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

CONTRACTS Nº: SF - 369/91 - ES/BE/UK
Nº: SF - 543/92 - ES/BE/UK

TECHNICAL REPORT
JULY 1992 - DECEMBER 1992

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Summary

The main activities during the period of this report have been in civil works for site preparation, the drilling of the second exploratory/monitoring well, planning and design of the deviated injection well, and the engineering design of surface plant.

In order to optimise civil works, site preparation for the second well was combined with the civil works for that part of the trial site on which subsequently the product well will be drilled and the equipment for product gas analysis and disposal will be installed. The second exploratory/monitoring well ET2 was drilled in December 1992. The results are presented and a correlation made with the lithologies of ET1 and T7, the latter being a nearby exploratory well drilled some years previously.

Technical directional drilling advice was sought from specialist companies providing such services to the oil/gas industries and this advice is reported together with its implications for the design of the deviated injection well. A specification of the surface plant engineering requirements was formulated and invitations to tender for Phase 1 of the work(Basic Design) were issued to selected companies in Spain who were able to demonstrate expertise in similar fields.

Two relatively small contracts were placed for related design studies.

1. INTRODUCTION

This report is the second technical report of the Underground Coal Gasification project being conducted in North Teruel, Spain, with financial support under the EEC´s THERMIE energy programme.

The main thrust of the work on site characterisation has continued. Before commitment to costly directional drilling and surface plant procurement, it is essential to obtain sufficient information on the location and depositional characteristics of the coal in order to be confident of its suitability for subsequent operations.

The previous technical report presented the results of the first exploratory well drilled on the selected gasification site and covered the reasoning behind the decision 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.

The second exploratory/monitoring well ET2 is located on the surface above a point 27 metres to the East of the first future CRIP injection point on the planned channel gasification axis. The location is determined by the objective to subsequently convert the exploratory well into a monitoring well by making a short-radius deviation transverse to the first CRIP cavity.

The exploratory well ET2 is similar in construction but slightly deeper than the exploratory well ET1, with less coring/testing and at lower cost. The casing in ET2 was installed and cemented at $\approx$ 40 m above the upper coal seam(instead of through the seam as in ET1) to enable the future sidetracking and drilling of the deviated section.

Planning and design of the deviated injection well and of the surface plant have been conducted in parallel with work involved in the second exploration well in order to minimise delay resulting from the additional exploration activities.

2. CIVIL WORKS

Because of the dual function of the well ET2, for both exploration and for subsequent future monitoring of cavity growth measurement, it was decided to place this well in a properly surveyed location and to combine the civil works required for the well with the final preparation of the upper part of the site where the recovery well and the transverse injection well will be drilled, and where the product gas surface plant will be installed.

The company ADARO was requested to carry out engineering planning of the civil works including the optimization of earth movements(without import of material from outside the site) and the comparison of 1-platform and 2-platform solutions. On analysis of the ADARO report, it was decided to adopt the 2-platform solution. The advantages of this layout were less earth movement, less visual impact, lower cost and thinner embankment(better stability) for the lower platform. The main disadvantage will be for the future installation of surface plant where access between the 2 platforms will be necessary.

The civil works were realized by the company SEDESA between 12 October and 19 November 1992. The works comprised the construction of the 2 additional platforms 6 m and 11 m respectively above the existing platform constructed for the ET1 drilling activities(see Figure 1). Access ramps between the three platforms and the installation of water drainage conduits were also included in the works. The civil works required the excavation of 16,600 m^3 of top soil, earth and rocks, and the formation of an embankment of 14,300 m^3. The total surface, approx. 12,000 m^2, was finally covered by a 30 cm layer of natural "zahorra". In addition, it was necessary to displace/relocate the rural road situated at the southern boundary of the site over a length of 200 m and to construct a new 90 m long access road to the trial site. These works complete almost all the civil work necessary for the final surface plant installation. The only remaining civil work is the enlargement of the lower platform on which the deviated injection well will be spudded and the injection plant installed.

3. EXPLORATORY WELL(ET2)

3.1 STRATEGY AND DESIGN

Because of the variations in seam thicknesses 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 for additional exploration of the deposit.

The initial objective was to drill vertically by conventional methods and to obtain additional information on the continuity, thickness, depth and dip angle of the two coal seams and the composition and sequence of the adjacent strata, by coring and logging. As in the first exploratory well(ET1), the coal seams themselves, their rooves and floors were cored and a complete logging programme including LDL, CNL, GR, ML and SHDT was performed by SCHLUMBERGER.

The second objective was to locate and prepare the well for use as a monitoring well during the gasification phases to measure the lateral growth of the reactor. In the future it is planned to re-enter ET2 and to extend the well by a short radius deviated section plus an in-seam section transverse to the channel gasification reactor. Thermocouples and fibre optic cables will be placed subsequently inside the borehole.

To fulfil these objectives the surface location of the well is offset 27 metres to the East of the future channel gasification axis(ET1-ET3-ET4) and 63 metres to the South of the ET1, a position corresponding to the first CRIP injection location(see Figure 2). The 27 metre offset corresponds to a displacement of 14 - 15 metres to achieve the short radius deviation into the coal seam and a section of 10 - 15 metres inside the future reactor. To prepare the vertical section for future drilling activities, a 7 " casing was installed and cemented approximately 40 metres above the upper coal seam.

The UTM co-ordinates of the well ET2 are:

X: 718587.4 m
Y: 4532603.0 m
Z: 659.6 m

The location of well ET2 close to the line ET1 - T7(T7 being an exploratory well realized by ENDESA in the year 1974) is also useful for correlation and site characterization.

3.2 OPERATIONS

3.2.1 Contractors

The following contractors were selected for the operations and services involved in the realization of the second exploratory well ET2:

- Civil works	ARIDOS GRACIA
Concrete platform for the derrick	
Cellar and guide tube	
Mud pit, channels to drain mud	
- Casing	
Supply of 7 " casing	COMERCIAL DE SONDEOS
Supply of 9 5/8 " casing	IBERICA DE SONDEOS
- Drilling	IBERICA DE SONDEOS
Drilling 12 1/4 "	
Casing and cementing 9 5/8 "	
Drilling and reaming 8 1/2 "	
Coring 4 "	
Casing setting 7 "	
Cement plug setting	
Preparation for logging and 7 " cementing	
- Logging	SCHLUMBERGER
Geophysical combined log(LDL, GR, ML, NL)	
Dipmeter/geometric log(SHDT)	
Cement bond log/Variable density log	
- Cementing	HALLIBURTON
Cementing of 7 " casing	
Supply of cementing equipment/accessories	
- Casing/tubing inspection	DRILLTEST

3.2.2 Platform/mud pit preparation

Following the civil works realized by SEDESA, minor works were required to prepare the site for the drilling activities for ET2. The works consisted of :
- minor maintenance of the access road/river crossing
- construction of 18 m x 3.5 m concrete platform with a cellar and guide tube
- excavation of a new mud pit(approx. volume 340 m^3)
- construction of channels to drain the mud from rig platform to mud pit

3.2.3 Rig operations

The Mayhew 2500 rig which drilled ET1 was mobilized again for the drilling of the second exploratory well ET2. The rig arrived on site on 18 November 1992 and the installation of rig equipment including mud pumps, mixers, tanks, shaker, desander, etc. took place over the following four days. Some additional installation activities were realized during the 12 1/4 " drilling /

9 5/8 " cementing phase. The UGE site office portakabin was moved to the vicinity of the rig.

From 22 November to 20 December 1992, the following operations were realized:

- Drilling	12 1/4 "	0 - 21 m	22 Nov.
- Casing/cementing	9 5/8 "	0 - 18.5 m	22 Nov.
- Drilling	8 1/2 "	21 - 547 m	23 Nov.-8 Dec.
- Coring	4 "	547 - 577 m	8 Dec.-10 Dec.
- Reaming	8 1/2 "	577 - 577 m	11 Dec.
- Coring	4 "	577 - 601.8 m	11 Dec.-12 Dec.
- Reaming	8 1/2 "	577 - 601.8 m	13 Dec.
- Drilling	8 1/2 "	601.8- 603 m	13 Dec.
- Open-hole logging		total depth	14 Dec.
- Cement plug setting		541- total depth	14 Dec.
- Casing/cementing	7 "	to 528.7 m	15 Dec.-18 Dec.
- Drilling out cement, plugs, float collar/shoe			18 Dec.
- CBL-VDL-CCL		total depth	19 Dec.
- Cement plug setting		510 - total depth	19 Dec.-20 Dec.

The final well completion is shown in Figure 3a and a summary of the operating time distribution is given in Table I.

UGE had decided to pay more attention to the mud system and mud properties than during ET1 drilling, to try to achieve better well caliper. For this purpose, the drilling contractor offered to request advice from a mud engineering company(MAGCOBAR). The mud engineer proposed the use of a low filtrate, low pH mud in order to prevent caving as a result of swelling of the Tertiary clays and also gave advice on the mud specification and system improvements for drilling/coring activities.

During the 8 1/2 " drilling phase, the mud specifications were set as follows:
- Bentonite, CMC(high and low viscosity), caustic soda and Spersene

- density(mud weight)	1.054 kg / l
- funnel viscosity	45 - 51 s
- plastic viscosity	26 - 29 cP
- yield point	25 - 29 lb / 100 ft^2
- filtrate(water loss)	7.5 - 8.6 cm^3 / 30 min
- pH	8.5 - 9

Despite these precautions and improvements, important changes in mud quality occurred during the drilling activities, either as a result of mud losses(15 - 18 m^3) between 32 - 36 m depth or by the addition to the mud of clays and silt from the formation. Thus, the last section of the 8 1/2 " phase was drilled with a mud with very different properties than those at the beginning of drilling. As a result of these variations in mud properties, and possibly other factors, no improvement over ET1 was obtained in the control of final hole diameter as observed in the caliper log.

At intervals, the deviation of the well was measured by TOTCO inclination surveys and found to be less than 1 ° at all survey points along the well, the final check point at 602 metres being 0.5 ° from vertical.

Four cementing jobs were realized:
- 9 5/8 " - 40 lb / ft - N80 casing(0 - 18.5 m)
- Cement plug(541.5 - 603 m)
- 7 " - 29 lb / ft - N80 casing(0 - 528.7 m)
- Cement plug(510 - 541.5 m)

The first cementing job was realized with the rig equipment and used 600 l of slurry at a density of 1.8 kg / l. The setting of cement plugs were also realized by the rig company.

As for ET1, the 7 " casing was cemented by a specialist cementing company (HALLIBURTON). Because the CBL of ET1 had indicated a bad cementing at the level of the Tertiary Formation, an improved cementing programme was adopted:
- Water injection(5 m^3)
- Spacer injection(5 m^3) prepared with
    * Water(2.5 m^3)
    * Flochek Injectrol(2.5 m^3)
      for better cohesion between formation and cement
- Water injection(1.5 m^3)
- Slurry injection(9 m^3) prepared with
    * Class "G" cement(19 tons)
    * Microsilica for slurry integrity(800 l)
    * Halad 361 A for gas control(800 l)
    * NF3 defoamer(11.4 l)
    * Water(7400 l)

The mean slurry density during injection was of 1.88 kg / l.

No major difficulties were experienced during well operations. The only significant events were:
- During the early stages of drilling, mud losses were encountered between 32 - 36 metres depth, a volume of approx. 15 - 18 m^3 being lost into a sandstone formation. The losses were controlled within a few hours by the addition of fluid loss control products.
- A further important feature occurred during trips, overpull being required in some sections of the well on several occasions; for example, near 289 m with 6 tons, and from 498 to 560 m, with a maximum of 10 tons.
- Possibly, for the same reason leading to overpull, the 7 " casing could not be installed to the planned depth 541 m, becoming stuck at 528.7 m. Fortunately, it was possible to maintain circulation and to set cement.

- Another important event was a water influx into the hole on the 21st day of progress(12 December), two days before reaching total depth, during drilling the Jurassic limestone. A rough calculation showed that water influx was approximately 1 m^3 per 16 hours. Water influx continued after the bottom plug was cemented on 14 December.
- A mechanical problem occurred to the piston of the rotary table. To repair, it was necessary to send some pieces in a Madrid workshop, causing a delay of 26.5 hours in the drilling activities.

3.3 INTERPRETATION

3.3.1 Lithology(from drilling cuttings, coring and logging)

The lithology of the exploratory well ET2(see Figures 3a - 3b) can be categorised as follows:

- Terciary(0 - 410 m). This zone is composed of clay, conglomerate, marls and high porosity sands. The sands were crossed at levels 136 - 139 m, 160 - 173 m, 195 - 203 m, 294 - 297 m and 310 - 320 m, as well as the sand/ fissured sandstone between 32 - 36 m where a partial mud loss of 15 - 18 m^3 was registered. The caliper log in this zone indicates an important increase of the hole size. Diameters up to 12 " were measured in clay zone. The zones of sand presented again caliper measurements of 8 1/2 " - 9 " with reduced mudcake.
- Cretaceous-Cenomanian(410 - 456 m). This zone is composed of red/white clay/marls in the upper section and red/brown marls in the lower section. The rate of penetration during drilling was very low, 4 - 5 times less than the drilling rate in the Terciary. From the logging, two zones with different characteristics could be observed: an upper zone, with simultaneous decrease of resistivity and density(min. 2.25 g / cm^3) and increase of gamma emission and neutron porosity; a lower zone exhibited low values of natural gamma emission(15 - 30 API), high values of resistivity, very low porosity(0 - 10 p.u.) and a density of 2.45 - 2.65 g / cm^3. No cavities were observed in this zone and caliper measurements indicated a diameter similar to the drilling diameter(< 9 ")
- Cretaceous-Albian/Aptian(456 - 587.7 m). In its upper section(Utrillas Formation from 456 m to 568.6 m) the zone is composed of clastic continental deposits: clay, multicolored sandy clay, sand with white mica and pyrite(occasionaly fine sand/silt). The lower section - The "Val de la Piedra" Formation - comprises the two coal seams separated by a layer of impermeable limestones with abundant carbonaceous inclusions. The clays of the upper section are impermeable and separate the sands layers into independent aquifers. The total zone can be divided into the following sub-zones for more detailed analysis:
  - Sub-zone A(456 - 471 m). This zone presents in its upper section a first clay zone($\approx$ 3.5 m) with montmorillonite(ρ = 2.15 - 2.18 g / cm^3, ϕN = 48 - 51 p.u.) separated by a metric sand layer from a second clay zone

(≈ 2 m) with less montmorillonite. The lower section is a transient zone to the sand sub-zone B.

- Sub-zone B(471 - 478 m). This zone is formed of the cleanest sands within the Cretaceous zone with high permeability and low gamma ray emission.
- Sub-zone C(478 - 498 m). This zone is composed mainly of multicolored clay(red, black, brown/green) with occasionally some sand crossings. The logging results indicate medium gamma ray emission, medium to low density, porosity and permeability.
- Sub-zone D(498 - 505 m). This zone is a transitory zone composed mainly of argillaceous sand(black) at its upper part and clay with low level of sand at its lower part(≈ 2 m thickness).
- Sub-zone E(505 - 535 m). This zone is composed of fine sand/silt with some crossings of sandy clay at 511 - 512 m and 518 m. The permeabilty is relatively high. A mud cake of 0.3 - 0.4 mm and a caliper slightly below the drilling diameter(≈ 8 1/5 ") were also observed in this zone.
- Sub-zone F(535 - 556 m). This zone is composed of waxy multicolored clay, where the highest gamma ray emission was found(mean values between 120 and 130 API, maximum values between 552 and 223 API). The neutron porosity log indicates also high values(mean value 42 p.u., maximum value 50 p.u.). The caliper log indicates cavity formation with diameters between 9 1/2 " and 10 ".
- Sub-zone G(556 - 568.6 m). This zone, which constitutes the roof of the upper coal seam, is mainly constituted of clayey sand with inclusion of coal at its lower part. Its upper part is still composed of an important quantity of clay with gamma ray emission between 75 and 130 API and a porosity of about 30 p.u.. The lower part indicates values of gamma ray emission much lower(≈ 60 API) and density abnormaly low(2.2 - 2.3 g / cm^3 when the mean value of sand is of about 2.65 g / cm^3). This phenomenon could be due to the important quantity of clay and coal inclusions inside the sand.
- Sub-zone H(568.6 - 571 m). This zone corresponds to the upper coal seam of the "Val de la Piedra" Formation. The presence of coal fragments inside the upper sand layer also suggests an erosion of the coal roof. The coal seam thickness of 2.4 m, 1.5 m less with respect to ET1, indicates stronger paleochannel erosion at the ET2 location. The coal is well consolidated with no indication of faults, and is of good quality(low ash content). The density is in the range 1.26 - 1.3 g / cm^3, porosity in the range 58 - 65 p.u.(see Table II). The coal seam exhibits a high level of gamma ray emission in its lower part(max. value of 184 API at approx. 20 cm from the floor of the seam).
- Sub-zone I(571 - 582.8 m). This zone is constituted mainly of compact limestones without apparent fissuration; also included in this zone is the lower carbonaceous clay zone(≈ 55 cm) of the upper coal seam and the top carbonaceous mudstone zone(≈ 105 cm) of the lower coal seam. The limestone contains "characeas" and carbonaceous

inclusions. The porosity measured by the neutron log is abnormaly high with a mean value of 24 p.u.(- 1 p.u. generally observed in limestone) and the density is relatively low (mean value of 2.37 g / cm^3) suggesting a zone of high porosity and permeability in contradiction with the visual characterization of the limestone and the high resistivity measured by the Microlog. This phenomenon could be produced by the properties of the Carbon present inside the carbonaceous inclusions. This zone presents also the lowest gamma ray emission of the whole column with values around 10 API.

- Sub-zone J(582.8 - 587.3 m). This zone corresponds to the lower coal seam of the "Val de la Piedra" Formation. The coal seam is 0.9 m thicker than at ET1 and 2.4 m thinner than at T7: it can be observed that the lower coal seam at T7 is split in two sub-seams, separated by a crossing of clay with roots. This clay layer appears at the bottom of the coal seam at ET2. The first 2.4 m of the coal seam is well-consolidated with no presence of faults and of good quality. The remaining part of the seam presents some clay inclusions/crossings. The density and neutron porosity are similar to those observed at ET1(see Table III). There is also a gamma emission marker at the floor of the coal seam(245 API at approx. 40 cm from the floor of the seam). These characteristics of the two coal seams could be useful reference markers for the in-seam drilling activity.
- Sub-zone K(587.3 - 587.7 m). This zone is composed of the bottom of the Cretaceous-Albian/Aptian Formation and is composed of carbonaceous clay with root inclusions.

- Jurassic(587.7 - 603 m). The Jurassic is composed of re-crystallized grey limestones with abundant fossils and some oolites. The contact with the coal seam presents a important network of fractures filled with black clay(Albian clay ?). Some fractures appear on the Microlog as abrupt jumps in the recording i.e. open permeability. In the lower part of the zone, the fracturation diminishes and the black clay filling the fractures is replaced by grey clay with pirite. Some fractures are also present which display an open permeability. The average density and neutron porosity are 2.7 g / cm^3 and 1.5 p.u. respectively. At 595 m there is a 0.9 m thick fault filled with pieces of limestone and coal mixed/linked in a matrix of carbonaceous clay. This fault is also perfectly recorded in the lithodensity log, neutron porosity log and photo-electiric factor log. There is also an abrupt decrease of density at 601 m but it is not easy to interpret this as a fault because coring was not conducted at this level.

3.3.2 Dipmeter

The SHDT log was processed in SCHLUMBERGER's computer center with a basic correlation programme "Mean Square Dip" (MSD), which finds the "best fit" satisfying all possible cross-correlations. These results were utilized to interpret the structural dip/azimuth and detect possible structural and/or stratigraphical anomalies in the formations crossed: Terciary, Cretaceous and Jurassic.

The structural dip of the Terciary is almost constant and leads to a mean value of 30 - 35 ° to the South.

The interpretation of the structural dip of the Cretaceous is less clear due to the importance of cross-bedded strata. The statistical study of the MSD results is presented in the Table IV. From this table, it is recognized that the dip angle of the Cenomanian is also approx. 30 °. Below the Cenomanian, abrupt changes in the sedimentation are present as a result of paleochannel and lagoon sedimentation. Some strata dip to the 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 °). The structural dip in some points of the Cretaceous formation are:

Cenomanian			
	419 m	29.8 °	N184W
	430 m	32.8 °	N181W
Albian/Aptian			
	474 m	30.4°	N186W
	505 m	30.0°	N172W

The statistical study of the Jurassic Formation indicates a mean structural dip of 33 ° .

In addition to the structural dip interpretation, two faults were recognized(at 595 - 596 m and 601 - 602 m) in agreement with the coring and the combined probe Log.

3.3.3 Cement Bond Log

Overall, the cementing of the 7 " casing at ET2 was better than the cementing of ET1. Cementation of relatively low quality was observed between 18 - 30 m, 80 - 105 m, 403 - 413 m and to a lesser extent over other zones. All of these zones correspond to clay zones with oversize annulus diameter(up to 12 "). This poor cementing can be explained as channeling of the slurry inside cavities. The best cementing zones are between 175 - 197 m, 212 - 215 m, 222 - 231 m and below 502 m to total depth(zones with very good caliper).

4. SITE CHARACTERIZATION

4.1 ET1 - ET2 - T7 CORRELATION(see Figure 4)

Generally, it is difficult to include the well T7 in the ET1-ET2 correlation. It should be remembered that T7 is a relatively old well, perhaps with some uncertainty of reference level, and a lack of accurate trajectory data. Nevertheless, it must be noted that the level of the upper coal seam floor(good reference point) in ET2 is located at a level much higher(≈ 20 m) than expected from ET1-T7 interpolation. This result could indicate confirmation of the results of the seismic interpretation which suggested faulting in the vicinity of the exploratory well T7. If such a fault was located to the West of T7, then the coal in well T7 would be situated in a separate block of coal displaced downwards relative to the block of the test area.

The dip angle of the floor of the upper coal seam, generally considered as the most uniform marker of the deposit, inferred from levels in ET1 and ET2 is 29 - 30 ° assuming dip azimuth to be true South. This dip angle correlates reasonably well with the calculation of the general dip angle of the deposit realized in previous interpretation. The increases in ET2 in the thicknesses of the intermediate strata and the lower coal seam itself lead to an apparent dip of the floor of the lower coal seam of 33 - 34 °, again assuming dip azimuth to be true South.

A comparison of the coal section between the 3 exploratory wells ET1-ET2-T7 can be summarized as follows:

Clayey sand roof

Measured thickness in well = 14 m(ET1), 12.6 m(ET2), 2.6 m(T7). Erosion action by the sand in well ET1 and ET2. Greatest effect in ET2. Presence of coal fragments inside the immediate roof of the coal seam in well ET1 and ET2.

Upper coal seam

Measured thickness in well = 3.9 m(ET1), 2.4 m(ET2), 8.7 m(T7).
Good quality coal with low ash content (<16%) in all the wells. Well-consolidated coal with no presence of faults

Intermediate limestone(including carb. clay-bottom upper coal seam and carb. mudstone/clay-top lower coal seam)

Measured thickness in well = 8.3 m(ET1), 11.8 m(ET2), 10.1 m(T7). Similar carbonaceous clay marker(≈ 20 - 60 cm) at the floor of the upper coal seam in all the wells. Similar compact limestone in all the wells with "characeas" and carbonaceous inclusions.

The roof of the lower coal seam in the wells ET1 and ET2 is composed of carbonaceous mudstone. The roof of the lower coal seam in the well T7 is composed of pyritic clay.

Lower coal seam

Measured thickness in well = 3.6 m(ET1), 4.5 m(ET2), 6.9 m split(T7). Good quality coal seam with low ash content(<14%) in wells ET1and ET2. The coal seam in T7 is split into 2 parts separated by a clay crossing(1.5 m) with roots: the upper section(2 m) is good quality coal with low ash content(<16%), the lower section (3.4 m) has a much higher ash content(48 %).

Clay(Albian)/limestone(Jurassic) floor

The coal seam in ET1 lays immediately on the Jurassic limestone(fault?). A clay layer with roots in well ET2(Bottom Albian) exists between the coal seam and the limestone in the well ET2 and T7. The Jurassic limestones are strongly fractured in wells ET1 and ET2, the fractures filled with black/grey clay. These fractures do not appear in well T7.

4.2 COAL ANALYSIS

The results of proximate analysis and ultimate analysis of the coal recovered from the well ET1 were received from "Instituto de Carboquimica" during the period of this report and are given in Tables V - X. The proximate analysis of the two coal seams confirms the very good quality of the coal. The moisture content of the coal is relatively high(> 26 wt%) and the ash content is very low(< 15 wt%). The total sulfur of the Upper Coal Seam(7.4 wt%) is higher than the Lower Coal Seam(4.5 wt%). The ultimate(elemental) analysis of the seams confirms the rank of the coal: Sub-Bituminous Class C(American Classification).

The results of the petrographic analysis received from "Instituto Nacional del Carbon" are given in Table XI. It must be noted from this table that the coal is non-agglomerating, as indicated by free swelling index of zero.

5. <u>ENGINEERING</u>

5.1 DEVIATED WELL

Work began on the planning/design of the deviated injection well, this being a key point in the project, with the requirement that it will be drilled as soon as possible consistent with engineering and procurement considerations. The following 5 major directional drilling companies were contacted for technical advice:

Anadrill Schlumberger
Eastman Teleco(Baker Hughes Inteq)
Geoservices/Horwell

Scientific Drilling Controls
Sperry-Sun

All the companies suggested the use of standard oil/gas industry sizes for the drilling programme because of the potential difficulties in obtaining casing and tools in non-standard sizes, and in order to benefit from the greater predictability of the behaviour of standard size Bottom Hole Assemblies (BHA´s). The standard sizes are:

Hole	Casing	
17 1/2 "	13 7/8 "	
12 1/4 "	9 5/8 "	
8 1/2 "	7 "	(Tubing/Liner)
6 1/8 "	5" or 4 1/2 "	(Tubing/Liner)

All the companies recommended 8 1/2 " drilling in the coal, though not absolutely essential. Anadrill Schlumberger have additional reason to propose drilling 8 1/2 " in-seam; they are the only company with a near-bit directional-gamma Measurement While Drilling (MWD) tool. This measures location and gamma only 5 ft from the bit compared to over 40 ft from the bit with conventional MWD tools. The collar size of the tool limits minimum hole size to 8 1/2 ".

All companies proposed the use of MWD tools and bent-housing Down Hole Motors (DHM´s), steering to achieve the required trajectory by reference to geometric data from MWD, if seam geometry can be specified sufficiently accurately. Cuttings, penetration rate, torque and MWD gamma are additional parameters to indicate location within the in-seam section. A "conventional" MWD tool gives geometric and gamma data approx. 40 ft behind the bit wheareas the new Anadrill near-bit tool gives geometric and directional gamma only 5 ft behind the bit i.e. in front of the motor. Sperry-Sun have an at-the-bit inclination tool but this does not measure gamma.

Land for the trial was acquired on the basis that the radius of the deviated in-seam well would be 100 metres(build rate of 17.4 ° / 100 ft). All the companies expressed concern regarding casing installation in the build section and recommended reducing the design build rate by moving spud location as far to the North as possible. There is some ability to locate the deviated well further to the North within the available site boundary, the available horizontal displacement from ET1 to the deviated well spud location being 70 - 80 metres, taking into account rig operational constraints. Such a move increases planned build radius to approx. 140 metres(build rate of 12.5° / 100 ft). The introduction of a short tangent section preferred by Anadrill and Sperry-Sun increases the build rate requirement. The companies advise that 9 5/8 " casing has been run in 12 1/4 " hole without problems at build rate up to 15 - 18 ° / 100 ft in some formations.

5.2 SURFACE PLANT

Technical enquiries were sent to 14 engineering companies involved in the chemical and oil and gas industries in Spain to establish a list of those companies which had the necessary relevant expertise and experience to provide engineering services for the design and construction of the surface plant. The enquiries had the objective of confirming the capability and interest of companies in becoming contractors for the project with a view to subsequent invitations to tender. The technical enquiries were subsequently analysed and detailed specifications of the requirements and invitations to tender were sent to a short list of selected companies in December 1992. A complete process phase description document was also produced during this period.

5.3 RELATED STUDIES

To face specific problems directly related to the engineering activities, two related studies were commissioned, each to be conducted over a duration of approx. 4 months from December 1992, at the two following Universities:

Université Catholique de Louvain(Prof. J. Patigny)

Modelling/simulation of the heat losses and pressure changes for three proposed recovery well configurations. Each configuration will be run with different flow conditions(gasification phases, reverse combustion/ pyrolysis phases). The modelling/simulation is based on existing software developed by the University of Louvain. Some improvement of the software will nevertheless be necessary to increase the software´s user-friendly character(data introduction, results presentation) and to allow more complex arrangements to be simulated(non-concentric tubings, diphasic flow conditions, etc.)

Université de Liège (Prof. J.-P. Pirard)

Calculation of flows and pressure distributions by Boundary Element Method(BEM) Flow Model for the final linkage phase and the reverse combustion/pyrolysis phase assuming a constant coal permeability and relatively simple geometry. The calculations will be based on an existing model able to simulate two-dimensional flow distribution in a porous media.

Gasification product composition calculation by Chemical Equilibrium Based Model during the channel gasification phase. Theoretical analysis of the reactions involving the different forms of sulfur in the UCG process will be realized prior to the introduction in the existing Model. The Model takes into account the chemical equilibrium inside two zones(reaction zone, pyrolysis and drying zone) of the underground reactor and the heat/mass exchange between them.

In parallel to these related studies, the "Instituto de Carboquimica" was approached and requested to propose a detailed laboratory programme for the determination of coal/char reactivities and pyrolysis behaviour of the "El Tremedal" coal at the proposed operating conditions(50-60 bar pressure).

Specific proposals for research were also received from RWTH Aachen and TU Delft/NOVEM.

6. PROJECT DIRECTION

6.1 ADMINISTRATION

The location of suitable premises for increased office space in the towns nearest to the trial site proved to be a problem. After an extensive search, two floors(350m^2) of a building in Alcorisa were located which were suitable for conversion to office accommodation and a rental agreement was signed in August 1992. One of the floors was converted in September/October and occupied by the project team in early November. The second floor will be converted in the Spring of 1993.

Some difficulty was also foreseen in the recruitment of suitable personnel to work on relatively short term contracts in the isolated area of North Teruel. Efforts were made to recruit engineering staff in the fields of drilling, well completions, instrumentation, surface plant design and administration, both by advertisements and via information distributed to Spanish Universities/School of Mines. Two additions to the team(drilling operations/well completions) took up appointments in October and December respectively, and a third person has accepted an offer but not yet taken up the appointment. Total team personnel at end December 1992 was seven. Further interviews will be held in early January with the aim of increasing to at least 10 staff as quickly as possible.

6.2 ENDESA/UGE AGREEMENT

Another version of the ENDESA/UGE Agreement giving authority to UGE to operate on the El Tremedal site was agreed with ENDESA. The agreement has not yet been signed despite a statement that "ENDESA should be able to sign the Agreement during October". The situation is totally unsatisfactory in that UGE has as yet no formal approval from ENDESA(nor legal agreement on responsibilities/liabilities) to operate in the deposit.

6.3 PROBLEMS/DIFFICULTIES

The most significant technical difficulty experienced in the period of the report was during the setting of the casing of the exploratory well ET2. In this operation, the casing string stuck 10 metres above the planned depth(although circulation could be maintained) and the casing was set at this level. The reason for sticking could be either squeezing of the strata, mechanical problem with the centralizers, or differential sticking, the latter effect being more probable because circulation was able to be maintained.

The inability to set casing to the planned depth is not a problem for the future because the well is designed for subsequent conversion for monitoring by means of lateral drilling. The only effect is that a longer vertical section will be drilled in cement before drilling the short-radius section. Nevertheless, the sticking event is regarded as important in order to plan for prevention of a similar difficulty in drilling the deviated injection well.

6.4 CHANGES IN TECHNICAL STRATEGY

As mentioned earlier, the results of the exploratory well ET2 have demonstrated the irregularity of the deposit and have increased the uncertainty of the thicknesses and disposition of the seams over the proposed gasification zone. These uncertainties together with the indication of nearby faulting detected in the well complicate seam choice in terms both of the suitability for drilling(in which seam floor regularity and thickness are important) and subsequent gasification(in which the thickness over the proposed gasification zone determines the maximum volume of coal which can be gasified).

The exploratory well ET2 was completed just before Christmas 1992 and the results will be evaluated carefully in conjunction with all other geological information available, in order to assess if additional information, possibly from a third exploratory well, is advisable in view of the extent of future investment.

6.5 FUTURE WORK

A third exploratory well will be drilled early in 1993 if this is considered to be desirable. Procurement of the special components and instrumentation for the deviated injection well will be initiated and invitations to tender will be issued for the service contracts involved in the well once the delivery dates of special components are known.

The results of studies on flow distribution/gas composition and product well conditions at the Universities of Liege and Louvain will be analysed and the implications for product well configuration will be determined. Suppliers of special insulated tubings for the product well will be identified.

The civil engineering work for site preparation will be completed and a contract for Phase 1 of the surface plant engineering will be placed.

6.6 CONFERENCES, PUBLICATIONS AND REPORTS

- "Informe Geológico y de Perforación del Sondeo Tremedal 2 "(61/IN/93/S) by C. BARRAT, A. OBIS.

- "Field Trial of Underground Gasification Europe(UGE) Teruel, Spain " (Coal R009/P1)
  Progress report prepared by ETSU, Harwell

- "Estudio Petrográfico y Ensayos Especiales sobre Muestras de Carbón del Sondeo Tremedal 1 "(31313/92)
  Report prepared by Instituto Nacional del Carbon y sus Derivados, Oviedo

- "Estudio de Explanacion en la Zona de los Estancos" + Anexo
  Report prepared by ADARO, Madrid

- ENDESA(REVISTA INTERNA)
  Julio / Octubre 1992 - nº 79
  by D. Martinez

- "Informe de Analysis Inmediato y Elemental sobre Muestras de Carbon" (11468 a 11489)
  Report prepared by Instituto de Carboquimica, Zaragoza

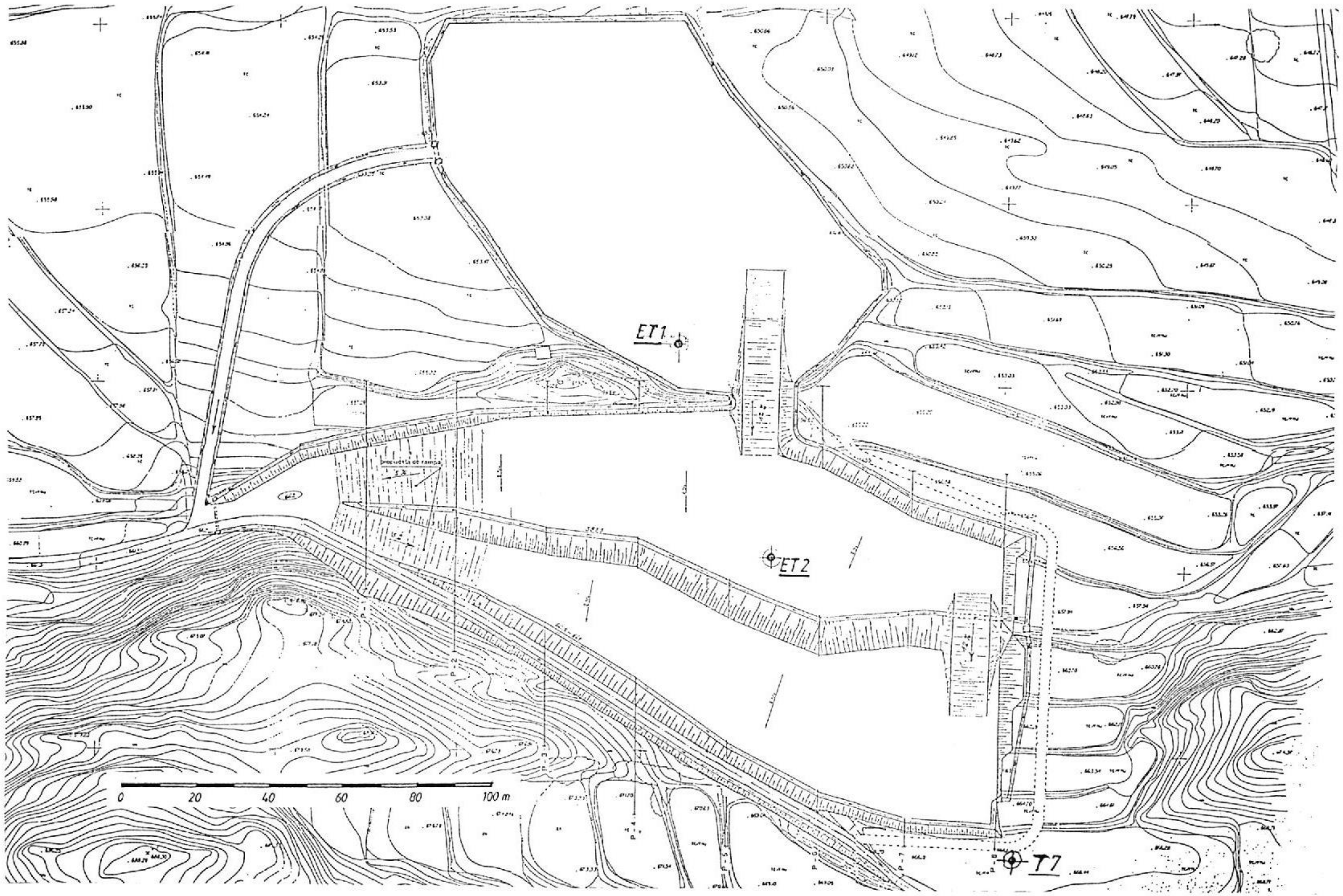

Figure 1 . Site Plan

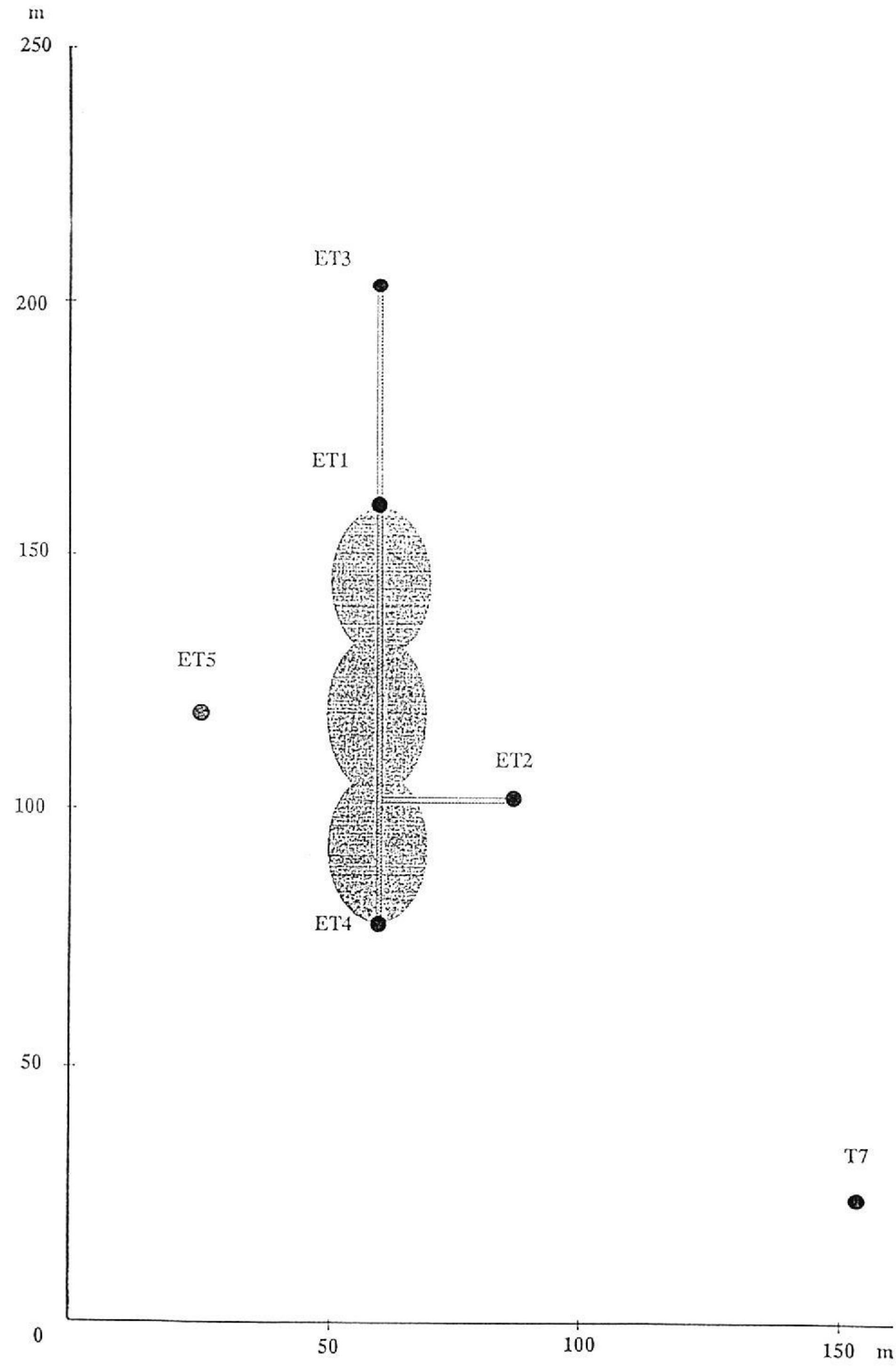

Figure 2 . Well Layout

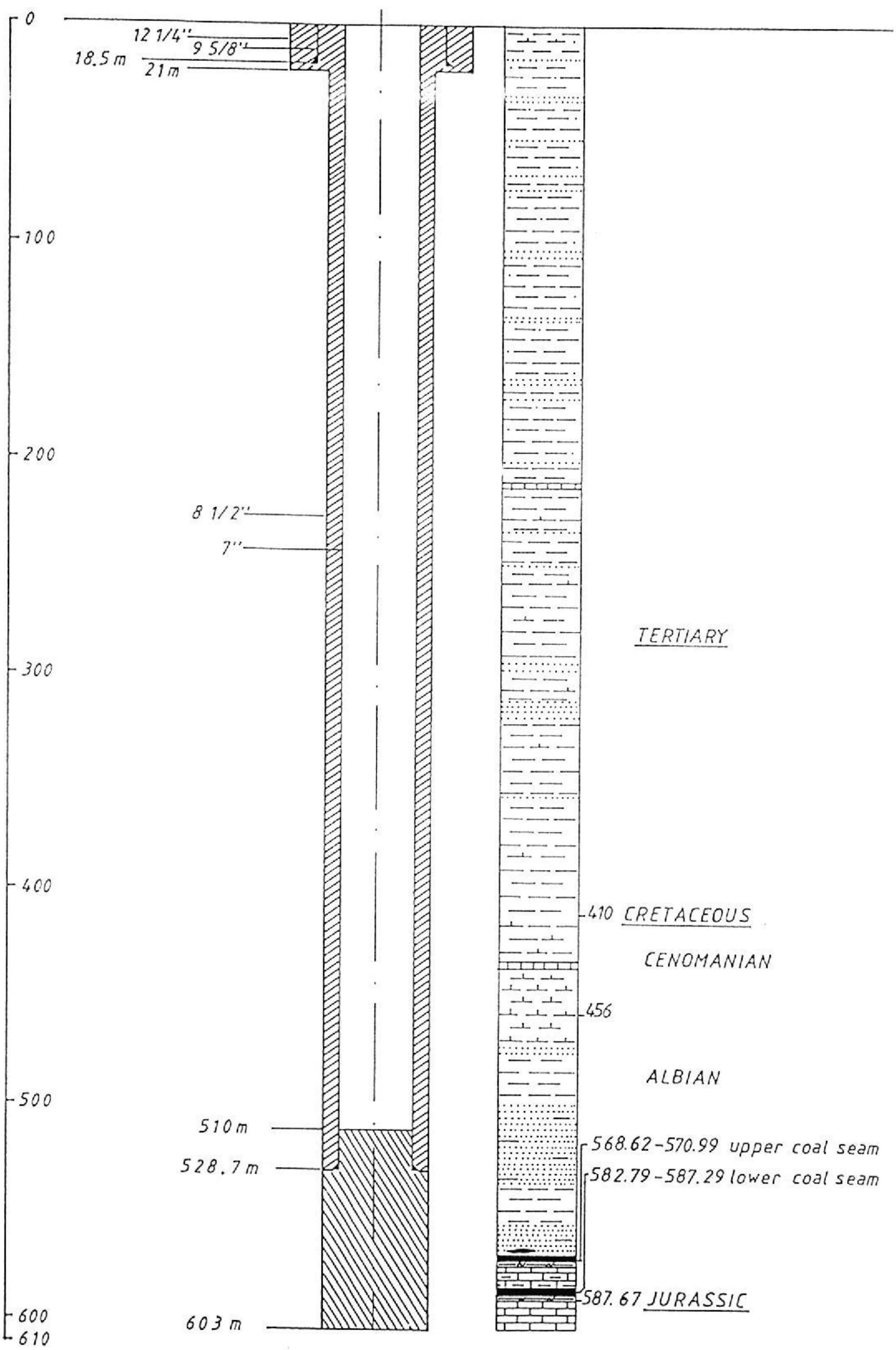

Figure 3a . Exploratory Well ET2 - Completion and Lithology (Depth in metres below platform level)

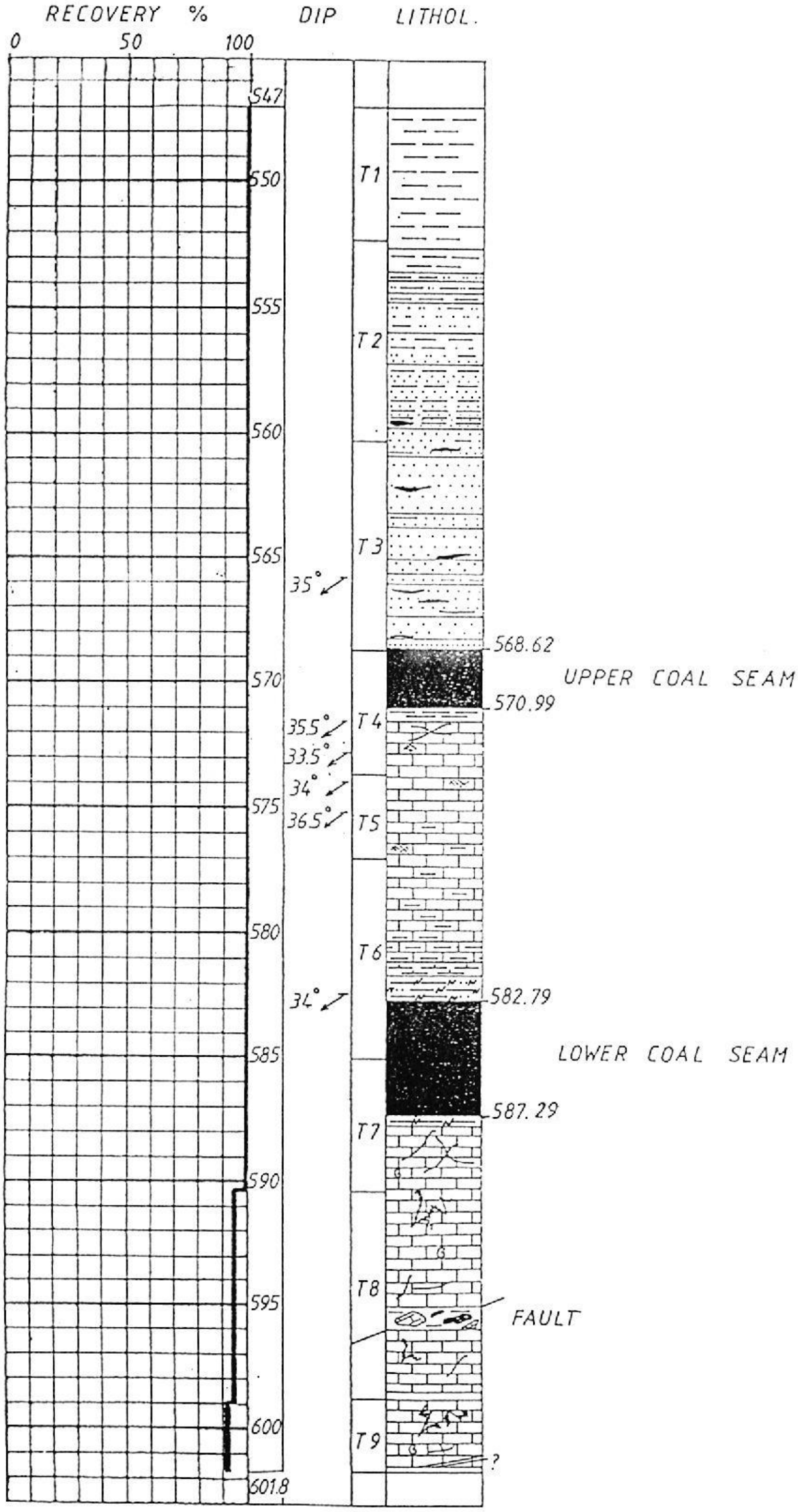

Figure 3b Exploratory Well ET2 Lithology - Core Section (Depth in metres below platform level)

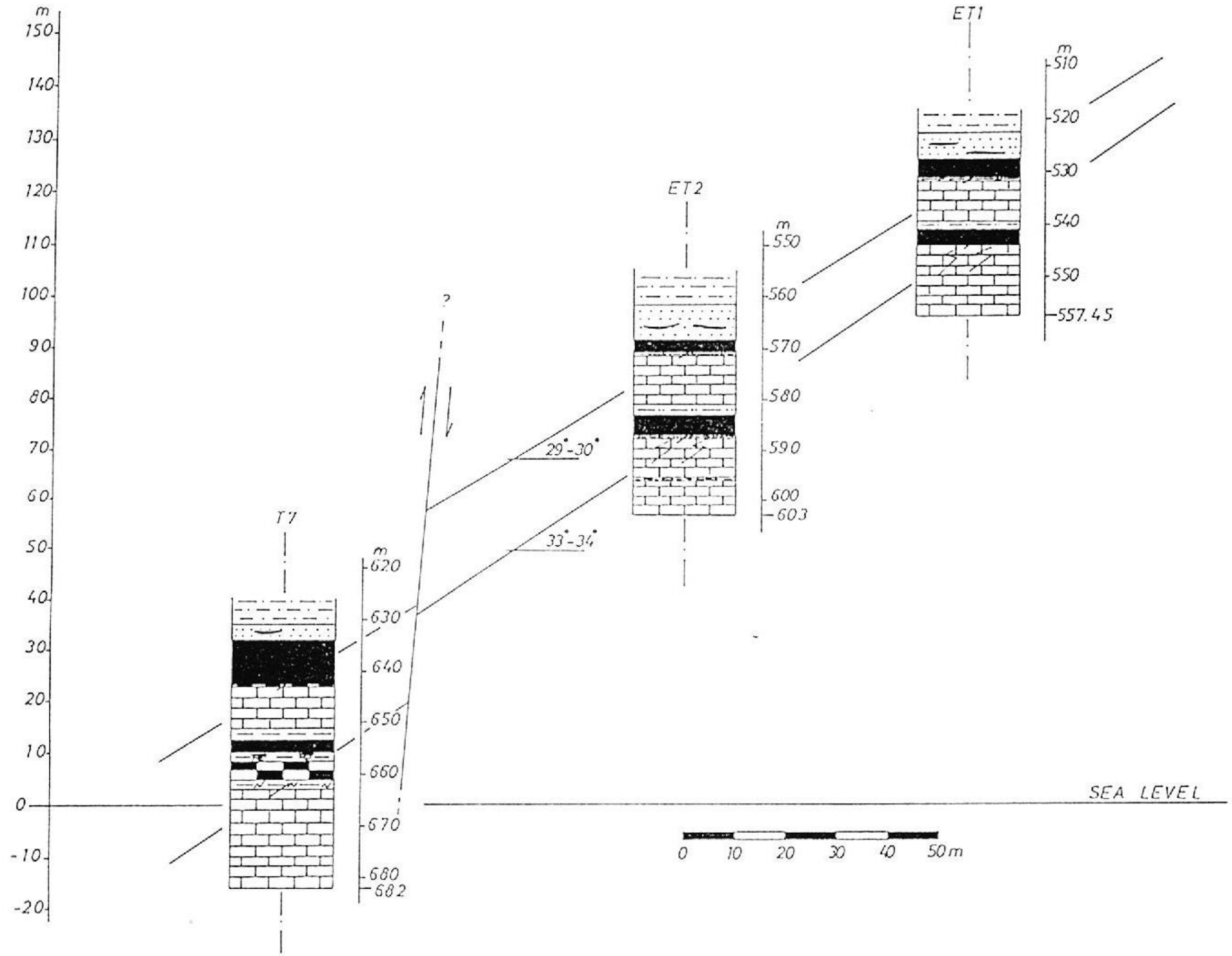

Figure 4 . ET1-ET2-T7 Coal Section Comparison

Day	Drilling	Stop/ Main- tenance	Rig Manoeuvre + Totco	Mud Prep./ Circul.	Casing Setting	Cementing/ Waiting	Coring	Reaming	Logging	Others
1	8.00		3.00		3.00	10.00				
2	6.00		1.00			15.00				2.00
3	18.00		4.25	1.75						
4	19.25		3.25					1.50		
5	19.00		4.00	0.50						0.50
6	19.25		3.75	0.50						0.50
7	14.00		5.75	0.50				3.25		0.50
8	20.50		1.25	1.75						0.50
9	16.50		5.00	0.50				2.00		
10	21.50		2.25	0.25						
11	20.25		3.25	0.50						
12	15.25	4.00	4.00	0.75						
13	22.75		1.25							
14	18.00		5.25	0.75						
15	4.00	16.50	3.00	0.50						
16	10.75	10.00	2.50	0.75						
17	14.75		7.00	0.50			1.75			
18			15.75	0.75			7.50			
19		1.00	15.50	0.50			7.00			
20			13.25	0.75			4.00	6.00		
21	1.75		11.25	0.25			10.75			
22			8.50	1.25			2.75	11.50		
23						9.50		7.00	6.50	1.00
24			5.50	1.00		8.00		9.50		
25			3.50	1.00	15.00					4.50
26				1.50		12.00		10.50		
27			4.00	2.50		17.00				0.50
28			2.50			18.50			3.00	
29			3.00			3.00				6.00
Total	269.50	31.50	142.50	19.00	18.00	93.00	33.75	51.25	9.50	16.00

Table I . Exploratory Well ET2 Operating Time Distribution(Hour.Min)

Depth(m)	Gamma Ray	Photo-Electric Factor	Bulk Density	Porosity (neutron)	Lithology	Core % Recovery
568.20	72	2.50	2.13	42	Argillaceous	100
568.40	70	1.90	1.95	49	Sand	"
568.62	65	1.60	1.55	61.0	Coal	100
568.80	52	1.40	1.41	64.0	"	"
569.00	45	1.25	1.34	64.0	"	"
569.20	30	1.16	1.32	63.0	"	"
569.40	25	1.25	1.28	62.0	"	"
569.60	25	1.27	1.30	61.5	"	"
569.80	35	1.24	1.29	60.0	Coal	100
570.00	48	1.18	1.27	58.0	"	"
570.20	82	1.27	1.28	60.0	"	"
570.40	127	1.41	1.32	65.0	"	"
570.60	170	1.75	1.37	64.5	"	"
570.80	185	1.83	1.50	64.5	"	"
570.99	160	2.33	1.68	63.0	Coal	100
571.20	105	3.30	1.85	51	Carbonaceous	100
571.40	60	4.25	2.10	32	Clay	"

Table II . Upper Coal Seam Log Data(API Units)

Depth(m)	Gamma Ray	Photo-Electric Factor	Bulk Density	Porosity (neutron)	Lithology	Core % Recovery
582.40	46	1.50	1.38	57.0	Carbonaceous	100
582.60	37	1.41	1.37	57.0	Mudstone	"
582.79	25	1.25	1.36	57.5	Coal	100
583.20	10	1.00	1.22	55.5	"	"
583.40	11	1.00	1.21	57.0	"	"
583.60	12	1.00	1.23	61.5	"	"
583.80	14	1.04	1.24	63.5	"	"
584.00	17	1.05	1.27	64.0	"	"
584.20	22	1.00	1.28	61.5	Coal	"
584.40	30	1.00	1.27	58.5	"	"
584.60	37	1.00	1.26	58.0	"	"
584.80	48	1.02	1.25	58.5	"	"
585.00	68	1.05	1.26	57.0	Coal	100
585.20	80	1.16	1.30	56.5	Sligh. Arg. Coal	"
585.40	97	1.20	1.33	56.0	Sligh. Arg. Coal	"
585.60	110	1.45	1.34	61.5	Dirty Coal	"
585.80	125	1.50	1.35	61.0	Dirty Coal	"
586.00	146	1.41	1.36	60.0	Sligh. Arg. Coal	"
586.20	165	1.16	1.32	58.5	Sligh. Arg. Coal	"
586.40	180	1.16	1.27	57.0	Argill. Coal	"
586.60	197	1.20	1.26	57.5	Argill. Coal	"
586.80	225	1.29	1.25	61.0	Argill. Coal	"
587.00	247	1.31	1.27	62.0	Argill. Coal	"
587.29	235	1.83	1.37	57.0	Argill. Coal	100
587.50	230	2.58	1.60	55.5	Carbonaceous	100
587.67	225	3.33	1.90	55.0	Clay	"

Table III . Lower Coal Seam Log Data(API Units)

Lithology		N° of Data	Mean Value	Standard Deviation	Minimum	Maximum
CENOMANIAN	Clays/Marls	90	29.9 °	10.1 °	6.9 °	64.2 °
ALBIAN	Multicolored Clay	197	34.1 °	10.3 °	2.3 °	58.7 °
	Grey/Black Sand	27	28.0 °	8.4 °	13.3 °	45.7 °
	Upper Coal Seam	5	23.6 °	13.6 °	7.0 °	34.9 °
	Intermediate Limestone	21	35.3 °	9.4 °	15.7 °	57.8 °
	Lower Coal Seam	9	32.1 °	9.2 °	10.2 °	39.6 °

Table IV . Statistical Study of the Structural Dip of the Cretaceous Formation

Lithology	Sample N°	Length (m)	%	Total Moisture (wt %)	Ash (wt %)	Fixed Carbon (wt %)	Volatile Matter (wt %)	High Heating Value(kcal/kg)
Coal Seam	1	0.30	7.69	31.8	14.4	30.6	23.2	3501
	2	0.30	7.69	20.4	39.1	21.6	18.9	2143
	3	0.40	10.26	29.9	13.3	33.2	23.6	3612
	4	0.54	13.85	28.6	11.9	33.9	25.6	3893
	5	0.33	8.46	28.5	12.1	34.1	25.3	3993
	6	0.33	8.46	27.5	16.3	32.5	23.7	3649
	7	0.15	3.85	32.5	9.4	32.3	25.8	4001
	8	0.35	8.97	26.6	14.7	33.3	25.4	3966
	9	0.35	8.97	31.3	7.9	35.1	25.7	4287
	10	0.48	12.31	24.9	16.5	32.9	25.7	3953
	11	0.37	9.49	29.5	7.7	35.1	27.7	4358
	Total	3.90	100.00	28.1	14.7	32.5	24.7	3785
Carbonaceous Clay	1	0.27	100.00	-	-	-	-	-
	Total	0.27	100.00	-	-	-	-	-

Table V . Proximate Analysis of the Upper Coal Seam at Well ET1(as received basis)

Lithology	Sample N°	Length (m)	%	Total Moisture (wt %)	Ash (wt %)	Fixed Carbon (wt %)	Volatile Matter (wt %)	High Heating Value(kcal/kg)
Carbonaceous Mudstone	1	0.50	43.86	16.8	40.5	18.7	24.0	2658
	2	0.29	25.44	14.1	48.5	1.6	35.8	1537
	3	0.35	30.70	22.1	33.1	23.8	21.0	2917
	Total	1.14	100.00	17.7	40.3	15.9	26.1	2452
Coal Seam	1	0.40	11.14	23.7	10.2	21.8	44.3	4596
	2	0.54	15.04	25.1	20.1	31.7	23.2	3759
	3	0.45	12.54	27.7	9.1	36.3	26.9	4540
	4	0.42	11.70	27.7	9.5	37.0	25.8	4516
	5	0.44	12.26	27.4	12.5	35.4	24.6	4277
	6	0.46	12.81	27.2	9.1	38.3	25.4	4491
	7	0.43	11.98	25.0	10.6	38.3	26.2	4439
	8	0.45	12.53	24.9	24.0	29.4	21.8	3308
	Total	3.59	100.00	26.1	13.3	33.6	27.0	4221
Carbonaceous Clay	1	0.00	-	-	-	-	-	-
	Total	0.00	-	-	-	-	-	-

Table VI . Proximate Analysis of the Lower Coal Seam at Well ET1(as received basis)

Lithology	Sample N°	Length (m)	%	C (wt %)	H (wt %)	N (wt %)	S (wt %)	O (wt %)	HHV (kcal/kg)
Coal Seam	1	0.30	7.69	69.63	4.7	0.6	7.5	17.6	6504
	2	0.30	7.69	61.3	4.3	0.7	-	-	5291
	3	0.40	10.26	68.1	4.5	0.6	7.0	19.8	6363
	4	0.54	13.85	71.1	4.6	0.5	-	-	6544
	5	0.33	8.46	71.7	4.6	0.5	-	-	6722
	6	0.33	8.46	70.5	4.4	0.6	6.4	18.1	6494
	7	0.15	3.85	73.0	4.7	0.5	-		6883
	8	0.35	8.97	69.9	4.4	0.5	-	-	6763
	9	0.35	8.97	74.3	4.6	0.5	-	-	7051
	10	0.48	12.31	71.1	4.7	0.5	6.0	17.7	6750
	11	0.37	9.49	73.4	4.7	0.4	46.5	15.0	6943
	Total	3.90	100.0	70.4	4.6	0.5	6.6	17.9	6578
Carbonaceous Clay	1	0.27	100.0	-	-	-	-	-	-
	Total	0.27	100.0	-	-	-	-	-	-

Table VII . Elemental Content of the Upper Coal Seam at Well ET1(moisture ash free basis)

Lithology	Sample N°	Length (m)	%	C (wt %)	H (wt %)	N (wt %)	S (wt %)	O (wt %)	HHV (kcal/kg)
Carbonaceous Mudstone	1	0.50	43.86	68.3	4.8	0.7	-	-	6227
	2	0.29	25.44	56.5	3.7	0.5	-	-	4111
	3	0.35	30.70	68.3	5.2	0.7	-	-	6476
	Total	1.14	100.0	65.3	4.6	0.6	-	-	5765
Coal Seam	1	0.40	11.14	74.3	4.8	0.6	6.2	14.1	6954
	2	0.54	15.04	73.2	4.8	0.6	-	-	6848
	3	0.45	12.54	73.7	4.9	0.5	-	-	7183
	4	0.42	11.70	75.4	4.8	0.5	-	-	7192
	5	0.44	12.26	75.3	4.5	0.5	4.8	14.9	7124
	6	0.46	12.81	75.3	4.5	0.4	-	-	7047
	7	0.43	11.98	74.3	4.7	0.5	-	-	6888
	8	0.45	12.53	70.7	4.6	0.4	4.8	19.5	6465
	Total	3.59	100.0	74.0	4.7	0.5	5.2	15.6	6958
Carbonaceous Clay	1	0.00	-	-	-	-	-	-	-
	Total	0.00	-	-	-	-	-	-	-

Table VIII . Elemental Content of the Lower Coal Seam at Well ET1(moisture ash free basis)

Lithology	Sample N°	Length (m)	%	Total Sulfur (wt %)	$S_{Pyritic}$ (wt %)	$S_{Sulfate}$ (wt %)	$S_{Organic}$ (wt %)
Coal Seam	1	0.30	7.69	7.6	2.4	1.1	4.1
	2	0.30	7.69	8.4	-	-	-
	3	0.40	10.26	9.0	3.6	1.5	3.9
	4	0.54	13.85	8.6	-	-	-
	5	0.33	8.46	6.5	-	-	-
	6	0.33	8.46	7.7	3.0	1.1	3.6
	7	0.15	3.85	5.0	-	-	-
	8	0.35	8.97	10.2	-	-	-
	9	0.35	8.97	5.4	-	-	-
	10	0.48	12.31	6.1	2.1	0.5	3.5
	11	0.37	9.49	5.6	1.2	0.3	4.1
	Total	3.90	100.00	7.4	2.6	0.9	3.9
Carbonaceous Clay	1	0.27	100.00	-	-	-	-
	Total	0.27	100.00	-	-	-	-

Table IX. Sulfur Distribution of the Upper Coal Seam at Well ET1(as received basis)

Lithology	Sample N°	Length (m)	%	Total Sulfur (wt %)	$S_{Pyritic}$ (wt %)	$S_{Sulfate}$ (wt %)	$S_{Organic}$ (wt %)
Carbonaceous Mudstone	1	0.50	43.86	4.2	-	-	-
	2	0.29	25.44	3.3	-	-	-
	3	0.35	30.70	4.7	-	-	-
	Total	1.14	100.00	4.1	-	-	-
Coal Seam	1	0.40	11.14	5.9	1.6	0.3	4.0
	2	0.54	15.04	4.2	-	-	-
	3	0.45	12.54	4.8	-	-	-
	4	0.42	11.70	3.5	-	-	-
	5	0.44	12.26	4.0	1.8	0.2	2.0
	6	0.46	12.81	4.7	-	-	-
	7	0.43	11.98	4.7	-	-	-
	8	0.45	12.53	4.7	1.7	0.6	2.4
	Total	3.59	100.00	4.5	1.7	0.4	2.4
Carbonaceous Clay	1	0.00	-	-	-	-	-
	Total	0.00	-	-	-	-	-

Table X. Sulfur Distribution of the Lower Coal Seam at Well ET1(as received basis)

Lithology	Sample N°	Vitrinite %	Exinite %	Inertinite %	Reflectance %	Swelling Index	Residual Semi-coke (Gray-King)	Semi-coke Type (Gray-King)
Upper Coal Seam	3	84.7	2.3	13.0	0.38	0.0	68.8	Pulverulent
	6	81.5	2.3	16.2	0.38	0.0	72.7	"
	10	81.8	1.9	16.3	0.36	0.0	73.2	"
	Total	82.7	2.2	15.2	0.37	0.0	71.6	"
Lower Coal Seam	2	83.3	2.2	15.0	0.38	0.0	75.7	Pulverulent
	5	84.7	1.7	18.2	0.39	0.0	71.3	"
	8	86.1	1.9	12.0	0.36	0.0	76.2	"
	Total	84.7	1.9	15.1	0.38	0.0	74.4	"

Table XI . Petrographic Analysis at Well ET 1

LEGEND

SAND

ARGILLACEOUS SAND

CLAY

SANDY CLAY

CARBONACEOUS CLAY

LIMESTONE

ARGILLACEOUS LIMESTONE

CARBONACEOUS LIMESTONE

MARL

BRECCIA

COAL

DIRTY COAL (>40 % ASH)

CALCAREOUS CARBONACEOUS MUDSTONE-SILTSTONE

FERROUS HARDGROUND

COAL INCLUSIONS

FOSSILS (IN GENERAL)

STYLOLITIC JOINTS

FRACTURES

CLAY FILLED FRACTURES

ROOTS