)	11.03	-240.74
26	7 in. Casing(29 lb/ft)	12.70	-253.44
25	7 in. Casing(29 lb/ft)	13.35	-266.79
24	7 in. Casing(29 lb/ft)	12.55	-279.34
23	7 in. Casing(29 lb/ft)	13.15	-292.49
22	7 in. Casing(29 lb/ft)	13.00	-305.49
21	7 in. Casing(29 lb/ft)	13.00	-318.49
20	7 in. Casing(29 lb/ft)	13.20	-33169
19	7 in. Casing(29 lb/ft)	12.55	-344.24
18	7 in. Casing(29 lb/ft)	13.05	-357.29
17	7 in. Casing(29 lb/ft)	13.00	-370.29
16	7 in. Casing(29 lb/ft)	13.05	-383.34
15	7 in. Casing(29 lb/ft)	11.85	-395.19
14	7 in. Casing(29 lb/ft)	10.70	-405.89
13	7 in. Casing(29 lb/ft)	13.00	-418.89
12	7 in. Casing(29 lb/ft)	13.00	-431.89
11	7 in. Casing(29 lb/ft)	11.05	-442.94
10	7 in. Casing(29 lb/ft)	12.75	-455.69
9	7 in. Casing(29 lb/ft)	13.45	-469.14
8	7 in. Casing(29 lb/ft)	13.35	-482.49
7	7 in. Casing(29 lb/ft)	12.25	-494.74
6	7 in. Casing(29 lb/ft)	13.21	-507.95
5	7 in. Casing(29 lb/ft)	13.45	-521.40
4	7 in. Casing(29 lb/ft)	13.50	-534.90
3	Float Collar	0.53	-535.43
2	7 in. Casing(29 lb/ft)	13.95	-549.38
1	Float Shoe	0.52	-549.90

TABLE II . 7" CASING COMPOSITION(DEPTH RELATIVE TO PLATFORM)

Interval(m)	Gamma Ray	Piezo-elec. Factor	Density (g/cc)	Porosity (neutron)	Lithology	Core % Recovery
526.3-528.3	63	2.9	2.20	35	Clayey Sand	100
528.3 - 528.8	75	2.4	1.68	54	Coal	100
528.8 - 529.4	60	1.7	1.48	59	Coal	100
529.4 - 530.0	42	1.4	1.33	58	Coal	92
530.0 - 530.8	35	1.2	1.28	59	Coal	91
530.8 - 531.3	45	1.2	1.31	59	Coal	100
531.3 - 531.8	74	1.2	1.32	58	Coal	100
531.8 - 532.2	105	1.9	1.52	57	Coal	100
532.2 - 534.0	25	4.2	2.35	20	Clay/ Limestone	100

TABLE III . UPPER COAL SEAM LOG DATA(API UNITS)

Interval(m)	Gamma Ray	Piezo-elec. Factor	Density (g/cc)	Porosity (neutron)	Lithology	Core % Recovery
538.0 - 539.3	17	4.0	2.35	23	Limestone	100
539.3 - 540.2	70	2.0	1.68	54	Carbonifer. Mudstone	96
540.2 - 540.75	88	1.5	1.48	59	Carb. Mud./Coal	100
540.75 - 541.25	120	1.2	1.30	56	Coal	100
541.25 - 542.5	195	1.3	1.33	57	Coal	100
542.5 - 543.5	300	1.2	1.31	62	Coal	100
543.5 - 544.1	318	1.2	1.50	63	Coal	78
544.1 - 545.3	128	4.2	2.35	15	Fissured Limestone	95

TABLE IV . LOWER COAL SEAM LOG DATA(API UNITS)

Assembly Component	Length(m)	O.D.(in.)	I.D.(in.)	Bottom Comp. Depth(m)
1 Pup Joint	5.05	3 1/2	2 11/16	+2.36
1 Pup Joint	3.15	3 1/2	2 11/16	-0.79
53 Drill Pipes	484.50	3 1/2	2 11/16	-485.29
2 Drill Collars	17.90	4 3/4	2 1/16	-503.19
1 Reverse Sub	0.30	4 3/4	2 5/8	-503.49
1 X-Over Sub	0.30	4 3/4	2 1/4	-503.79
1 Shut-In Valve	1.50	5	1	-505.29
1 Sampler	1.03	5	1	-506.32
1 Spacer(GEOSERVICES Memory Quartz Gauge)	2.44	4 3/4	2 1/4 (Gauge 1 11/16)	-508.76
1 Inside Recorder	1.36	5	1	-510.12
1 X-Over Sub	0.30	4 3/4	2 1/4	-510.42
1 Spacer(GEOSERVICES WTD Gauge)	6.60	4 3/4	2 1/4 (Gauge 1 11/16)	-517.02
1 X-Over Sub	0.30	4 3/4	2 1/4	-517.32
1 Hydraulic Jar	2.01	5	1 1/4	-519.33
1 Safety Joint	0.65	4 3/4	2 3/16	-519.98
1 Pump	2.38	5 1/8	1	-522.36
1 Screen	1.16	5 1/8	1	-523.52
1 Packer Stick Up	0.50	5	1	-524.02
1 Packer Element	1.24	5 3/8	1	-525.26
1 Packer Stick Down	0.86	5	1	-526.12
1 Port Sub	0.42	5	1	-526.54
1 Outside Recorder	2.06	5	1 1/4	-528.60
1 Blind Sub	0.30	5	-	-528.90
1 Belly Spring	2.00	5	2 1/4	-530.90

TABLE V . UPPER COAL SEAM PRODUCTION TESTWORK ASSEMBLY
(DEPTH RELATIVE TO PLATFORM)

Assembly Component	Length(m)	O.D.(in.)	I.D.(in.)	Bottom Comp. Depth(m)
1 Drill Pipe	9.10	3 1/2	2 11/16	-5.38
1 Pup Joint	3.15	3 1/2	2 11/16	-8.53
51 Drill Pipes	466.50	3 1/2	2 11/16	-475.03
2 Drill Collars	17.90	4 3/4	2 1/16	-492.93
1 Reverse Sub	0.30	4 3/4	2 5/8	-493.23
1 X-Over Sub	0.30	4 3/4	2 1/4	-493.53
1 Shut-In Valve	1.50	5	1	-495.03
1 Sampler	1.03	5	1	-496.06
1 Spacer(GEOSERVICES Memory Quartz Gauge)	2.44	4 3/4	2 1/4 (Gauge 1 11/16)	-498.50
1 Inside Recorder	1.36	5	1	-499.86
1 X-Over Sub	0.30	4 3/4	2 1/4	-500.16
1 Spacer(GEOSERVICES WTD Gauge)	6.60	4 3/4	2 1/4 (Gauge 1 11/16)	-506.76
1 X-Over Sub	0.30	4 3/4	1 1/4	-507.06
1 Hydraulic Jar	2.01	5	1 1/4	-509.07
1 Safety Joint	0.65	4 3/4	2 3/16	-509.72
1 Pump	2.38	5 1/8	1	-512.10
1 Screen	1.16	5 1/8	1	-513.26
1 Packer Stick Up	0.50	5	1	-513.76
1 Packer Element	1.24	5 3/8	1	-515.00
1 Packer Stick Down	0.86	5	1	-515.86
1 Port Sub	0.42	5	1	-516.28
1 Outside Recorder	2.06	5	1 1/4	-518.34
1 Spacer	1.22	5	1	-519.56
1 Packer Stick Up	0.50	5	1	-520.06
1 Packer Element	1.24	5 3/8	1	-521.30
1 Packer Stick Down	0.55	5	1	-521.85
1 Belly Spring	2.00	5	2 1/4	-523.85

TABLE VI . SAND LAYER PRODUCTION TESTWORK ASSEMBLY
(DEPTH RELATIVE TO PLATFORM)