CONFIDENTIAL

Cabre Maroc Limited

ADR Surveys
Morocco
2007 to 2008

An evaluation by J. Ward of ADR work carried out for Cabre Maroc by Adrok Limited

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Executive Summary

ADR technology has been confirmed as a valid new method of locating gas sands in the subsurface in advance of drilling. These results are based largely on the ADR analysis of well DNO-1 in the Rharb basin, Morocco. ADR predictions of the depths of gas-bearing sands in that well prior to its having been drilled were remarkably accurate.

A project to apply ADR technology to exploration for gas in the Rharb Basin, Morocco was carried out by Adrok on behalf of Cabre Maroc (part of the Caithness Petroleum group) from 2007 to 2008. The ADR data was processed in Edinburgh, Scotland.

AT DNO-1, ADR technology predicted with remarkable accuracy the depths at which gas sands would be found in the subsequently drilled well. An even better match of the depths at which gas zones were found in the drilled well with the depths at which gas was predicted in the virtual well was achieved when the values of all of the ADR depths were reduced by ten metres (Sections 7.5 and 7.6). Nine of the ten "significant" virtual gas zones were then found to have near identical depths to corresponding gas zones in the real well (Table 6 and Plots A and B). It is improbable that these results could have occurred by chance. The implication has to be that ADR technology successfully predicted the depths of subsurface gas zones in advance of drilling the DNO-1 well. That the technology requires further research however is clear from the less successful application of ADR to the well AHF-1. ADR analysis relating to other wells in the Rharb Basin was carried out at the preliminary stages of the project and is discussed here in less detail.

AT DNO-1, all the relevant sands were thin: of the order of 0.5 to 1.5 metres. Thus the ADR system does not appear to be dependent on reservoir thickness for the successful identification of gas.

It is concluded that based on the impressive results of the ADR work at DNO-1 this new technology represents an important breakthrough in hydrocarbon exploration.

1 Introduction

This report is a geological evaluation of the ADR work carried out by Adrok Limited on behalf of Cabre Maroc in Morocco, and in Edinburgh, Scotland in 2007 and 2008. The principles and applications of ADR technology are summarised in Appendix 1.

2 Objectives

In 2007 Cabre Maroc (Caithness Petroleum) contracted Radar World Limited (name now changed to Adrok Limited) to carry out ADR surveys at certain gas well locations in the Cabre Maroc licence areas of the Rharb basin in Morocco.

The above project in Morocco was the first use of ADR technology for hydrocarbon exploration anywhere in the world. Cabre Maroc's principal objective in engaging Adrok to carry out ADR survey work in Morocco was to determine whether or not ADR could be used as a reliable direct hydrocarbon indicator in subsurface rock formations, and in particular, to identify significant gas accumulations and the depths at which they could be located at an undrilled prospect.

The Rharb basin was selected as a suitable trial area because of its relatively uncomplicated stratigraphy in which discrete gas accumulations are to be found in porous sandstones within thick marl sequences. The methodology was first to train the ADR equipment to identify sets of frequencies associated with specific downhole components such as gas, sand, etc., at existing wells (control wells). Then, where the same sets of frequencies would be encountered in a test well the presence of the corresponding components could be inferred.

At the start of this project Adrok intended to identify both "significant" and "minor" gas shows in the subsurface of the Rharb basin, but the two terms were not clearly defined. Petrophysically, a "significant" gas show would be one that had the potential to be economically useful. For example, a sand with a gas saturation of 25% and good porosity, though not productive at a particular well could be called "significant" because of its potential to have a higher gas saturation at some structurally higher location. But a sand with only 5% gas saturation would be less likely to have a commercial potential. Such a gas show would be considered "minor". It appears likely, however, that in their early analysis of the ADR data, Adrok through unfamiliarity with gas exploration, were treating minor gas shows as significant and this caused over-reporting of "significant" gas zones in the test wells. The numerous minor gas zones recorded at the wells probably represented background gas.

Adrok had also intended to identify lithologies, particularly sands, and also zones in the subsurface containing water. But since significant gas shows could only be associated with sands there was no requirement to actually identify the sands; only the gas. To identify water was also of little value since that would only indicate the absence of gas.

The application of ADR technology for identification of stratigraphic boundaries was of only subsidiary interest in this study due to the preponderance of claystone/marl lithologies in the Rharb basin.

It is hoped that the technology might be applicable to areas where the use of conventional geophysical exploration technologies would be of limited value. One such area could be the Cabre Maroc licence in the Fez region where the seismic records tend to be poor due to the effects of complex nappe geology.

3 ADR Survey Work, 2007

In mid-2007 Adrok conducted ADR surveys at four pre-existing Cabre Maroc well locations in the Rharb basin. Surveys were also made in the vicinities of two exploration prospects which were to be drilled later in 2007.

The well locations were as follows:

Pre-existing wells:	BFD-1
	ZHA-1
	ZHA-5
	SAR-1
Undrilled prospects:	DNO-1
	AHF-1

4 ADR Virtual Well Profiling

In the second half of 2007 Adrok generated virtual well profiles for well locations where ADR surveys had earlier been conducted. Cabre Maroc provided Adrok with limited amounts of data from existing wells so that the ADR system could be trained to recognise discrete frequencies associated with gas, water and sand at these control wells. Three frequencies were found by Adrok to be associated with gas, four with water and two with sand. When these frequencies occur in the test well then the corresponding downhole components are inferred to be present. A virtual well is then generated with the frequency data displayed in log format alongside previously computed electronic borehole records: depths, lithology, horizon thickness, dielectric constants, etc., the tail of the log contains a key to the layout of the parameters measured or derived from the ADR surveying and processing. The log is not drawn to scale. All the virtual wells that were generated by Adrok for Cabre Maroc are included as appendices to this report.

The ADR surveying and processing techniques used by Adrok are confidential and protected by patent.

5 ADR Analysis of Wells BFD-1 and ZHA-5 by Adrok, August 2007

Appendix 2: Virtual well record for BFD-1
Appendix 3: Virtual well record for ZHA-5
Appendix 4: "ADR Analysis of wells BFD-1 and ZHA-5 by Adrok: Initial Project Results, September 2007" by J Ward

The results are outlined below. For the virtual well profile of BFD-1 and ZHA-5, Adrok were given limited data from three control wells: ZHA-1, ZHA-4 and SAR-1.

BFD-1

ADR analysis of this well achieved the following:-

(i) Main gas zone identified
(ii) Differentiation between the sandy lithologies in the upper section of the well (0 to 570 metres) and the lower marl section (570 to 1015 metres)

ZHA-5

ADR analysis of this well was less successful. The main gas sand at 1096 to 1103 metres was found; but the thick sand at 1243 to 1252 metres had been missed.

The partial success of this first ADR analysis work was promising, but too many sands and "significant" gas zones than were actually present were being predicted in these two wells.

6 ADR Virtual Wells, October 2007

6.1 Generation of virtual wells

In October 2007 virtual wells were generated for the following extant wells:

- BFD-1 (Appendix 5)
- ZHA-5 (Appendix 6)
- ZHA-1 (Appendix 7)
- SAR-1 (Appendix 8)

and for the undrilled exploration prospects DNO-1 and AHF-1 that were to be drilled at the end of the year 2007. (Appendices 9 and 10 respectively).

Adrok was given a larger training data base from which to generate the virtual wells. Sixteen gas zones from four of the wells were selected:

Well	***Number of training zones***
ZHA-1	7
ZHA-5	4
BFD-1	3
SAR-1	2

Table 1: Training data from wells ZHA-1, ZHA-5, BFD-1 and SAR-1 for ADR virtual wells (October 2007)

Well	***Depth (metres)***	***Gas %***
ZHA-1 gas zone	800 - 803 805 - 806 806 - 808 808 - 811.5	2.6 to 3.73 6.67 to 8.56 8.56 to 7.87 7.99 to 8.94
ZHA-1 depleted gas zone	931 - 932 931 - 933 933 - 934	15.1 0.1 to 15.1 trace
ZHA-5 gas + salt water zones	1076 - 1069 1069 - 1074 1097 - 1097.5 1177 - 1179	Minor gas Minor gas Significant gas Very minor gas
BFD-1	844 - 886 892 - 893 897 - 899	75 59 37
SAR-1	1129 1158	75 57.2

In all of the four pre-existing wells ZHA-1, ZHA-5, BFD-1 and SAR-1 it was again found that despite the input database being larger than for the previous work the number of ADR “significant” gas zones was far more than in reality. The ADR results are summarised below:

ZHA-1

Well:	Gas sand at 800 to 830 metres. Six gas shows from 931 to 934 metres.
Virtual well:	Six significant gas zones including one at 820 metres, but none between 931 and 934 metres.

ZHA-5

Well:	Gas sand at 1097 metres.
Virtual well:	Twenty seven significant gas shows which did not include the above sand

BFD-1

Well:	Four thin non-commercial gas sands between 885 to 899 metres.
Virtual well:	Twenty four significant gas shows

SAR-1

Well:	Two commercial gas sands at 1122 to 1129 metres and 1153 to 1166 metres
Virtual well:	Twenty five significant gas shows that did not include the above two sands.

Many years of gas exploration in the Rharb basin had shown that most of the successful gas wells had no more than two or three zones that could be developed commercially. Hence it was clear that the ADR analysis needed modification to reduce the number of spurious “significant” gas zones.

Discussions between Caithness and Adrok went some way towards the resolution of the problem of over-recording of “significant” gas shows.

Included in the parameters used by Adrok in the mathematical modelling to generate a virtual well had been the gas content of particular sands in the control (or training) wells.

Adrok had used gas percentages derived from the mudlogs of ZHA-1, ZHA-5 and SAR-1, but for BFD-1 gas percentages from wireline log analysis were used. Due to unfamiliarity with drilling technology there was confusion about the meaning of gas percentages. Adrok had assumed both types of data were comparable, but this is not the case. Mudlogging hotwire gas detectors do not directly measure gas volumes in a rock, the measurement is of percentage of gas in a gas/air mixture extracted from the mud.

In a borehole the rock cuttings and gas contained in the column of drilled rock are pumped to the surface in the drilling fluid (mud). There the gas is extracted from the mud flowline by a small stirring device (like a food processor), and sucked with air to the hotwire detector where it is recorded as a percentage of the gas/air mixture. High gas saturation in a formation gives a high reading, e.g. SAR-1, depth 1129 metres, total gas 75.26%. That is a qualitative measurement of the amount of gas in the rock. At shallower depths, 300 to 400 metres, there are frequently gas shows (1-4%). For various reasons the mud may not have been made heavy enough to prevent minor gas pockets from bleeding into the borehole. Other factors might also affect percentages: a gas-bearing formation being drilled slowly could release gas that would be diluted in the circulating mud and give a lower hotwire reading at surface.

Data from BFD-1 were derived from log analysis. This gives an accurate gas saturation for a reservoir rock, i.e. it measures the percentage of the porosity of the rock that is gas-filled. Ideally, well log analysis data for all the wells would be best for the mathematical modelling. However, the electric and nuclear logs are not usually run over unprospective sections of the hole in the Rharb basin.

Where significantly high gas saturations occur, for example 75% at SAR-1, mudlog and wireline log analyses data tend to be similar. It was agreed that Adrok should use the mudlog data from SAR-1 for the next modelling run unless well log analysis data was available. Caithness suggested that values of 5% or less (mudlog) should be disregarded as insignificant.

6.2 Exploration Prospects: DNO-1 (RW-8a) and AHF-1 (RW-3)

The two exploration prospects DNO-1 and AHF-1 were drilled in November 2007. Adrok had produced virtual well profiles in advance of drilling for each of the wells in October 2007. To guarantee the scientific integrity of the ADR work, Adrok had received no data concerning these prospects prior to their being drilled. The ADR virtual well profiling of these two wells is discussed in detail in Sections 7 and 8.

7 DNO-1 Exploration Well and ADR Virtual Well Profile

7.1 DNO-1: (RW-8a) Location, Prognosis and Drilling.

The geological prognosis for this well made by Cabre had been based on the interpretation of seismic AVO signals (Equipoise 2007). AVO anomalies are routinely used to identify potential gas accumulations in the Rharb basin. The Cabre geological prognosis had indicated potential gas sands within two sections: at 495 and 520 metres (+/- 10 metres) and in deeper sands at 665, 690, 715 and 775 metres (+/- 25 metres).

On completion of the drilling, mudlogging and wireline logging of DNO-1, the prognosis that there would be two sections of the well containing gassy sands was shown to be basically correct. All the sands in these two sections were thin with only three sands exceeding one metre in thickness, i.e., 733.4 – 734.9, 735.2 – 736.5 and 738.9 – 740.3 metres in the lower section. In the upper section, five gassy sands were about a metre in thickness; one less than a metre. Two of the thicker sands: 457.8 – 458.8 metres and 484.2 – 485.2 metres had excellent porosities: 35% and 33% with good gas saturations of 47% and 33% respectively. These could certainly be considered as “significant” gas shows, though only sub-commercial.

7.2 DNO-1: Wireline Logging Analysis

Wireline logging analysis of DNO-1 showed two sections of the well containing significant or potentially commercial gas sands (as per prognosis): an upper gassy section, depths 458 to 506 metres, and a lower gassy section, depths 709 to 743 metres.

Details of the petrophysical properties of these sands are shown in Table 2, the data being derived from the composite log sections in the post-drilling report (figures 1 and 2) and from wireline logging interpretation shown on the left side of Log Plots A and B.

Figure 1 (Composite log for upper reservoir sands)
Figure 2 (Composite log for lower reservoir sands)
Note: Figures 1 and 2 consist of figures 12 and 13 of the DNO-1 Post-Drilling Report (Cabre Maroc 2008)

Table 2:- DNO -1 Petrophysical Properties of the Gas Zones from Wireline Log Analysis.

Upper zones				
	Depth interval (metres)	***Thickness (metres)***	***Porosity (%)***	***Gas saturation (%)***
(iii)	457.8 – 458.8	1.0	35	47
(iv)	484.2 – 485.2	1.0	33	33
(v)	492.1 – 492.5	0.4	20	18
(vi)	494.7 – 495.4	0.7	36	10
(vii)	501 – 502	1.0	30	10
(viii)	504.6 – 505.6	1.0	25	18
Lower zones				
	Depth interval (metres)	***Thickness (metres)***	***Porosity (%)***	***Gas saturation (%)***
(i)	640			
(ii)	709 – 709.3	0.3	29	36
(iii)	710 – 710.4	0.4	29	36
(iv)	730.1 – 730.7	0.6	30	55
(v)	733.4 – 734.9	1.5	30	55
(vi)	735.2 – 736.5	1.3	30	65
(vii)	736.6 – 737.2	0.6	27	40
(viii)	737.4 – 738.3	0.9	27	40
(ix)	738.9 – 740.3	1.4	31	75
(x)	742 – 742.8	0.8	15	25
(xi)	756	-	-	-

From Table 2 above, all the sands are thin, only seven of the fifteen attaining thicknesses of a metre or more. Except for Sand 9 of the lower gassy section that has only moderate porosity (15%) and sands 1 and 11 where no petrophysical data is available all other sands have exceptionally good porosities ranging from 25 to 36%. There are also high gas saturations in four of the lower section sands; elsewhere their saturations are lower and likely to be sub-commercial. Three sands show good neutron-density cross-overs and these were perforated as potentially commercial, (Figure 2).

All the above sands had shows that could certainly be described as significant even those which were sub-commercial at this location. Nearby lateral thickening or structural elevation of those sands might result in higher gas saturations that could be potentially productive.

7.3 DNO-1: The ADR Virtual Well

Location: At the time of the ADR survey (May 2007) the DNO-1 prospect location was inaccessible.

The ADR survey took place some distance from the DNO-1 well location, the coordinates for both being:-

DNO-1 Location	ADR Survey Location
X - 454 595 mE	X - 454 605 mE
Y - 444 996 mN	Y - 444 985 mN

DNO-1 was drilled to TD: 838 metres brt. The Adrok survey extended from surface (i.e. 4 metres brt) to 1049 metres (1101 metres brt).

Processing of the data generated a virtual well with twenty two “significant” gas zones or shows and forty seven minor shows. These minor shows have a total thickness of more than half of the stratigraphic section of the well – an unrealistic situation since the lithology is predominantly marl which is not a reservoir rock. The minor gas shows can therefore be disregarded and considered to represent only background gas, less than 1% on the mudlog but ubiquitous below about 200 metres in the well. The marl is gassy because it constitutes the source rock for the biogenic methane gas that migrates into the porous, though mainly thin sandstones in the Rharb basin.

The twenty two “significant” gas shows are shown in Table 3 with corresponding depths, mudlog data and with comments in the right hand column.

7.4 Geological Interpretation of DNO-1 “Significant” Gas Shows

Table 3:- DNO-1: Geological interpretation of "significant" gas shows

Well Sections	*ADR Zone*	*Depth below GL (metres)*	*Depth below rotary table (mrt)*	*Mudlog Gas*	*Comments*
Behind 9 $^{5}/_{8}$ inch casing	1 2 3 4 5 6	95 129 159 223 340 375	99 133 163 227 344 379	Top mudlog gas detection starts at 380 metres	(Wireline logging starts at 350 metres)
	7 8	400 406	404 410	Gas less than 1%	No gas (electric log)
Upper Gassy Section	9 10	492 510	496 514	497 – 512 1 to 4%	
Lower Gassy Section	11	638	642	642 – 685 less than 1%	Poor correlation of mudlog data with wireline log analysis
	12	643	647		
	13	688	692	685 – 693 0.8 to 5%	
	14	716	720	702 -713 0.5 to 30%	
	15	721	725	735 – 750 1 to 10%	
	16	743	747		
	17	746	750	755 – 765 1 to 10%	
	18	761	765		
Below well TD at 838	19 20 21 22	978 986 1001 1049	782 990 1005 1053	Below TD	

<u>DNO-1 Geological Interpretation of the DNO-1 Virtual Well Results</u>

From Table 3, ADR analysis of DNO-1 showed there to be twenty two “significant” gas shows present. These shows are discussed from the top down. The top six shows are above the depth (380 metres brt) at which the mudlog gas detection equipment was operational, the top five are all behind casing so were not logged by wireline. No interpretations can therefore be made of these top shows. Gas pockets are frequently encountered in the sandy upper sections of the Rharb wells, so some of the shows may be valid though commercially insignificant. At the depths of the next two shows there were no indications of gas either on the mudlog or the electric logs.

The gas shows at 496 metres and 514 metres have low values: 1 to 4% (mudlog). The next eight shows from 642 to 765 metres are within the lower gassy section. The last four ADR values are below TD and therefore cannot be evaluated.

The "significant" gas shows found by ADR at DNO-1 can therefore be reduced from 22 to about 9, between depths 496 to 765 metres.

The mudlog gas percentages in these two sections do have some high values (up to 30%) but they do not correlate well with the gas saturations found by well log analysis, thus indicating the unsuitability of mudlog data for use in ADR mathematical modelling.

7.5 DNO-1: Tables 4 and 5: Interpretation

Tables 4 and 5 compare the depths of gas sands as predicted by ADR with the actual depth of gas sands found by drilling and log analysis.

Table 4: Comparison of depths of significant gas shows in the upper gassy section of DNO-1 from wireline log analysis, ADR (and prognosis). Scale approximate (depth metres brt)

Depth (m)	*Log Analysis*	*ADR*	*Pre-drilling Prognosis*
450			
455	458 - 459		
460			
465			
470			
475			
480			
485	484 - 485		
490	492 – 493		
495	495 – 496	496 – 497	495
500	501 – 502		
505	505 – 506		
510			
515		514 – 516	
520			520

Of the two ADR significant gas shows, the upper at 496 to 497 metres is effectively identical to that at 495 to 496 metres from log analysis. The lower at 514 to 516 metres is some eight metres below the log analysis depth of 506 metres.

DNO-1

Table 5: Comparison of depths of significant gas shows in the top part of the lower gassy section of DNO-1 from wireline log analysis, ADR (and Prognosis). Scale approximate (depth metres brt)

Depth (m)	Log Analysis	ADR	Prognosis
640	640 – 641	642 - 644	
		647 - 649	
650			
660			
			665 +/- 10
670			
680			
690		692 – 693	690 +/- 10
700			
	709		
710	710		
			715 +/- 25
720		720 - 722	
		725 - 729	
730	730 – 731 733 – 735		
	737 737 – 738 739 – 740		
740	742 – 743		
		747 - 749	
750		750 – 752	
760			
		765 – 767	
770			
			775 +/-25
780			

From Table 5 the ADR gas zone 642 to 644 metres is effectively the same as that from log analysis 641 to 642 metres (0.15% difference) and ADR zone 647 to 649 metres is also close (about 1% difference).

The ADR gas zones 720 to 722 metres and 725 to 729 metres lie immediately above the principal gassy zone in the well i.e. 730 to 740 metres, while ADR 747 to 749 metres and 750 to 752 metres are very close below it.

Conclusion

The close convergence of the depths of the ADR "significant" gas shows with the depths of the gas zones determined by log analysis is striking and seems unlikely to be coincidental. The conclusion has to be reached that the ADR analysis has been successful in predicting the locations of the gas zones in both the upper and lower gassy sections of DNO-1.

7.6 DNO-1: ADR Virtual Well – Log Plots A and B

(Enclosures 1 and 2)

In these plots the ADR virtual well "significant" gas zones data summarised in Tables 4 and 5 have been redrawn in log format at scale 1:500 for direct comparison with the wireline logs.

Gas zones determined by different technologies are shown by different coloured codes. The ADR "significant" gas zones are shown in red and highlighted with red dots. ADR minor gas shows are in blue. Yellow dots represent gas zones ADR algorithm analysis. Green dots show gas zones predicted from the geological prognosis. Only ADR zones below 450 metres are logged, higher zones are likely to be insignificant.

Log Plot A: Virtual Well DNO-1 compared to the Wireline and Interpretation Log. (Enclosure 1)

Log Plot A shows ten "significant" ADR gas zones highlighted with red dots. The wireline composite logs and computerised interpretation logs are shown to the left of the vertical well. Orange dots highlight the fourteen individual thin sands that had gas shows determined either from the wireline interpretation log or from that in the post-drilling report (Figures 1 and 2).

As concluded in Section 7.5, the convergence between the wireline log depths and those from the vertical well is impressive. An even more remarkable match between the two sets of gas zone depths can be achieved, however, if all the virtual gas depths are moved uphole by about 10 metres. This is shown in Log Plot B (otherwise similar to Log Plot A).

Log Plot B: Virtual Well DNO-1 compared to the Wireline Interpretation Log with ADR depths reduced by 10 metres. (Enclosure 2)

From Plot B nine out of the ten red dots can now be seen to lie almost directly opposite similar groupings of the thirteen orange dots. The great similarities between the corresponding depths for the two sets of data is shown in Table 6.

Table 6:- DNO-1: Comparison of depths of significant gas shows from wireline log analysis with ADR depths from which 10 metres have been subtracted

Comparison of the depths for significant gas shows from wireline log analysis and ADR depths minus 10 metres.		
Log analysis	ADR -10 metres	ADR metres
484	484 - 486	494 - 496
505 - 506	504 - 506	514 - 516
640	637 - 639	647 - 649
709 - 710	710 - 712	720 - 722
730 - 740	737 - 739	747 - 749
742 - 743	740 - 742	750 - 752
756	755 - 757	765 - 767

7.7 DNO-1 ADR Virtual Well: Discussion and Conclusions

The remarkable match between the ADR depths minus 10 metres and the depths determined by well log analysis for the gas shows at DNO-1 are the most significant results presented in this report, (Log Plot B and Table 6). It is improbable that the match between the two sets of data could have occurred by chance. The implication therefore has to be that the ADR analysis has been successful in identifying significant gas zones in DNO-1 but with a discrepancy of 10 metres.

The ten metre difference for the ADR gas zone depths can most likely be accounted for by either stratigraphic dip or faulting between the borehole and virtual well location, or a combination of both. The borehole was almost certainly drilled on a structural crest, therefore all nearby locations could be expected to occur downdip. Also, some faulting of the DNO-1 structure is indicated by seismic. And if the virtual location was higher at ground level than the wellsite this too would increase the depths of the virtual gas shows. Whatever the explanation the result remains very impressive and demonstrates that ADR technology has been successfully applied to hydrocarbon exploration.

8 Exploration Prospect: Well AHF-1 (RW-3)

8.1 Location and Drilling

AHF-1 was the second of the two exploration prospects drilled by Cabre in November 2007. The ADR survey for the well took place at the wellsite location. As was the case with DNO-1, Adrok had used data from control wells ZHA-4, ZHA-5 and BFD-1 that had been largely derived from mudlogs. An ADR virtual well for AHF-1 was generated in October 2007 prior to the drilling of the well in November.

8.2 Results from Drilling: Wireline Log Analysis of AHF-1

The wireline interpretation log for AHF-1 (depths 370 to 830 metres) shows there to be only one gas zone in the well at depths 536 to 539 metres comprised of two thin sands: 536 to 537.5 metres and 538 to 539 metres. The two sands are considered as separate gas accumulations for production purposes. There is an extremely thin (less than one metre thick) sand at 462 metres with a minor gas show. From the upper part of the log from 370 to 440 metres some very minor gas indications are possible in some very thin sands in that section. The sands found in the marl section are generally thin, though some sands up to two metres in thickness are found from 568 to 596 metres but without gas shows.

8.3 The Virtual Well

The ADR virtual borehole record for AHF-1 produced an unrealistically large number of “significant” gas zones. Five zones were indicated in the well between zero and 293 metres. These cannot be checked since the present log data starts at 370 metres (KB). A further thirteen zones are set out below in Table 7.

Table 7: AHF-1 "Significant" gas zones compared to wireline log analysis.

SIGNIFICANT GAS ZONES Depth (KB) in metres	***LITHOLOGY and SHOWS from WIRELINE LOG ANALYSIS***
393 – 381	Thin SS at 381 – 382 very minor gas show
412 – 414	Silty sand very minor gas show
523 – 525	Marl no show
526 – 528	Marl no show
557 – 559	Marl no show
562 – 564	Marl no show
609 – 611	Marl/siltstone no show
634 – 637	Marl/siltstone no show
704 – 706	Marl no show
713 – 715	Marl no show
741 – 743	Marl no show
766 – 767	Marl no show
794 – 796	Marl no show

From the wireline log the lithologies which in the virtual well had been described as sands with "significant" gas were almost entirely marl with no shows.

The two gas bearing sands in the zone 536 to 539 metres were not recorded by the ADR though ADR "significant" gas zone at 526 to 528 metres is only eight metres away, an error of less than 2%. But the fact that ADR recorded the presence of many spurious sands is disappointing. One possible explanation might be that some of the gas zones predicted by ADR may represent multiples of small gas zones possibly present in the higher sandy section of the actual well. This would be by analogy with the common occurrence of such phantom events in seismic records.

9 ADR Analysis by Algorithm

In October 2007 Adrok developed a mathematical algorithm to generate a numerical parameter that could be related to the presence or absence of gas in the sands of the Rharb wells. The results of this Adrok work is collated in Appendix 11: Adrok ADR Analysis by Algorithm.

In summary, if:

(i) The parameter is less than 1: Insignificant gas present

(ii) The parameter is equal to 1: Minor gas present

(iii) The parameter is greater than 1: Significant gas present

(iv) The parameter is greater than 2: Very significant gas present

Adrok labelled the parameter: the ADR matching value. The system appeared to work for the prediction of some but not all of the wells. The following were examples of the successful application of this numerical system:

Table 8: Training Data for ADR Algorithm Analysis

Well	***Zone depth (m)***	***% Gas***	***ADR matching value and well status***
SAR-1	1129 1158	73 57	1.8 Gas productive 1.2 Gas productive
ZHA-1	431 699	3.87 1.30	Less than 0 Insignificant gas

For training (or control) well data gas “percentages” were taken from mudlog records. It is likely that the use of such data may have had adverse effects on the ADR analysis. Adrok refined the system so that where gas would be present, ADR matching values were required to have a minimum number less than 0.7 and a maximum matching value greater than 2.7.

ADR analysis by algorithm successfully predicted the depths of the main gas sands in SAR-1. The algorithm had been trained using only significant gas shows in ZHA-1 (803 to 809 metres) and (931 to 934 metres) and ZHA-5 (1098 to 1103 metres). The algorithm gas predictions for SAR-1 were: 1127 to 1131 metres and 1155 to 1157 metres. This compares well to the actual depths of gas sands in SAR-1: 1123 to 1132 metres and 1153 to 1158 metres.

In January 2008 Adrok used the algorithm method to predict gas zones in DNO-1. Two depths were predicted: 540 metres brt and 749 metres brt. The latter depth was close to the actual depths of gas sands in the well.

In terms of petroleum geology evaluation of the Adrok algorithm method is largely beyond the scope of this report.

10 Stratigraphy by ADR

Various studies were carried out to determine if ADR could define important stratigraphic or lithological boundaries in the geological sections of the Rharb wells. Some success was obtained in distinguishing sandy lithologies from the marls, but otherwise results have been negative or inconclusive. This is likely to be due to the boundaries between the lithologies being often gradational rather than sharp except for the deeper, thin gas sands. ADR may have more stratigraphic potential where there are strong contrasts between the values of the dielectric constants in the encountered lithologies.

11 Conclusion

In this report it has been shown that in DNO-1, from Log Plot A and most importantly from Log Plot B in which ADR depths were raised by 10 metres, and in Table 6 the virtual depths and the true depths of significant gas shows were nearly identical (many to within less than a metre of difference). ADR analysis has successfully identified with great precision the depths at which gas sands were located in the well. This is a major breakthrough in gas exploration technology and should have important economic consequences.

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