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TASK

for the qualifying work of the degree ___bachelor____
(bachelor, master)

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title __ Technical project for drilling an exploration well in the Abu Ghirab field (Iraq)

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Section	Keeping	Deadline
Technologic	Geological survey of drilling of the wells at the gas-condensate genus. Design of construction of drill wells, method of drilling and drilling equipment.	02/05/2022
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ESSAY

Thesis project 75 pages, 35 figures, 6 tables, 31 biblicals.

The object of the study is drilling a well at the Abu Ghirab field (Iraq) with the development of measures to improve the quality of drilling fluids.

The purpose of the work is to design a well at the Abu Ghirab field (Iraq).

Research tools - literature analysis and theoretical research.

The thesis is compiled in accordance with the requirements of the guidelines. Contains information about the area of drilling, geological structure and characteristics of productive horizons. In the design part, the issues of well construction are resolved: the well structure has been designed, the equipment for the drilling rig, the rock cutting tool, the drilling and cementing technology have been selected. Measures have been developed to improve the quality of drilling fluids during preparation. Safety precautions are given when drilling wells. The issues of subsoil and environmental protection are highlighted. The estimate of well drilling has been substantiated.

PRODUCTION WELL, SKEW WALL, COMPLICATION, DRILLING FLUID PREPARATION.

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INTRODUCTION

Iraq is one of the most petroleum-rich countries in the Middle East, and is endowed with multiple petroleum systems that include Paleozoic, Mesozoic, and Cenozoic rocks. The majority of Iraq's petroleum resources are located in the Zagros-Mesopotamian Cretaceous-Tertiary Total Petroleum System (TPS) (USGS, 2000). These systems are oil prone with lesser amounts of natural gas, as demonstrated by reserve, resource and geologic data. Natural gas is also a significant resource in Iraq; ranking eighth (195 trillion cubic feet, TCF, or 32.5 billion barrels of oil equivalent, BBOE) among the Organization of Oil Exporting Countries (OPEC) in terms of reserves (USGS, 2000). The combined recoverable resources of Iraq, exclusive of reserve growth, are currently estimated to be 184 BBOE. Because the estimated oil endowment in Iraq is almost five times larger than the natural gas endowment, this paper will focus on Iraq's oil resources.

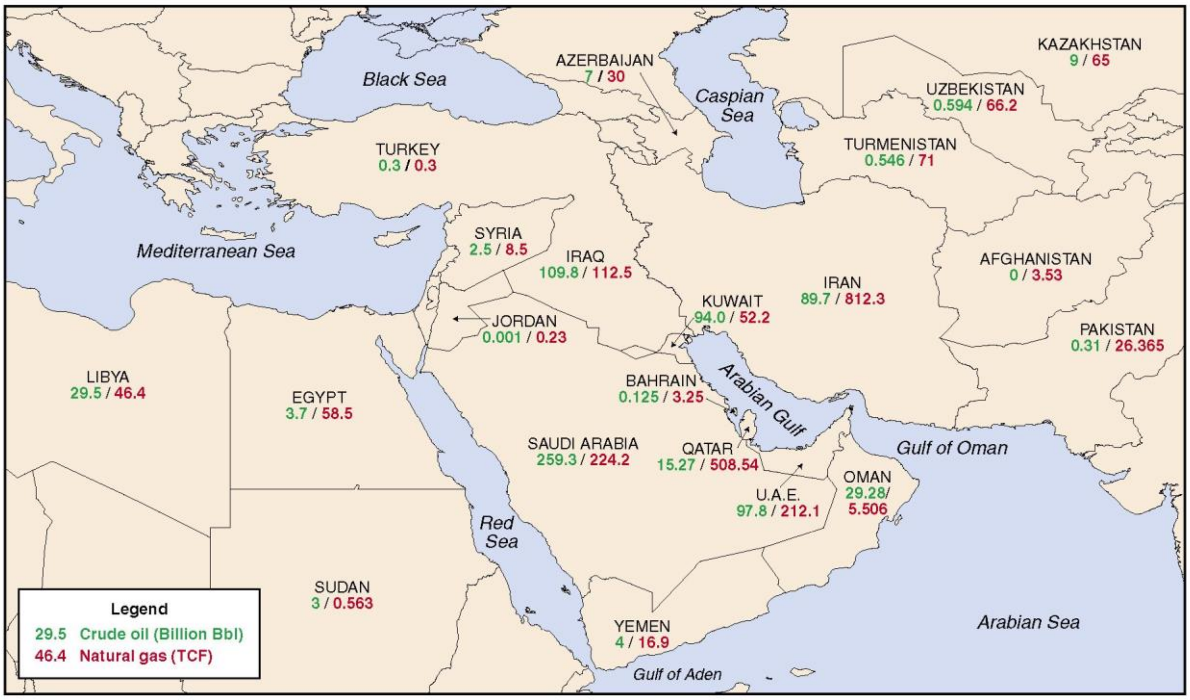


Figure 1.1 - Map showing proved oil and gas reserves in the Middle East countries. Based on reported reserves, Iraq is the second largest in oil reserves in the Middle East and third largest in the world. Data source: Oil and Gas Journal, December 23, 2002.

The recoverable reserves (summation of proved reserves and cumulative production) in giant and super-giant fields in the Middle East are shown in Table 1. In the Middle East, five countries (Saudi Arabia, Iraq, Iran, Kuwait, and United Arab Emirates) have the bulk of oil reserves. The giant fields in these countries, with reserves between 1 and 5 billion barrels of oil (BBO), and super-giant fields, with reserves greater than 5 BBO, account for 85 to 90% of recoverable reserves. Iraq has 6 super-giant fields (not including Nahr Umr, which is now named Bin Umr) with recoverable reserves of about 84.8 BBO, and 11 giant fields with recoverable reserves of 22.6 BBO, for a total of 17 giant and supergiant fields with 107.4 BBO of recoverable reserves (IHS, 2001). These reserves account for about 88% of Iraq's recoverable reserves.

Table 1.1 - Giant Middle East Fields

Country	Super-giant Oil Fields		Giant Oil Fields		Total of Giant and Super-giant Oil Fields		
	No.	Recoverable Reserves	No.	Recoverable Reserves	No.	Recoverable Reserves	Proved Reserves, January 2001
		Billion bbls		Billion bbls		Billion bbls	Billion bbls
Saudi Arabia	10	246.70	16	29.60	26	276.30	199.97
Iraq	6	84.80	11	22.60	17	107.40	85.97
Iran	5	77.50	16	36.08	21	113.58	71.71
Kuwait	3	73.23	3	9.52	6	82.75	53.90
Abu Dhabi	5	56.60	5	7.31	10	63.91	47.98
Neutral Zone	1	6.86	1	3.40	2	10.26	5.16
Qatar	1	5.30	2	2.70	3	8.00	2.49
Dubai	0	0.00	2	3.91	2	3.91	1.14
Oman	0	0.00	2	3.53	2	3.53	1.17
Syria	0	0.00	1	1.71	1	1.71	0.71
Bahrain	0	0.00	1	1.05	1	1.05	0.08
Total	31	550.99	60	121.41	91	672.397	470.271

Giant fields (with recoverable oil reserves between 1 and 5 billion barrels) and super-giant fields (with recoverable reserves equal to or greater than 5 billion barrels) of the Middle East are listed here. Source: IHS, 2001.

With 113 BBO of proved reserves, Iraq ranks second to Saudi Arabia (259 BBO reserves) in the Middle East, and third in the world if the sharp increase in Canada's reserves from 5 to 180 BBO through the inclusion of Alberta's tar sands is considered (Radler, 2002).

The proved petroleum reserves of the Middle East as of January 1, 2003 (Figure

1.1, Radler, 2002) are compared with the rest of the world in Figure 1.2 (oil) and Figure 1.3 (gas). For proved oil reserves, the Middle East has historically maintained its share of about 65% of the world's reserves, except in 2003 when the percentage dropped to 56.5% because of Canada's reserves change. With respect to natural gas reserves, the Middle East contains about 37% of the world's proved reserves, with the remaining 63% shared between the Former Soviet Union countries (32%) and the rest of the world (31%) (Radler, 2002).

Relatively few reports and technical papers are available on Iraq's geology and petroleum resources. Also, whereas some proprietary databases provide a field-by-field record of the geology, reserves, and production history, there is no comprehensive documentation of Iraq's overall petroleum resources, and its present capacity to produce oil and gas. This paper is intended to provide an overview of Iraq's petroleum resources and reserves, as well as a brief discussion of the current status of its upstream infrastructure. Papers by Pitman et al. (2003, in press) discuss the modeling studies of petroleum generation and migration for the Mesozoic/Cenozoic Total Petroleum Systems and focus on the Jurassic source rocks. United States Geological Survey (USGS) studies of the Silurian Total Petroleum System have been reported by Ahlbrandt et al. (1997), Fox and Ahlbrandt (2002), and Schenk et al. (2004).

SECTION 1 GEOLOGICAL AND TECHNICAL CONDITIONS FOR CONDUCTING DRILLING WORKS

1.1 Regional Geologic Overview

The tectonic evolution of the Arabian Plate has been summarized by Al-Naqib (1967), Murris (1980), Beydoun (1991), Al-Husseini (2000), Konert et al. (2001), Sharland et al. (2001) and Pollastro (2003). At least five distinct phases are recognized (Figure 1.5). The first is a Precambrian compression phase, when island-arc and micro-continent terranes accreted and assembled to form the Arabian Plate from about 715 to 610 Ma (# 1 in Figure 1.5). Many of the structural elements that formed during this period controlled later sedimentation, structural development, and petroleum accumulation (Al-Husseini, 1997, 2000; Sharland et al., 2001). The second phase involved late Precambrian to Late Devonian extension and subsidence from 610 to 364 Ma (# 2 in Figure 1.5). Infra-Cambrian sedimentation was largely controlled by the development of intracratonic rift basins associated with the Najd Fault System (Al-Husseini, 2000), with evaporites and carbonates accumulating in equatorial latitudes. In the Silurian, a major source-rock sequence was deposited that was related to high-latitude sedimentation, including glacial sequences in the late Ordovician.

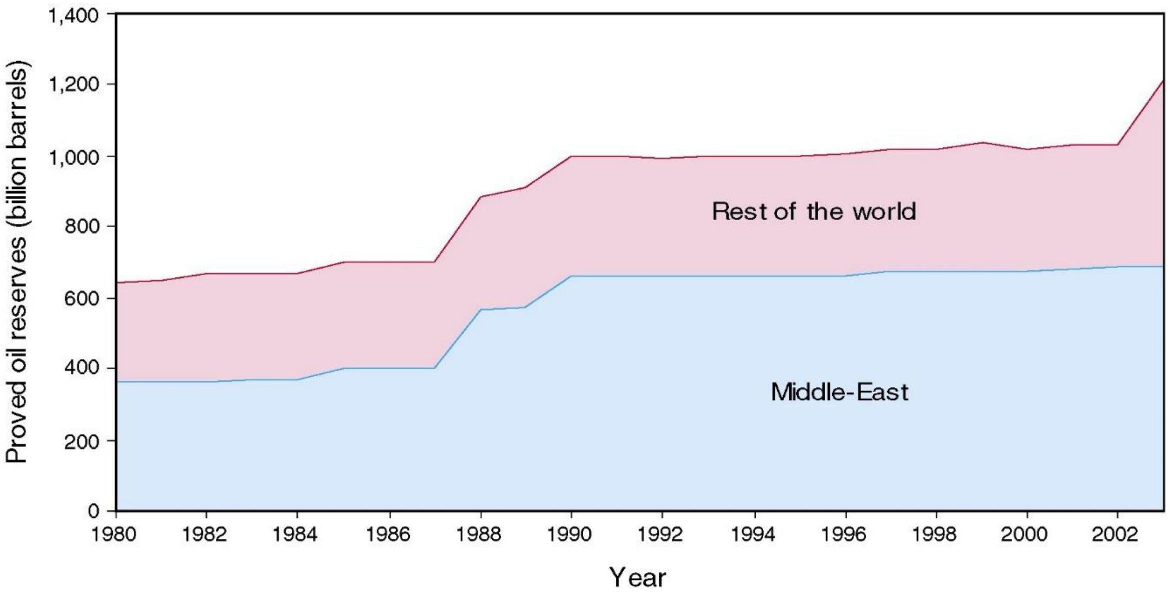


Figure 1.2 - Plot showing comparison of Middle East proved oil reserves and the rest of the world's reserves. The Middle East has historically maintained a two-thirds share of the world's oil reserves, except for 2003 when there was an increase in Canada's oil reserve from 5 to 180 billion barrels through inclusion of Alberta's tar oil sands. Data source: Oil and Gas Journal, December 23, 2002.

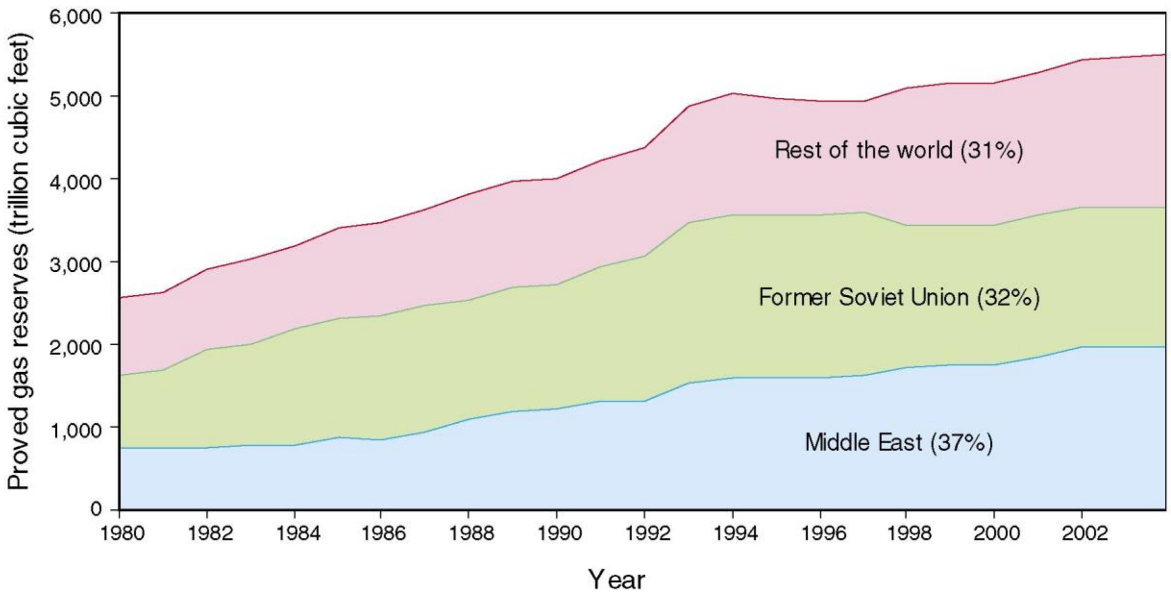
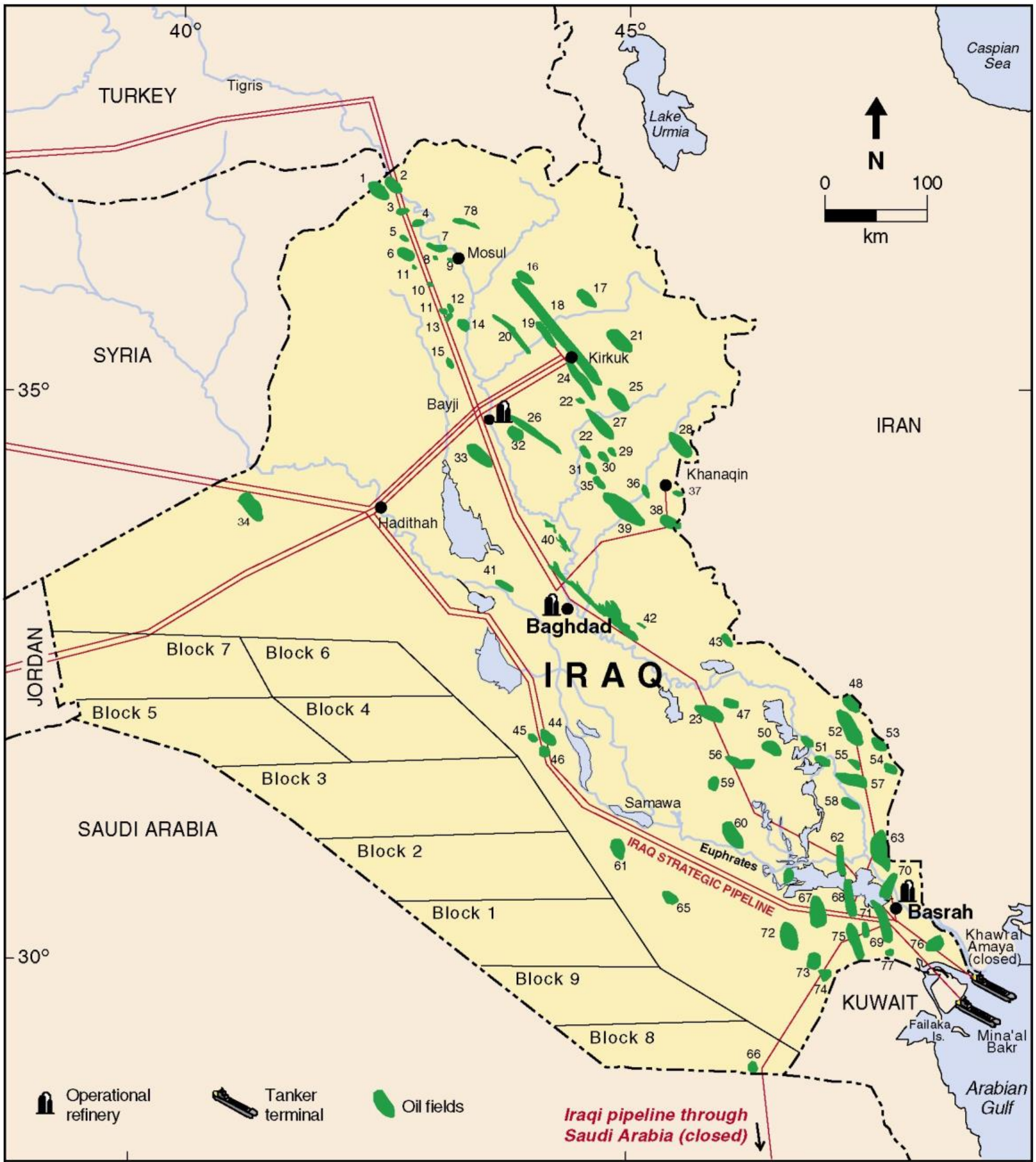


Figure 1.3 - Plot showing comparison of Middle East proved gas reserves and the rest of the world’s gas reserves. Data source: Oil and Gas Journal, December 23, 2002.

The third phase occurred during the Late Devonian to mid-Permian (364 to 255 Ma) and encompasses the mid-Carboniferous Hercynian Orogeny (# 3 in Figure 1.5). Late Carboniferous and Early Permian glaciation followed the orogeny (Sharland et al., 2001), and the glaciation ended before the opening of the Neo-Tethys Ocean, which started the fourth tectonic phase. This phase (255 to 92 Ma) commenced with rifting and associated passive margin settings (# 4 in Figure 1.5). The upper Paleozoic and Lower Mesozoic (Triassic and Jurassic) rocks are largely cyclic carbonates and evaporites, whereas the lower Cretaceous strata are dominantly open marine and a mixture of clastics and carbonates that were deposited along the Neo-Tethys Shelf. The fifth phase, the Zagros Orogeny (# 5 in Figure 1.5) extended from late Cretaceous time (92 Ma) to the present-day, and was largely compressional. This stage resulted in the closing of the Neo-Tethys Ocean, and the development of a foredeep associated with its closure. Ophiolite obduction in Oman, followed by the uplift of the Oman Mountains, the collision of the Arabian Plate with Asian continent to form the Zagros Mountains, and finally the rifting of the Red Sea and Gulf of Aden in Tertiary time, all occurred during this final phase (Sharland et al., 2001).

The oil fields of Iraq are within the prolific petroleum provinces of the Arabian Peninsula, the geological history of which dates back to Precambrian time, as discussed above. The stratigraphic column, nomenclature, lithology and tectonic phases of the northern Arabian Peninsula, with an emphasis on Iraq, are shown in Figure 1.5.



IRAQ : Oilfields and Exploration Blocks

1. Sufaiya	17. TaqTaq	33. West Tikrit	49. Amara	65. Diwan
2. Mushorah	18. Kirkuk	34. Akkas	50. Dujaila	66. Abu Khaima
3. Ain Zalah	19. Bai Hassan	35. Khashmal Ahmar	51. Kumait	67. Ratawi
4. Butmah	20. Qara Chauq	36. Nau Doman	52. Buzurgan	68. Rumaila North
5. Gusair	21. Chemchemal	37. JariaPika	53. Jabal Fauqi	69. Zubair
6. Sasan	22. Khabaz	38. Naft Khana	54. Huwaiza	70. Nahr Umr
7. Alan	23. Ahdeb	39. Mansuriya	55. Noor	71. Tuba
8. Qalian	24. Jambur	40. Balad	56. Rafidain	72. Luhais
9. Atshan	25. KorMor	41. Fallujah	57. Halfaya	73. Rachi
10. Adaiyah	26. Hamrin	42. East Baghdad	58. Rifae	74. Jerishan
11. Jawan	27. Pulkhana	43. Badra	59. Gharraf	75. Rumaila South
12. Qasab	28. Chia Surkh	44. Kifl	60. Nasiriya	76. Siba
13. Najmah	29. Qumar	45. Merjan	61. Samawa	77. Safwan
14. Qaiyarah	30. Gilabat	46. West Kifl	62. West Qurnah	78. Kand
15. Sadid	31. Injana	47. Dhafriya	63. Majnoon	
16. Demir Dagh	32. Ajeel (Saddam)	48. Abu Ghirab	64. Subba	

Figure 1.4 - Map showing oilfields and exploration blocks in Iraq. Major pipelines are shown in red. Source: GeoDesign Communication, 2003.

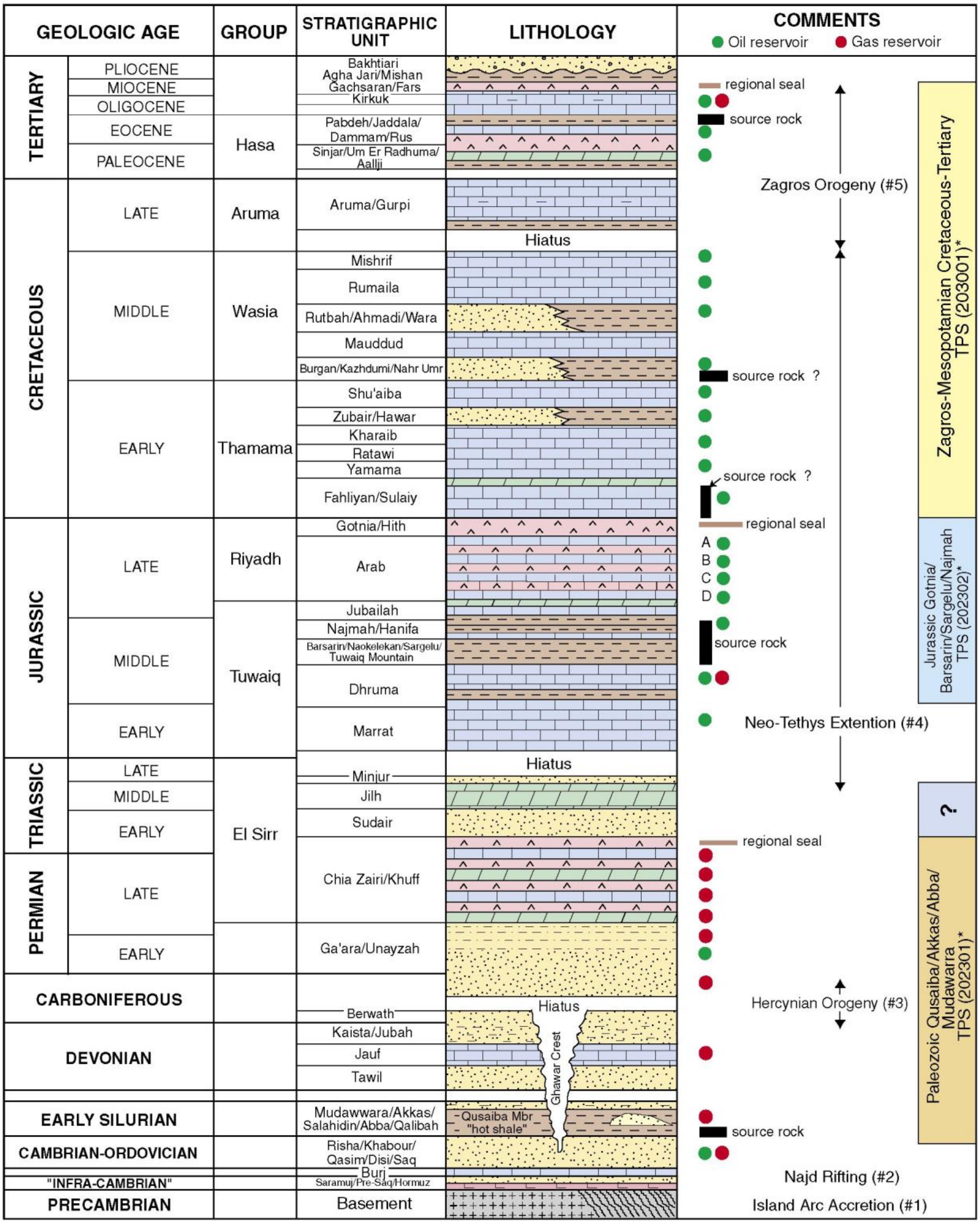


Figure 1.5 - Stratigraphic section and major tectono-stratigraphic phases, relevant to the Paleozoic, Jurassic, and Cretaceous-Tertiary Total Petroleum Systems (TPS) of the northern and eastern Arabian Peninsula and Iraq. Modified from Janahi and Mirza (1991), Chaube and Al-Samahiji (1995), Mendeck and Al-Madani (1995), Jawad Ali and Al-Husseini (1996), Alsharhan and Nairn (1997), Wender et al. (1998), Bordenave (2000), Sharland et al. (2001), and Pollastro (2003). Stratigraphic names include equivalent names in northern Saudi Arabia, Iraq, and Iran. Total

petroleum systems and their six digits numerical code (*USGS 2000) are shown in comments column.

The southern part of Iraq is believed to be underlain by an Infra-Cambrian salt basin, which originated during Najd wrench faulting (Alsharhan and Nairn, 1997; Sharland et al., 2001). Further episodes of tectonism coincided approximately with the Hercynian orogenic event, and resulted in the development of an early NS-trending basin during Paleozoic time. Because the large NS-trending structures were uplifted during the mid-Carboniferous, sediments of this age generally were eroded. Throughout most of its subsequent geologic history, Iraq remained stable until the late Tertiary, when the area became tectonically active, with the formation of the Zagros Mountains (Figure 1.6). During the Mesozoic, most sediments were deposited in continental to moderately deep marine-shelf settings on the slowly subsiding passive margin of the Afro-Arabian Plate. In contrast, synorogenic sediments were restricted in time (early to middle Cretaceous and late Tertiary) and space (northeast Iraq). Several tectonic trends developed within the sedimentary basin, of which three are dominant: a NW-SE Zagros trend, a NE-SW trend and an earlier NS Arabian trend (Figure 1.6) (Al-Gailani, 1996).

Four main structural zones have been defined within the boundaries of Iraq (Figures 1.6 and 1.7). The first two are the Near Geosynclinal Flank of the Mesopotamian Foredeep and the Central Faulting zones (Figures 1.6 and 1.7). They are tectonically related to the Zagros Belt, and are characterized by a thick, strongly-folded sedimentary cover. This belt includes the Nappe Zone to the east (Figures 6 and 7) where more complex folding occurred, including thrust-folded structures and overthrusted blocks consisting of both basinal strata and magmatic rocks.

In general, the Zagros Belt is composed of folded and faulted sedimentary rock in northeastern Iraq. In addition, there are several areas in these thrusted zones that were affected by Miocene, Late Jurassic and Infra-Cambrian salt tectonics. Thrusting and the resulting NW-SE-trending folds in the Zagros Belt (Figures 1.6 and 1.7) are widely regarded as the result of northeast rotational drift of the Arabian Plate, which collided with the Iranian Plate (Al-Gailani, 1996; Glennie, 2000).

The Near Geosynclinal Flank of the Mesopotamian Foredeep (Figures 1.6 and 1.7) in northern Iraq is characterized by intense folding. En-echelon, linear anticlines and synclines coincide with the area of the Paleogene molasse.The strata are dominantly marine-interbedded carbonates, marls, and evaporites. Terrigenous clastics are rare except in areas adjoining the margins of the stable shelf, where they were sourced from the Arabian Shield, or recycled from earlier deposits. The clastics interfinger with limestones and marls of late Paleozoic and Mesozoic age (west of the Arabian Gulf region).

The Zagros Central Faulting Zone is characterized by a thick sedimentary cover (as much as 13 km thick) and well-developed folding formed by long, narrow, NW-SE trending anticlines separated by broad, flat synclines (Figure 1.6). A number of major commercial oil fields are situated in this area, including Kirkuk, Bai Hassan, and Jambur (Figures 1.4, 1.6 and 1.7).

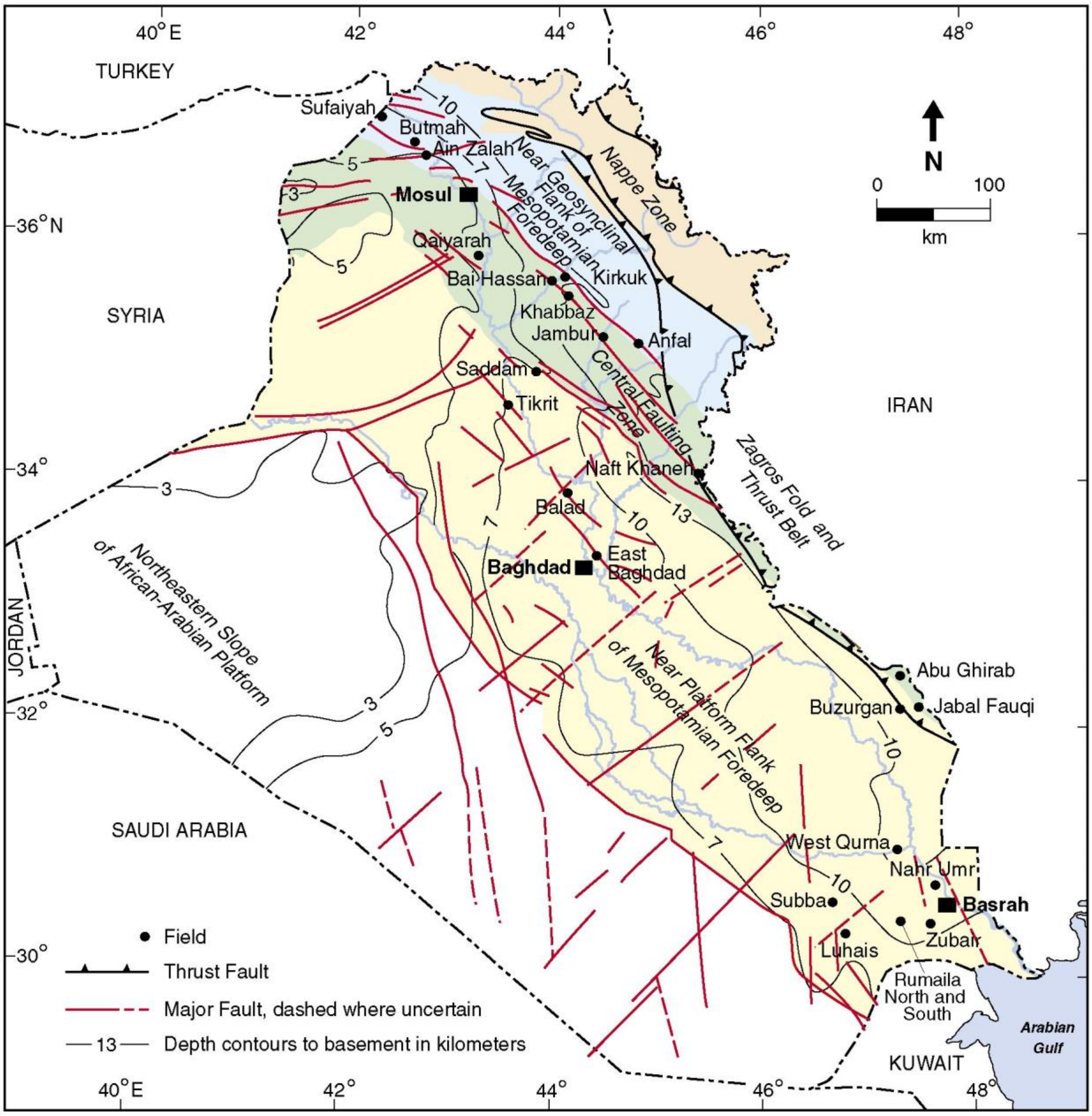


Figure 1.6 - Map showing the structural zones (Near Geosynclinal Flank of the Mesopotamian Foredeep, Central Faulting zone, Near Platform Flank of Mesopotamian Foredeep, and Northeastern Slope of African-Arabian Platform), and isopach contours (sediment thickness to basement). The Zagros thrust fault zone and other major faults are also shown (Buday and Jassim, 1987).

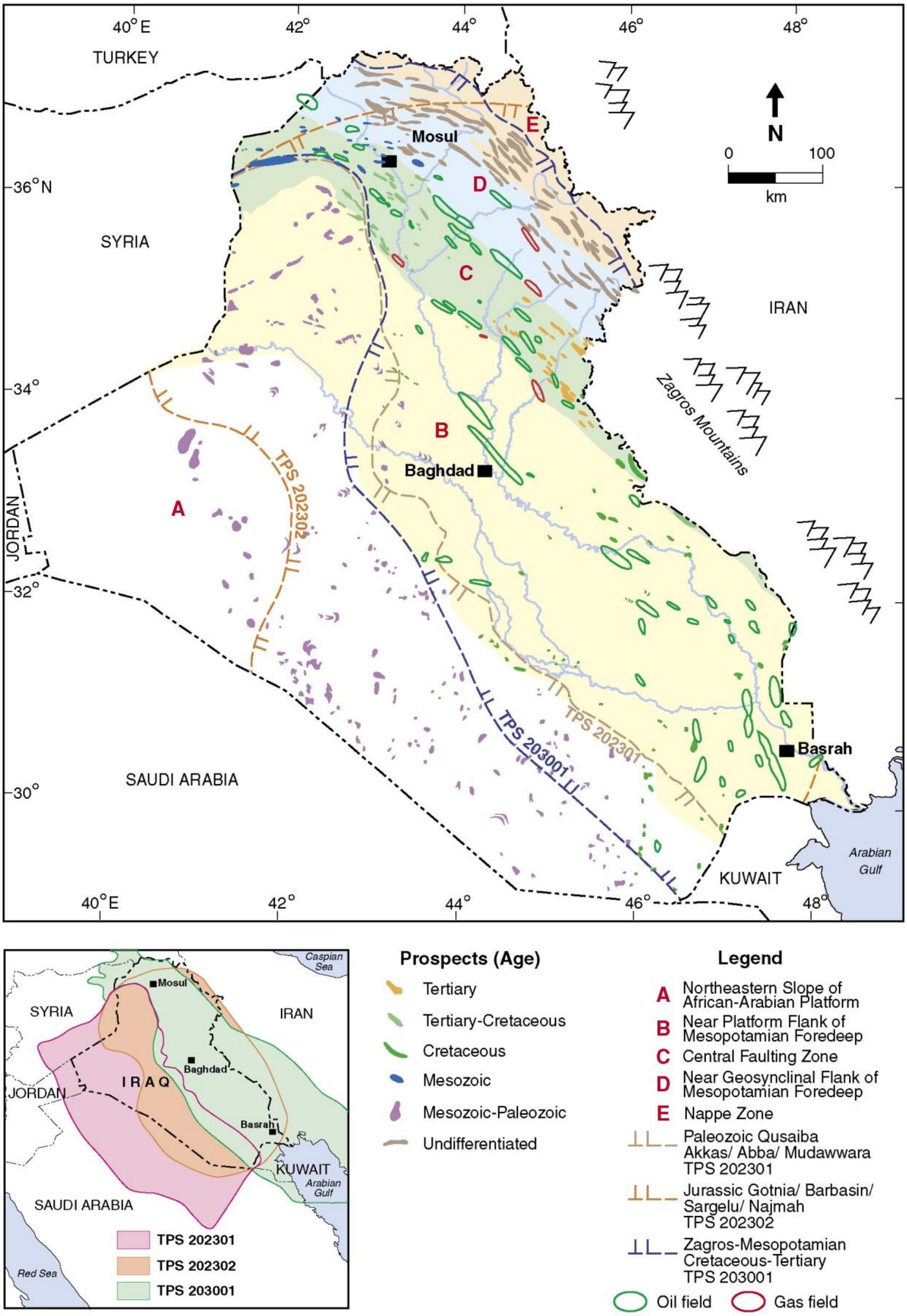


Figure 1.7 - Map showing oil and gas fields, prospects (Al-Gailani, 2003) and the three Total Petroleum Systems (TPS) that have contributed to the petroleum accumulations in Iraq (Ahlbrandt et al., 2000).

The Near Platform Flank of the Mesopotamian Foredeep and Northeastern Slope of African-Arabian Platform zones are generally part of the less-intensly deformed Mesopotamian foreland (Figures 1.6 and 1.7). The Near Platform Flank of the Mesopotamian Foredeep is characterized by a gentle monocline dipping toward the northeast and broad symmetrical synclines filled with Quaternary sediments. The zone is characterized by rapid subsidence since at least Mesozoic time. The first structural growth in this area may have been initiated in the late Cretaceous, when deep-seated NS- trending basement features were reactivated. Tectonic activity culminated in the late Cenozoic with folding of the sedimentary cover of the late Neogene foredeep during the Zagros Orogeny. Important oil fields are located in this area, including Rumaila and Zubair.

The Northeastern Slope of the African-Arabian Platform Zone is characterized by tectonic stability and thinner sedimentary cover (thickness generally less than 7 km) (Figure 6). Folding is absent, but a number of block-faulted zones exist, such as the Ga'ara Block and the Abu Jir sub-zones in northwest Iraq and eastern Syria (Al-sharhan and Nairn, 1997). Prospects in this zone are commonly in older Paleozoic reservoirs (Figure 7).

1.2 Iraq’s Petroleum Reserves And Resources

Three components of Iraq's petroleum potential will be discussed: (1) reserves, including an analysis of reservoirs, (2) potential reserve (or field) growth, and (3) undiscovered resources.

1.3 Reserves: Proved, Probable and Possible

Proved (or remaining) reserves are defined as those quantities of petroleum which, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date onward, from known reservoirs and under current economic conditions, operating methods, and government regulations. If probabilistic methods are used, there should be at least a 90% probability that the quantities actually recovered will be equal to or exceed the estimate (McMichael, 2001).

Probable reserves are those unproved reserves which analysis of geological and engineering data suggests are more likely than not to be recoverable. If probabilistic methods are used, there should be at least a 50% probability that the quantities actually recovered will be equal to or exceed the sum of estimated proved plus probable reserves (McMichael, 2001).

Possible reserves are those unproved reserves which analysis of geological and engineering data suggests are less likely to be recoverable than probable reserves. In this context, when probabilistic methods are used, there should be at least a 10% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable plus possible reserves (McMichael, 2001).

Iraq's total petroleum volumes including reserves (proved, probable and possible) and the cumulative production as of year-end 1998 are 136 BBO and 108 TCFG from 84 fields (GeoDesign, 1999). Of these, 23 are producing fields (Table 2, Figure 8), 41 are non-producing fields (Table 3, Figure 8), and 20 are non-commercial fields (Table 4). Reserves in some of the non-producing and all of the noncommercial fields are classified as probable or possible reserves. There are an additional 17 fields (Table 5) that have reported individual reserves ranging from 1 million barrels of oil (MMBO) to 1 BBO (IHS, 2001).

The 23 producing fields (Table 2, Figure 8) contain 83.3% of Iraq's recoverable oil reserves, and 78.3% of recoverable gas reserves. Five non-producing fields (Majnoon, Halfaya, Himreen, Ratawi, and Tuba) with proved individual reserves ranging from 0.6 to about 8.0 BBO are not yet on production.

.

Table 1.2 - Producing Fields, Iraq

No.	**Field** * giant field ** super-giant field	**Recoverable Oil Reserves**	**Proved Oil Reserves**	**Gas-Oil Ratio**	**Recoverable Gas Reserves**	**Proved Gas Reserves**	**Oil Gravity**	**Sulphur**
		Billion bbls	Billion bbls	SCF/STB	TCF	TCF	°API	Weight %
1	Abu Ghirab*	1.040	1.034	550	0.572	0.569	23.0	4.0
2	Ain Zalah	0.295	0.101	278	0.090	0.036	31.0	2.7-3.1
3	Anfal	0.030	0.030	66,667	1.766	1.745	57.0	0.0
4	Bai Hassan*	2.200	1.727	600	9.200	8.916	26.8-34.0	2.3-3.9
5	Balad*	1.380	1.372	290	0.400	0.398	25.0	NA
6	Butmah	0.080	0.038	500	0.040	0.019	29.3-36.2	1.1-2.6
7	Buzurgan*	1.800	1.675	650	1.080	0.999	24.0	3.7-3.8
8	East Baghdad**	16.000	15.987	156	2.500	2.498	23.0	4.0
9	Jabal Fauqi	0.730	0.727	550	0.450	0.448	19.0-26.0	3.8
10	Jambur*	3.100	2.985	1,500	9.200	9.026	41.0-49.0	1.3
11	Khabbaz*	2.000	1.980	1,500	3.000	2.970	36.0	1.9
12	Kirkuk**	25.000	10.823	480	8.220	2.795	36.0	2.0

13	Luhais*	1.060	1.011	480	0.500	0.477	32.5	2.2
14	Naft Khaneh	0.430	0.316	870	0.340	0.241	43.0	0.7
15	Nahr Umr**	6.500	6.500	NA	9.900	9.900	NA	NA
16	Qaiyarah	0.450	0.424	160	0.065	0.061	11.5-19.0	6.5-8.0
17	Rumaila N-S**	30.000	22.027	680	20.000	16.338	34.0	2.0-3.8
18	Saddam (Ajeel)	0.500	0.497	1,000	0.500	0.496	36.0	NA
19	Subba*	2.200	2.198	365	1.100	1.099	28.0	2.7
20	Sufaiyah	0.210	0.161	180	0.060	0.051	25.0	3.0
21	Tikrit	0.500	0.493	290	0.145	0.143	23.0	NA
22	West Qurna**	9.800	9.500	800	9.445	9.205	25.0	NA
23	Zubair**	8.200	6.878	500	5.920	4.862	27.5-36.0	1.7-3.5
	Total	113.505	88.486		84.493	73.2907		

SCF/STB : Standard cubic feet per stock-tank barrel TCF : trillion cubic feet ^{o}API : degree American Petroleum Institute a measure of oil gravity NA : not available weight % : a measure of H_2S content in weight percentage

It is likely that reservoirs in the producing fields have not been fully evaluated, and therefore the limited production history was analyzed in an attempt to estimate recoverable reserves of individual fields using decline curve analysis. Butmah, which has produced 52% of its known recoverable reserves, is the only field that appears to have adequate cumulative production to allow declinecurve analysis (Figure 1.9). Generally, reservoirs may have to produce about 35 to 50% of their reserve before a declining production trend can be observed on a cumulative production versus production rate plot. Analysis of Butmah's production indicates possibly higher recoverable reserves than the reported 80 MMBO (Figure 9). After 20 years of consistently high production rates with cumulative production greater than 34 million barrels, Butmah's sudden drop in production in 1973 seems to indicate operational problems or planned decreased production, rather than the effect of initial buildup or flush production. As of year-end 1998, Butmah had produced 42 million barrels or 53% of its initial reserves.

The remaining 22 producing fields do not show declining trends, indicating their cumulative production volumes to be less than 35 to 50% of their recoverable reserves. If a field does not show a definite production-decline trend, even after producing 50% of its reserve, then its reserve estimate needs to be re-evaluated. Ain Zalah field is a good example as it does not show any decline in its production, even after 194 MMBO (65% of its recoverable reserves) had been produced as of December 1998. Therefore, the recoverable reserves in Ain Zalah must be much higher than the reported 295 MMBO. Similarly, the super-giant Kirkuk field, with its cumulative production of more than 14 BBO does not show any signs of decline; thus its recoverable reserves must be in excess of the reported 25 BBO.

Based on the analysis of the reserve data, it is evident that reported average oil-recovery factors are generally low, and hence, the initial recoverable-reserve estimates are conservative. Summary of total and remaining oil and gas reserves by field, and important oil properties for producing oil and gas fields in Iraq. Anfal is a gas field, based on gas-oil ratio. Source: GeoDesign dataset, 1999.

1.4 Reserve Growth

Reserve (or field) growth in discovered accumulations is a well-recognized phenomenon in the oil industry (Klett and Schmoker, 2003). The IHS database provides initial reserve values on 13 Iraqi fields over a 20-year period (1981-2001), with data missing for some years. Analysis indicates reserve growth in ten fields, no growth in one field, and a slight decline in two fields. Of the ten fields with growth, the recoverable reserves in 6 fields grew by 1.0-to 2.1-fold (Figure 10), two fields grew by about 3.5-fold, one field grew by 13.5-fold; and one field, which grew by 32.5-fold in the 12th year, but then showed a decline in the 19th year resulting in an overall growth of about 23.3-fold by the 20th year (Figure 11). Among these fields, Majnoon and Nahr Umr (now named Bin Umr) were not producing as of end-1998, while West Qurna and Jambur showed much higher growth. The remaining six fields grew by 1.0 to 2.1 fold over the same 20-year period (1981-2001). An average growth for these six fields is about 1.6-fold (2.4% per year). For comparison, reserve in oil fields in the Volga-Ural Province of Russia grew 3.6-fold, and in the USA Lower 48 states by about 5-fold (Verma et al., 2000, 2001), also over a 20-year period. In addition, a 2-fold reserve growth in oil fields of West Siberian Basin has been reported; the basis being the first production or first reserve reporting year as the starting time (Verma and Ulmishek, 2003).

Table 1.3 - Non-Producing Fields, Iraq

No.	**Fields**	**Discovery Year**	**Estimated Total Reserve**	
			OIL	GAS
			‘Billion STB	‘TCF
1	Abu Khema	1977	0.100	0.075

2	Ahdab	1979	0.500	0.000
3	Akkas	1993	0.100	2.500
4	Amara	1980	0.250	0.000
5	Badra	1979	0.150	0.000
6	Chemchemal	1930	0.025	2.154
7	Dhufriya	1978	0.130	0.000
8	Diwan	1988	0.150	0.000
9	Gharaf	1975	0.500	0.000
10	Gilabat	1959	0.120	2.000
11	Halfayah	1975	0.700	0.700
12	Hamrin	1961	1.780	0.750
13	Huwaiza	1980	0.100	0.000
14	Jaria Pika	1976	0.000	0.918
15	Jawan	1937	0.100	0.025
16	Judaida	1978	0.200	0.000
17	Khanuqah	1930	0.100	0.200
18	Khashm Al Ahmar	1928	0.075	1.413
19	Kifl	1960	0.400	0.000
20	Kumait	1980	0.140	0.000
21	Majnoon	1977	7.600	5.600
22	Mansuriya	1978	0.050	3.284
23	Merjan	1983	0.200	0.100
24	Nahrawan	1981	0.250	0.000
25	Najmah	1934	0.200	0.045
26	Nasiriyah	1975	0.500	0.000
27	Nau Doman	1978	0.050	0.000
28	Noor	1977	0.500	0.000
29	Qara Chauq	1961	0.200	0.080
30	Qasab	1936	0.200	0.050
31	Qumar	1980	0.200	0.250
32	Rachi	1957	0.870	0.000
33	Rafidain	1976	0.500	0.000
34	Ratawi	1950	2.500	1.356
35	Rifaee	1980	0.070	0.000
36	Safwan	1977	0.400	0.250
37	Siba 1	1969	0.160	0.110
38	Taq Taq	1978	0.130	0.100

39	Tel Ghazal	1980	0.000	0.900
40	Tuba	1959	0.615	0.430
41	West Kifl	1987	0.400	0.000
*STB, stock tank barrel; TCF, trillion cubic feet.				

Potential hydrocarbon reserves in Iraqi nonproducing fields. Oil reserves in individual fields vary from 25 million to 7.6 billion barrels; gas reserves vary from a very low value to as much as 5.6 TCP. Source: GeoDesign dataset, 1999.

Table 1.4 - Marginal Fields, Iraq

No.	**Field**	**Discovery Year**	**Estimated Probable Reserves**	
			Oil	Gas
			‘Billion STB	‘TCF
1	Adaiyah	1938	0.010	0.000
2	Alan	1955	0.165	0.055
3	Atshan	1954	0.070	0.000
4	Chia Surkh	1905	0.040	0.000
5	Demirdagh	1960	0.040	0.040
6	Dujaila	1961	0.260	0.000
7	Fallujah	1958	0.180	0.000
8	Gusair	1954	0.035	0.000
9	Ibrahim	1957	0.030	0.000
10	Injana	1958	0.140	0.020
11	Jabal Kand	1980	0.030	0.000
12	Jraishan	1976	0.080	0.000
13	Makhul	1956	0.030	0.000
14	Pulkhana	1959	0.145	0.000
15	Qalian	1936	0.015	0.000
16	Rattan	1976	0.010	0.000
17	Sadid	1935	0.025	0.000
18	Samawa	1959	0.060	0.000
19	Sarjoon	1956	0.070	0.025
20	West Luhais	1974	0.050	0.050

‘STB, stock tank barrel; TCF, trillion cubic feet.

Oil- and gas-reserve estimates in noncommercial or uneconomical Iraqi fields. Oil reserves for individual fields vary from 10 to 260 million barrels, and gas reserves are low and in only a few fields. Source: GeoDesign dataset, 1999.

1.5 Undiscovered Resources

Undiscovered resources are the potential hydrocarbons that have not been established through drilling and production tests (McMichael, 2001). Virtually all of Iraq (440,000 sq km) lies within the northeastern part of the Arabian Basin, which extends from the Arabian Platform in the west to the Zagros Belt in the east (Figure 1.12a, b). The basin dates from the Precambrian, and contains more than 15 km of Infra-Cambrian to Recent sedimentary strata (Konert et al., 2001). The hydrocarbon potential of these rocks forms three major Total Petroleum Systems (TPS) in Iraq (Figure 1.7 and 1.12a, b; USGS, 2000).

Table 1.5 - Fields Under Evaluation, Iraq

No.	Field	Discovery Year
i	Abu Ghir	1939
2	Boheira 1	1999
3	Boliyah 1	1975
4	Hibbarah 1	1935
5	Hit 1	1939
6	Ismail 1	1997
7	Jabal Sanam 1	1978
8	Khidr Almaa	1982
9	Muhainya 1	1979
10	Mushorah	1949
ii	Nafatah 1	1938
12	Quwair	1929
13	Sasan	1956
14	Siba 2	1974
15	Sindbad 1	1976
16	Umm Qasr 1	1979
17	West Baghdad	1958

The USGS (2000) methodology requires knowledge of the discovery history of the assessment (a subdivision of the TPS), and an estimate of the range of potential sizes and all of which produce a light gravity (commonly greater than 40^{o}API), low-sulfur oil in the subbasin to the north of the Central Arabian Arch (Mahmoud et al., 1992; McGillivray and Al-Husseini, 1992; Cole et al., 1994a,c; Bishop, 1995; Aqrawi, 1998; Milner, 1998; Jones and Stump, 1999). The main source-rock interval (the so called ‘hot shale') is up to 65 m thick with total organic carbon (TOC) of as much as 16.6% and a hydrocarbon yield of 49 kilograms per ton, at the Akkas and Khliesa wells in western Iraq (Al- Gailani, 1996). The Paleozoic oils are generally devoid of H_2S (Al-Gailani, 1996; Al-Gailani et al., 1998; Aqrawi, 1998; Wender et al., 1998; Fox and Ahlbrandt, 2002). The Iraqi portion of TPS 202301 (Figures 1.7 and 1.12b) is estimated to contain undiscovered hydrocarbons ranging for oil from 0.5 (F_{95}) to 3.1 (F5) BBO with a mean of 1.6 BBO and for gas from 12.6 (F_{95}) to 68.8 (F_5) TCFG with a mean of 38.7 TCFG (Ahlbrandt et al., 2000), where F_{95} and F_5 are the 95% and 5% probability levels.

Iraqi oil and gas fields that have not been fully evaluated. With the exception of West Baghdad and Abu Ghir, all other fields have relatively smaller oil reserves that range from 1 to 300 million barrels. Estimated reserves of Abu Ghir and West Baghdad fields range from 0.4 to 1 billion barrels. Source: IHS database, 2001.

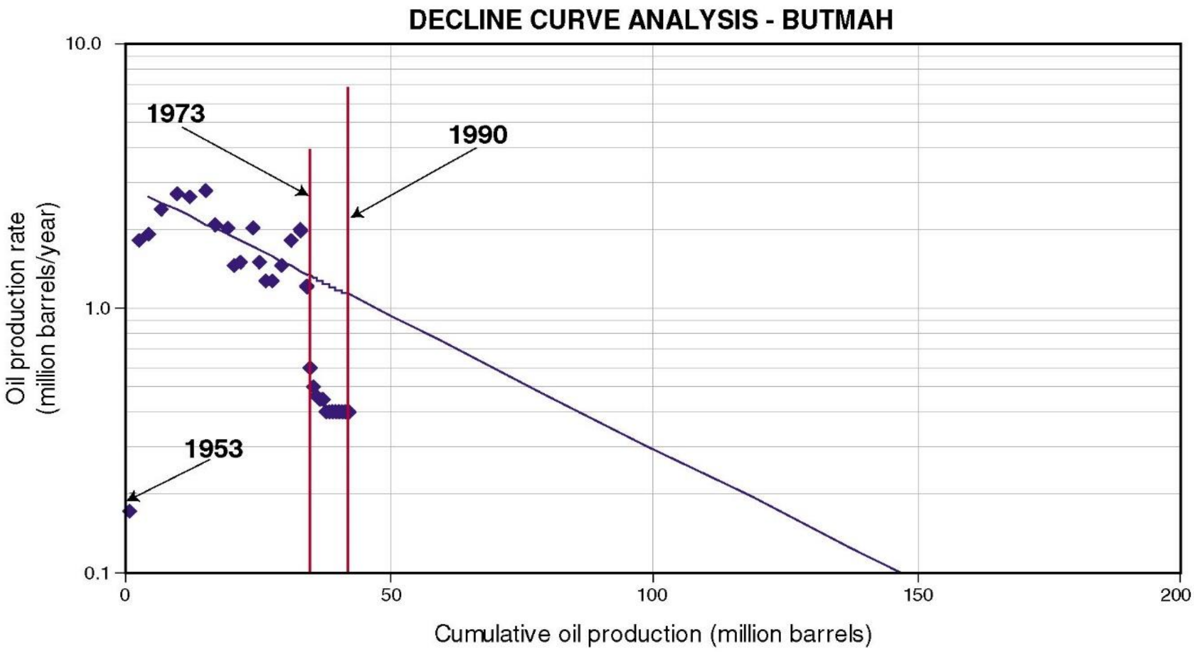


Figure 1.9 - Plot showing the production rate in million barrels per year versus cumulative production in million barrels for the Butmah oil field (discovery year 1953), Iraq. Recoverable reserves were reported as 80 million barrels and cumulative production of 42 million barrels (about 53% of initial reserve) as of year-end 1998. The decline-curve-analysis curve indicates higher reserves than reported. Source: IHS database, 2001.

The Jurassic Gotnia/Barsarin/Sargelu/Najmah System (TPS 202302, Figures 1.7 and 1.12b) consists of Middle and Upper Jurassic source rocks of the Sargelu, Naokelekan and Gotnia formations, and reservoirs of the same age in the Gotnia Basin of Iraq. The TOC in type II Kerogen source rocks ranges from 2 to 5%; oils have API gravity ranging from 25° to 35° API, and sulfur contents range from 1 to

4% (Cole and et al., 1994b; Alsharhan and Nairn, 1997; Sadooni, 1997; Pitman et al., 2003, in press). The TPS lies almost entirely in central and eastern Iraq, and extends into northwestern Iran (Figures 1.7 and 1.12a, b). The Iraqi portion of TPS 202302 (Figures 1.7 and 1.12b) is estimated to contain undiscovered hydrocarbons ranging for oil from 1.7 (F) to 9.2 (F5) BBO, with a mean of 5.3 BBO; and for gas from 5.0 (F_{95}) to 32.8 (F5) TCFG, with a mean of 17.6 TCFG (Ahlbrandt et al., 2000). The petroleum modeling used to support the Jurassic TPS assessment as well as the TPS 203001 assessment are described by Pitman et al. (in press).

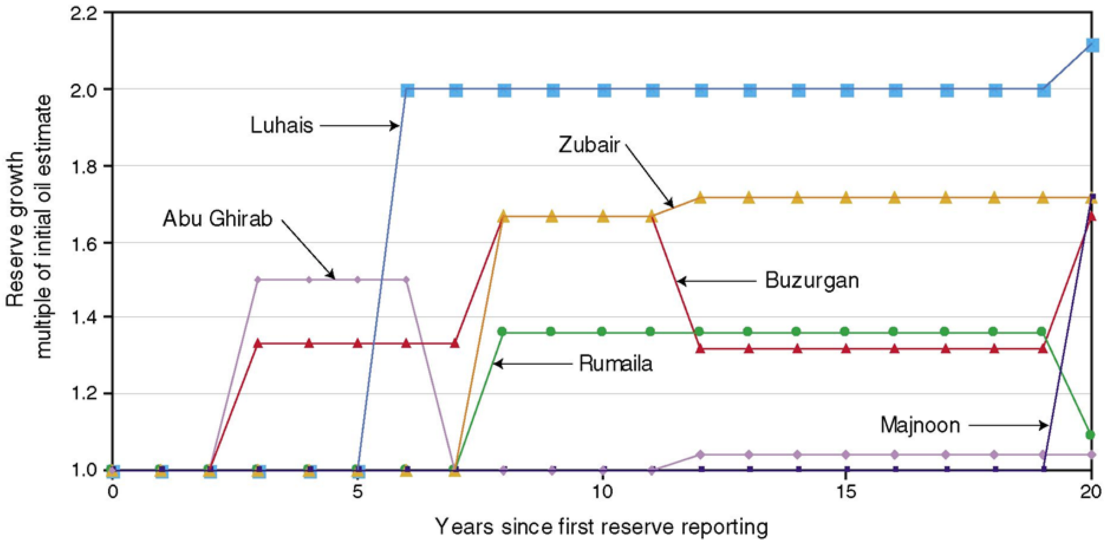


Figure 1.10 - Plot showing the reserve growth of two northern Iraqi fields - Bai Hassan, Jambur, and two southern Iraqi fields, Nahr Umr (now named Bin Umr) and W. Qurna, with large high reserve growth. Field growths in Jambur and W. Qurna are relatively high, whereas the two other fields are similar to the six fields shown in Figure 10. Source: IHS dataset from 1981 through 2001.

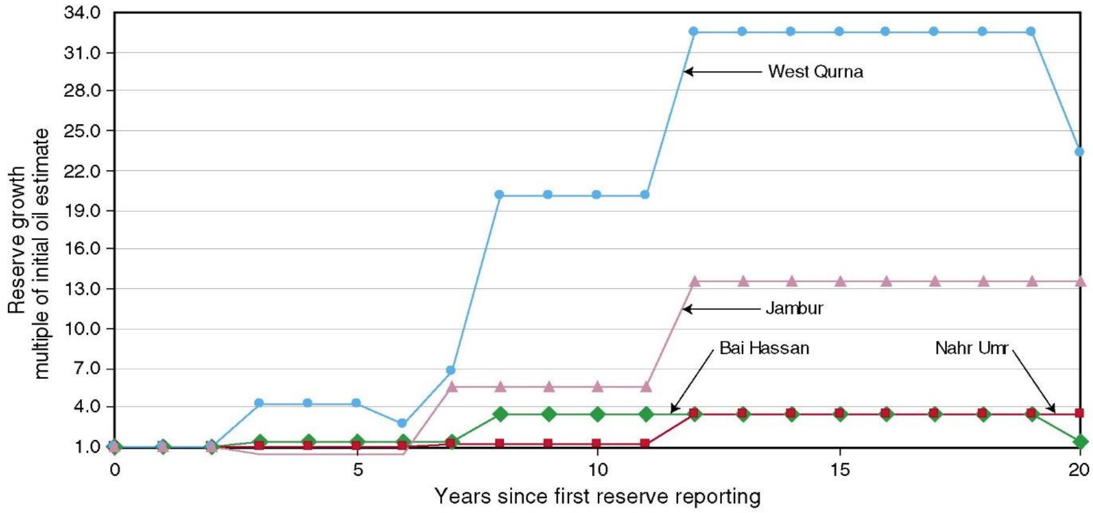


Figure 1.11 - Plot showing the reserve growth of some southern Iraqi fields - Abu Ghirab, Buzurgan, Luhais, Majnoon, Rumaila and Zubair. Source: IHS dataset from 1981 through 2001.

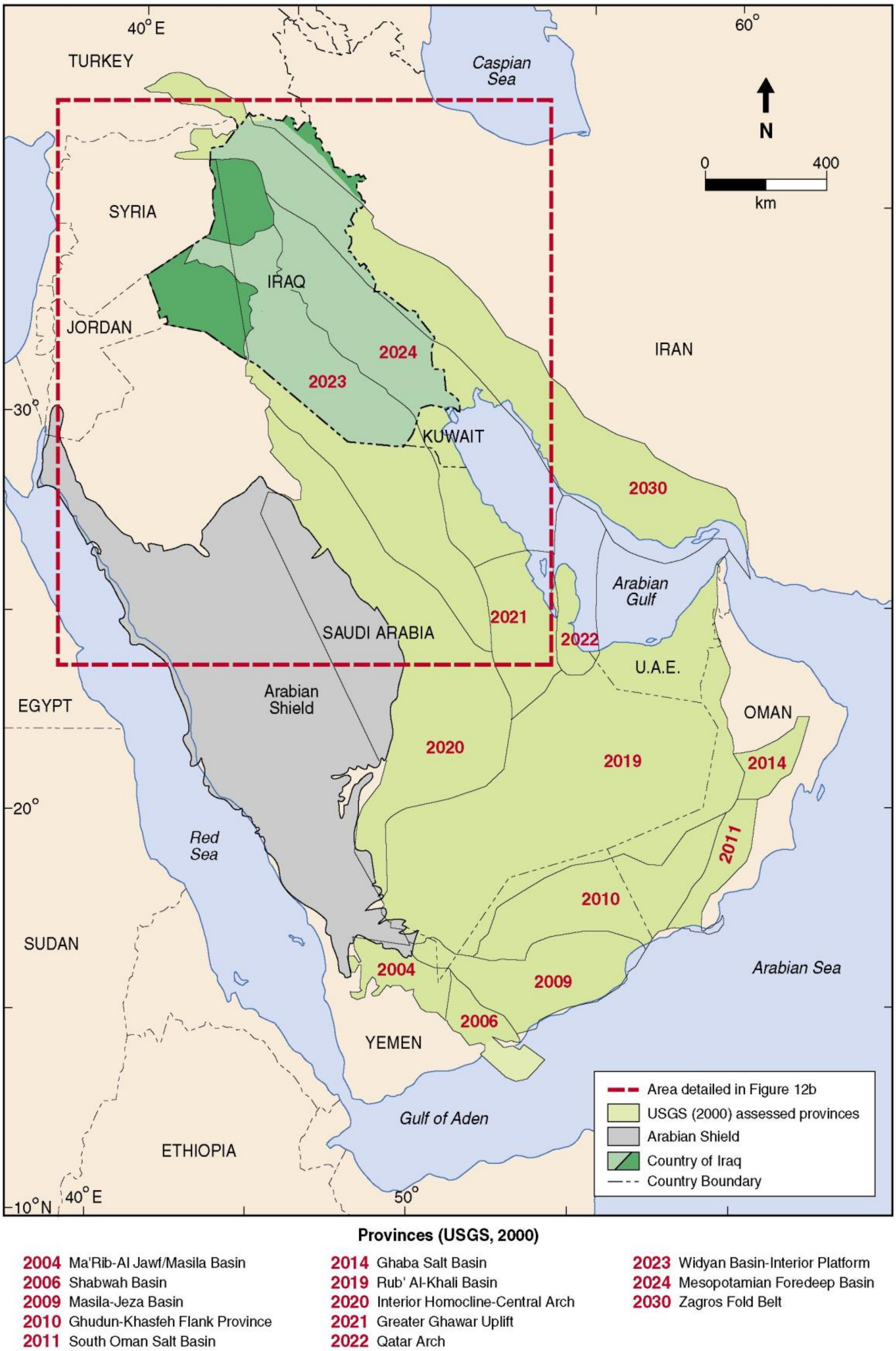


Figure 1.12 - Maps showing boundaries of Total Petroleum Systems (TPS) in and near Iraq.

(a) Provinces (4-digit code) as defined in USGS (2000) for Arabian Peninsula area. Arabian Shield outlined to the west.

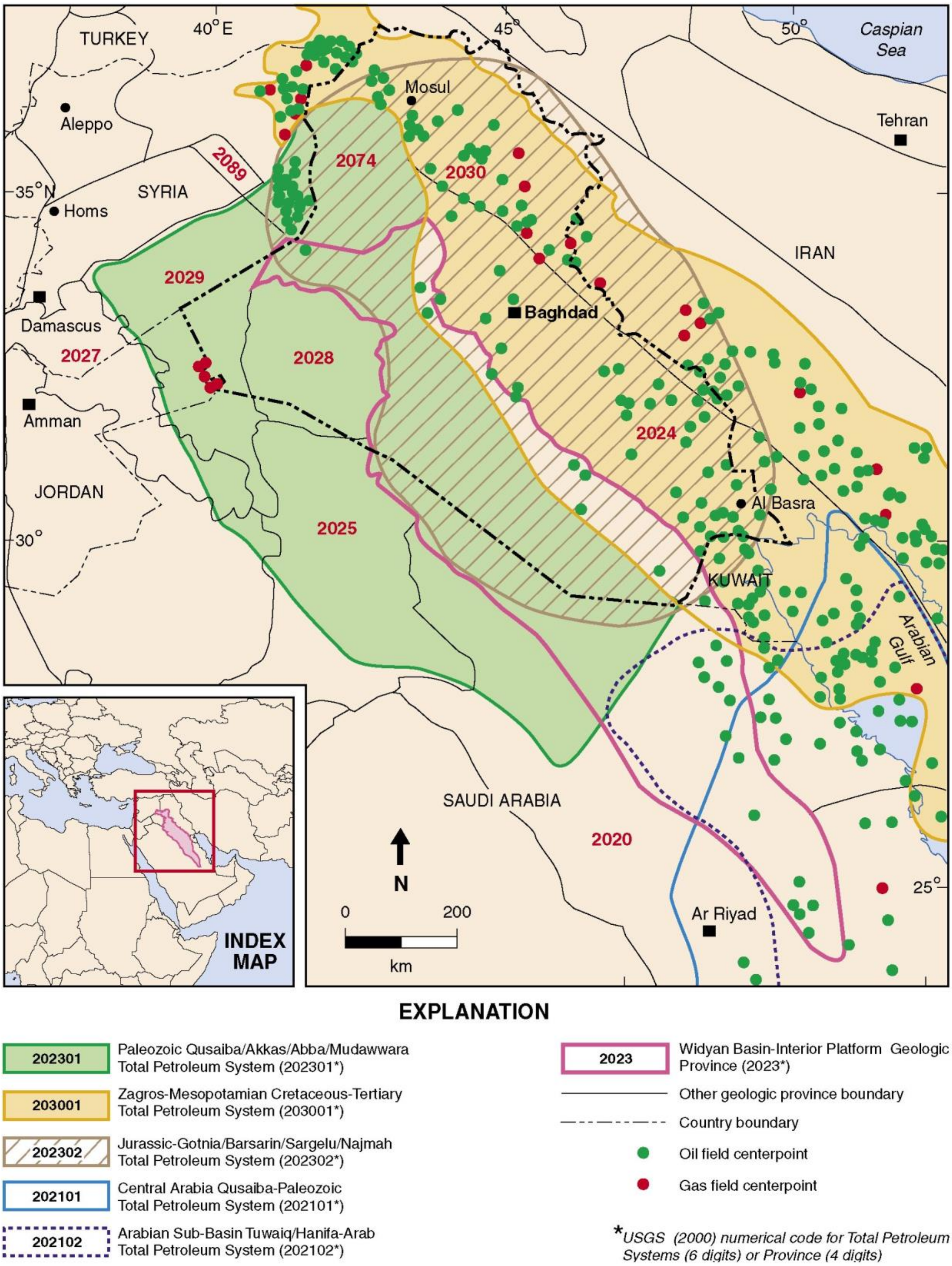


Figure 1.13 - (b) Total Petroleum Systems (TPS, 6-digit code), oil- and gas-field centers, and provinces (4-digit code) in and near Iraq as defined in USGS (2000). The Paleozoic Qusaiba/Akkas/Abba/ Mudawwara TPS (202301) and the Jurassic Gotnia/Barsarin/Sargelu/Najmah TPS (202302, hatched) were formally assessed in Iraq. The distribution of TPS that were assessed in adjacent countries includes the

Central Arabia Qusaiba-Paleozoic TPS (202101, blue outline). The Arabian Sub-Basin Tuwaiq/Hanifa-Arab TPS (202102, dashed line) and the Zagros-Mesopotamian Cretaceous- Tertiary TPS (203001) are also shown.

Total Petroleum System 203001: Cretaceous and Tertiary

The Zagros-Mesopotamian Cretaceous-Tertiary System (TPS 203001, Figures 1.7 and 1.12b) constitutes the single largest petroleum system in the USGS World Petroleum Assessment (2000). The Cretaceous reservoirs are deltaic sandstones and carbonates in the Zubair/Ratawi, Burgan/Nahr Umr and Ahmadi/Rutbah formations. Tertiary reservoirs include the Oligocene-Miocene Kirkuk Limestone. In addition to hydrocarbons generated by the Jurassic Sargelu Formation and equivalent source rocks, shale facies of the Sulaiy (Neocomian), Kazhdumi or Nahr Umr (Albian), Gurpi (Campanian- Maastrichian) and Eocene-Miocene Pabdeh formations are source rocks in some areas (Alsharhan and Nairn, 1997; Bordenave, 2000). The Iraqi portion of TPS 203001 (Figures 1.7 and 1.12b) is estimated to contain undiscovered hydrocarbons ranging for oil from 12.0 (F_{95}) to 71.7 (F5) BBO, with a mean of 38.2 BBO; and for gas from 19.2 (F_{95}) to 125.4 (F_5) TCFG, with a mean of 63.7 TCFG (Ahlbrandt et al., 2000).

Combined Undiscovered Potential

The combined hydrocarbon potential of the three TPS in Iraq for oil ranges from 14.2 (F_{95}) to 84.0 (F_5) BBO, with a mean of 45.1 BBO; and for gas from 36.8 (F_{95}) to 227.0 (F_5) TCFG, with a mean of 120.0 TCFG; and 6.2 BB of NGL (Ahlbrandt et al., 2000). Additional potential might exist in other Total Petroleum Systems (Ibrahim, 1978, 1983; Ziegler, 2001) for which there are limited data, such as the Triassic in northern and western Iraq (Sadooni and Alsharhan, 2004).

1.6 Iraq's Production History And Productive Capacity

Figure 1.13 shows the oil production history of Iraq and some of its major fields. Production began in 1927 from Naft Khaneh field at a rate of 1,100 BOPD. In 1934, Kirkuk field, with initial recoverable reserves of 16 to 25 BBO, was put on production, thus raising Iraq's production to more than 70,000 BOPD in 1935. Subsequently, other fields came on production and raised Iraq's production significantly (for example, Zubair in 1950, Rumaila in 1954 and Bai Hassan in 1960). Iraq's oil production peaked at about 3.5 MMBOD in 1979, at which time Kirkuk was producing 1.4 MMBOD and Rumaila 1.5 MMBOD (Figure 1.13).

Based on the location of facility infrastructure, the 23 producing oil fields in Iraq have been grouped into the north and south areas. In the north area, there are 12 developed oil fields (Ain Zalah, Bai Hassan, Butmah, East Baghdad, Jambur, Khabbaz, Kirkuk, Naft Khaneh, Qaiyarah, Ajeel - previously Saddam, Sufaiyah and Tikrit), one undeveloped oil field (Balad), and one gas field (Anfal). Of these, the four most productive fields are: (1) Kirkuk with the largest production capacity of 755,000 BOPD; (2) Bai Hassan with 95,000 BOPD; (3) Jambur with 45,000 BOPD; and (4) Khabaz with 5,000 BOPD. Also, four other fields have the potential to increase total production by about 15-30,000 BOPD from Ajeel (previously Saddam) and 5,000 BOPD from each of Ain Zalah, Butmah and Sufaiyah fields (UN Security Council, 2000). Thus, the total capacity of producing fields in the north area is about 930,000 BOPD. Six fields (Balad, East Baghdad, Jambur, Naft Khaneh, Qaiyarah, and Tikrit), with large productive capacities, were not on production as of March 2000 (UN Security Council, 2000).

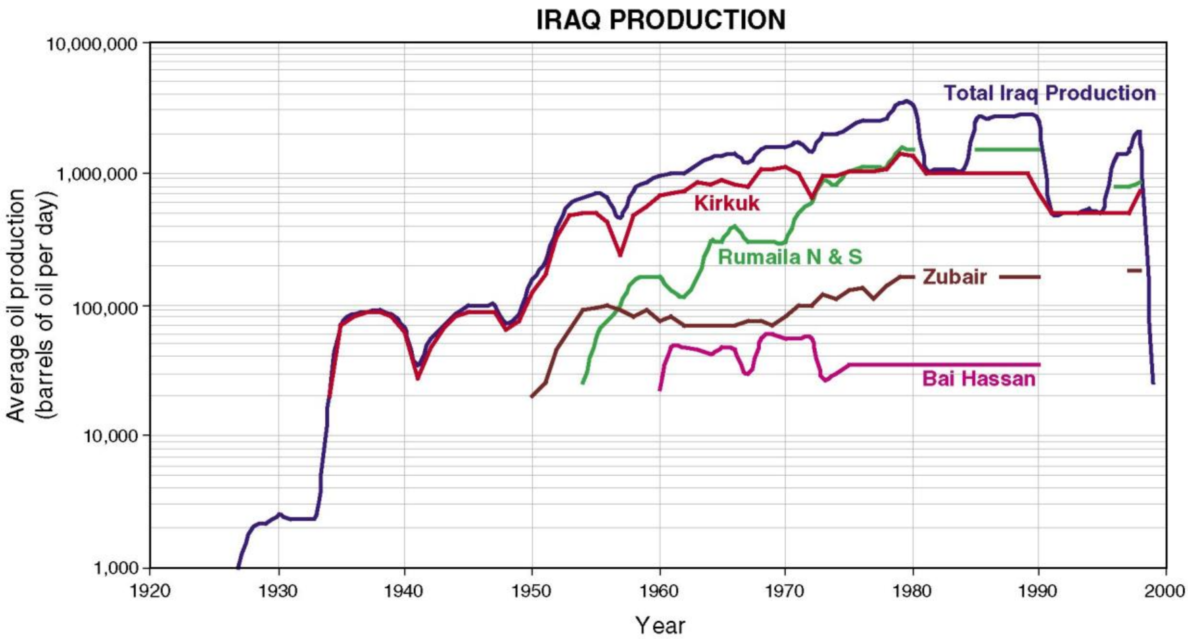


Figure 1.14 - Plot showing production history of major oil fields in Iraq, as well as the combined total production for all fields. Kirkuk is the largest producer. Other important contributors are Rumaila, Zubair, and Bai Hassan fields. Data source: GeoDesign 1999 dataset.

In the south area, there are seven developed fields (Abu Ghirab, Jabal Fauqi, Luhais, Rumaila, Subba, West Qurna, and Zubair) and two undeveloped fields (Bin Umr, and Amara). Rumaila, one of the four super-giant fields in the south, is operated as two separate fields, South Rumaila and North Rumaila. South Rumaila has a production capacity of 690,000 BOPD, North Rumaila 525,000 BOPD, Zubair 155,000 BOPD, West Qurna 55,000 BOPD, Amara 45,000 BOPD, Luhais 25,000 BOPD and Bin Umr 5,000 BOPD; thus, the total production capacity of the southern area is 1.5 MMBOD. Three developed fields (Abu Ghirab, Subba, and Jabal Fauqi) were not on production by March 2000 (UN Security Council, 2000).

Iraq's sustainable production capacity was expected to increase from its current 1.0 MMBOD to 2.8 MMBOD in 2004 (Khadduri, 2003). The two oil companies of Iraq - South Oil Company and North Oil Company, manage the upstream sector. They plan to restore the production capacity of the northern area to about 0.93 MMBOD, and boost the capacity of the southern area from 1.5 to more than 1.9 MMBOD. Also, the Iraq Ministry of Oil plans to restore pre-1990 production capacity of 3.5 MMBOD during 2004-2005 (Khadduri, 2003).

1.7 Prospects Of Waterflood, Improved And Enhanced Oil Recovery

Most Iraqi fields produce either medium- or light-gravity oil (Figure 1.14), except for a shallow Jeribe/ Euphrates reservoir in Qaiyarah field that has oil gravities ranging from 11.5° to 19.0°API, and a low recovery factor (17%). Some fields, such as Sufaiyah and Tikrit in the north, and Abu Ghirab, Jabal Fauqi, Buzurgan, Subba and East Baghdad in the south, produce medium-gravity oil (22-30°API) either from Cretaceous (clastic) formations - such as the Zubair, Nahr Umr sandstones and Mishrif carbonates, or Oligocene-Miocene carbonates in the Kirkuk Formation. The other fields produce light oil (greater than 30°API), and some, Kirkuk and Rumaila, are currently under waterflood. At Kirkuk, gas was initially injected into the Avanah Dome in 1957, but it was substituted by water injection in 1961 resulting in an increased rate of oil production (Al-Naqib et al., 1971). A study of waterflood performance in the Kirkuk Main Limestone reservoir showed that the recovery factor could range from 47 to 55%, depending on the relative contribution from fractures and matrix (Al-Naqib et al., 1971). However, the Avanah and Baba domes of Kirkuk field showed signs of substantial water encroachment, whereby some areas had 30 to 50 m of oil column left by the end of 2000 (UN Security Council, 2000). An evaluation of reservoir performance is required to prevent water breakthrough along the fracture system in the Kirkuk Main Limestone reservoir.

Oil recovery from reservoirs can generally be increased in most fields through the application of waterflood (Fanchi, 1984; Munn and Jubralla, 1987). Based on the performance of reservoirs around the world, waterflood recovery could range from 20 to 50% (Farouq, 1995), and therefore there is a potential for 10 to 15% additional oil to be recovered from most fields in Iraq, which could result in as much as an additional 45 BBO.

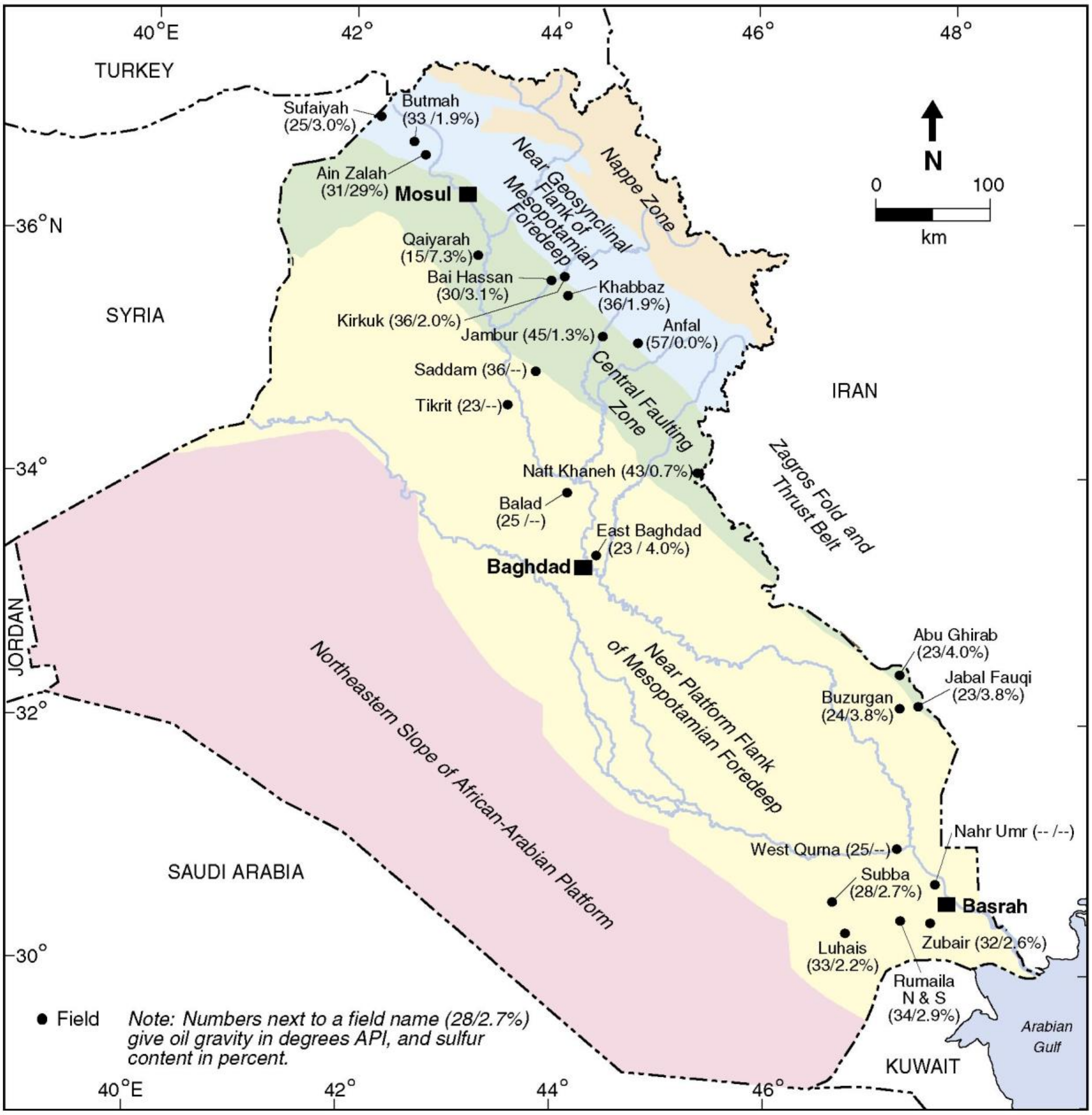


Figure 1.15 - Map showing locations of 23 producing fields with their reported oil gravities and sulfur contents. Data source: GeoDesign 1999 dataset.

In addition, application of improved oil recovery (IOR) techniques, which include horizontal drilling, advanced logging tools and interpretation, advanced well-completion techniques, 3-D seismic (for not only defining structures but also defining fracture orientation, and monitoring of the oil-water contact), and EOR methods (such as thermal recovery in heavy oil reservoirs, CO_2 injection and various other chemical injection methods in medium and light oil reservoirs) can further increase oil recoveries beyond those due to waterflood. These additional recoveries could range from 10-15% of initial oil-in-place, depending on the complexity of reservoir and the successful application of EOR methods (Stalkup, 1984; Farouq, 1995; Taber et al., 1996; Moritis, 2000). In the absence of reservoir and geologic data, and of the historical performance of various reservoirs, only an overall estimate can be made for additional oil reserve for Iraq's fields. Using a conservative estimate of only 1 to 6% of additional oil from application of the EOR methods, as much as 5 to 25 BBO would be added to that of waterflood recovery, for a total potential of 50 to 70 BBO of new resources.

1.8 Sour Crude in Iraqi Fields

Most of Iraq's oil fields produce sour crude with sulfur content in the range of 0.7 to 4.0%, except for Qaiyarah field (7%) (Figure 1.14) (GeoDesign, 1999). Only a few formations produce sweet crude oil; for example, Jambur field produces oil from two formations: (1) sweet crude from the shallow Tertiary (about 4,400 ft deep); and (2) sour crude from the deeper Cretaceous (5,100 ft deep). Paleozoic oils in the Western Desert fields have very low sulfur content, but are not in production. The crude oil from Mesozoic and Cenozoic formations requires the stripping of H2S during stabilization ahead of shipping. Consequently, the design of facilities for well heads, oil and gas separating plants, pipelines, and refineries needs to take into account the H_2S content of the fluids.

1.9 Iraq’s Upstream Infrastructure

There are two oil processing plants in north Iraq. One handles crude from Kirkuk (about 80% of its production), Khabbaz, Bai Hassan and Jambur and has a processing capacity of 1 MMBOD. The second plant at Saralu only handles Kirkuk oil and its capacity is 240,000 BOPD (UN Security Council, 2000). In the south, the processing plant at Rumaila handles about 1.5 MMBOD from the southern fields: Rumaila North and South, Zubair, West Qurna, Buzurgan, Luhais and Bin Umr. Other fields, such as Abu Ghirab, Subba and Jabal Fauqi, are also large and could increase the production capacity of the southern area. The water injection plant in the southern area, which has been injecting water into the Rumaila field since March 1999, is incapable of producing sufficient water for pressure support due to lack of spare parts (UN Security Council, 2000).

Section Conclusions

Fourteen fields in Iraq are currently in production, and 28 are awaiting development. The large structures having the potential to contain substantial resources and undeveloped fields probably represent one of the largest untapped hydrocarbon resources in the world. Most of the developed reservoirs are of Cretaceous age, and account for approximately 76% of total production. Tertiary production contributes about 23.9%, and the Jurassic, Triassic, and Ordovician production the remaining

0.1% (Al-Gailani, 1996).

Iraq's proved petroleum reserves, as of January 2003, are estimated to range from 100 to 113 BBO, and 97 to 110 TCFG (depending on the source of data), mostly from Cretaceous and Tertiary formations. At the end of 2002, cumulative production in Iraq is reported to be more than 22 BBO. In addition, an estimated 50 to 70 BBO may be recovered from known fields through application of waterflood and enhanced oil-recovery techniques. Based on large untapped petroleum potential and low recovery factors in the fields, higher reserve growths are expected in the future. Iraq has undiscovered potential from three Total Petroleum Systems (Paleozoic, Jurassic, and Cretaceous-Tertiary) with statistical distribution for oil from 14.2 (F_{95}) to 84.0 (F5) BBO, with a mean of 45.1 BBO; and for gas from 36.8 (F_{95}) to 227.0 (F5) TCFG, with a mean of 120.0 TCFG (Ahlbrandt et al., 2000). The size distribution of the undiscovered potential was estimated from known field sizes. To date, of the 526 identified structural prospects in Iraq, only 156 have been drilled and tested (Al-Gailani, 2003).

SECTION 2 WELL DESIGN.
SELECTION OF DRILLING EQUIPMENT AND TOOLS

2.1 Geological and technical drilling conditions

From 0 to 200 m there are sand, clay in layers of marl. They have II category from hardness and II category from abrasiveness. Reservoir pressure gradient is 0.0100 MPa/m and hydraulic fracturing pressure gradient is 0.0155. In this depth is possible absorption, landslides.

From 200 to 400 m there are chalk. They have II category from hardness and II category from abrasiveness. Reservoir pressure gradient is 0.0100 MPa/m and hydraulic fracturing pressure gradient is 0.0155. In this depth is possible absorption, landslides.

From 400 to 1020 m there are clay, sand and limestone. They have II category from hardness and V category from abrasiveness. Reservoir pressure gradient is 0.0103 MPa/m and hydraulic fracturing pressure gradient is 0.0160. In this depth is possible absorption, of drilling liquid landslides.

From 1020 to 1400 m there are argillite sandstone limestone and conglomerate .they have III category from hardness and VI category from abrasiveness .Reservoir pressure gradient is 0.0103 .MPa/m and hydraulic fracturing pressure gradient is 0.0160 in this depth is possible absorption, of drilling liquid landslides.

From 1400 to 1850 there are sand , clay, argillite and siltstone .they have II category from hardness and VI category from abrasiveness .Reservoir pressure gradient is 0.0103 mPa/mand hydraulic fracturing pressure gradient is .0.0166 .

From 1850 to 2980 there are siltstone sandstone and limestone .they have V category from hardness and VIII category from abrasiveness .reservoir pressure gradient is 0.0108 MPa/m and hydraulic fracturing pressure gradient is 0.0166 .in this depth is possible falling , narrowing of the wellbore .

From 2980 to 3750 m .there are argillite sandstone limestone .there have VI category from hardness and VIII category from abrasiveness .Reservoir pressure gradient is 0.0137 mPa/m and hydraulic fracturing pressure gradient is 0.0174 . in this depth is possible oil and gas manifestation.

From 3750 to 4550 m .there are argillite sandstone limestone .there have VI category from hardness and VIII category from abrasiveness .Reservoir pressure gradient is 0.0137 mPa/m and hydraulic fracturing pressure gradient is 0.0174 in this depth is possible oil and gas manifestation.

2.2 Selection and justification of the drilling method

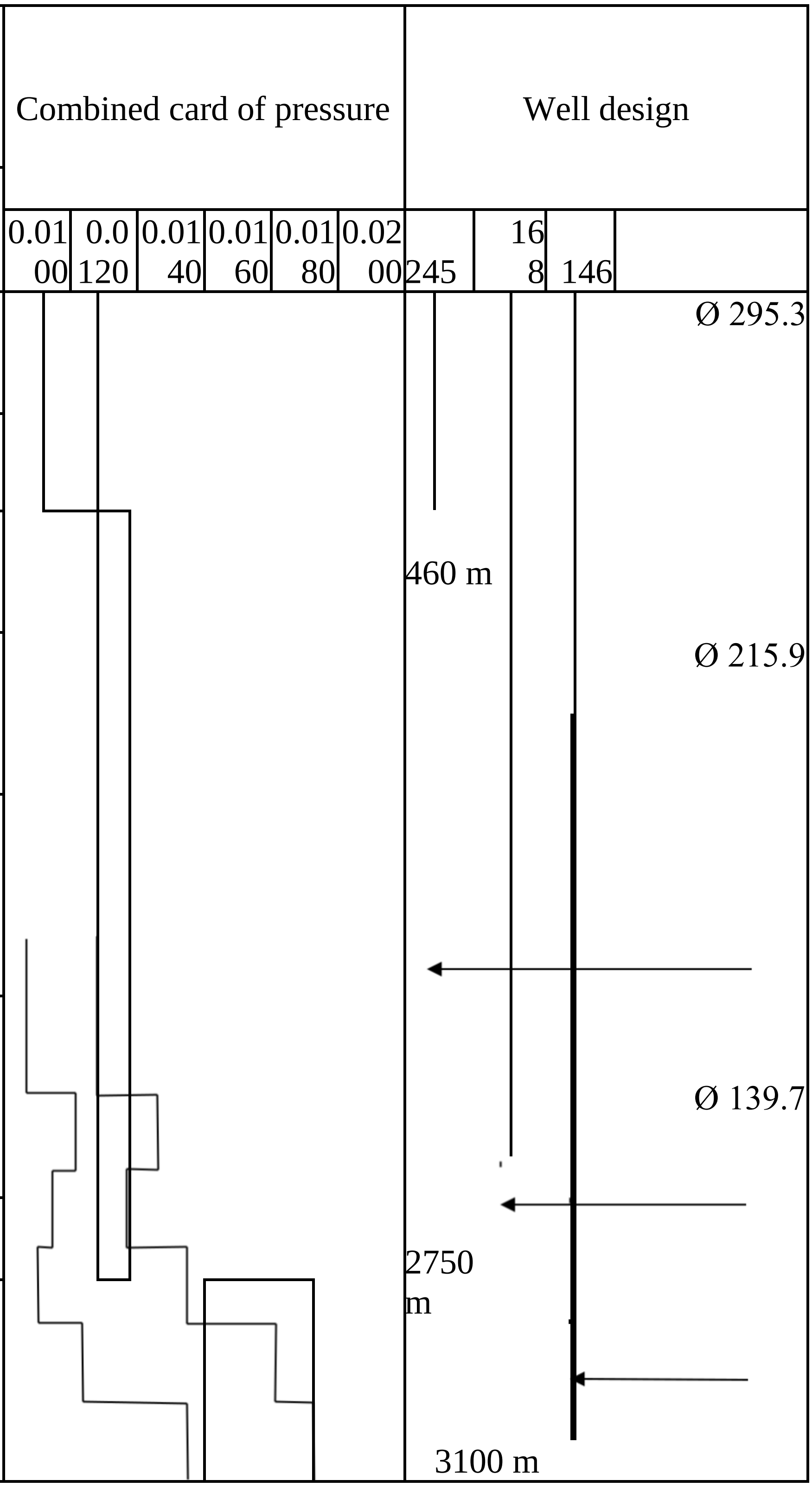
Project geological section along the well № 3

Occurrence interval, m	Lithological characteristics of sediments	Category		Pressure gradient, MPa/m		Expected complications
		From hardness	From abrasiveness	Reservoir	Hydro-rupture	
0-200	Sand, clay, marl,	II	II	0.0100	0.0155	Absorption, landslides
200-400	Chalk	II	II	0.0100	0.0155	
400-1020	Clay, sand, limestone	II	V	0.0103	0.0160	Absorption of drilling liquid
1020-1400	Clay, sand, limestone, conglomerate	III	VI	0.0103	0.0160	
1400-1850	Sand, clay, argillite, siltstone	II	VI	0.0108	0.0166	Falling, narrowing of the wellbore
1850-2980	Siltstone, sandstone, limestone	V	VIII	0.0108	0.0166	
2980-3750	Argillite, sandstone, limestone	VI	VIII	0.0137	0.0174	Oil-manifestation
3750-4550	Argillite, sandstone, siltstone	VI	VIII	0.0137	0.0174	

The diameter of the production casing is 146 mm.

Combined pressure schedule and well design

Occurren Ce interval, M	Pressure gradient, MPa / m	
	Reservoir	Hydro-rupture
0-200	0.0100	0.0155
200-400	0.0100	0.0155
400-1020	0.0103	0.0160
1020-1400	0.0103	0.0160
1400-1850	0.0108	0.0166
1850-2980	0.0108	0.0166
2980-3750	0.0137	0.0174
3750-4550	0.0137	0.0174



The diameter of the production casing is 146 mm.

1. The diameter of bore bit under a production casing is delineated after equation

$$Д^э_д = Д_м + 2$$

$$=127 + 2*5=137 \text{ mm}$$

Standard bit

$$Д^э_д = 139.7 \text{ mm}$$

2. Delineate the bore diameter of the previous boring casing, coming from that a difference between the bore diameter of previous column and bit diameter must be a 6-8 mm, so

$Д_в = Д_д + (6÷8)$

$$Д_в = 139.7 + 7 = 146.7 \text{ mm}$$

3. Standard casing

$d^{пр}_н = 168$ мм; $d^{пр}_{вн} = 153.7$ мм; $d^{пр}_м = 187.7$ мм.

4. Drill bit for intermediate casing

$$Д_д = Д_м + 2$$

$$Д_д = 187,7 + 2*10 = 207,7 \text{ mm}$$

5. Standard bit

$$Д^э_д = 215.9 \text{ mm}$$

6. Surface casing

$Д_в = Д_д + (6÷8)$

Дв = 215.9 + 7 = 222.9 mm

7. Standard surface casing diameter

к

dн = 245 мм; dвн

228.7 мм; dк м

= 269.9 мм.

8. Drill bit for surface casing

Дэд

Дэд = 269,9 = Дм +2

+ 2 *10 =289.9 mm

9. Standard bit

Д = 295.

2.3 Drilling Technologies

Oil well drilling is a complex operation and the drilling industry engages the services of personnel and a complicated array of machinery and materials to drill an oil/gas well to depths greater than 6000 meters, The drilling industry has seen technological progress, however, these advances have not changed the fact that, besides the use of complicated machinery, successful drilling is a result of tremendous team effort. Numerous personnel from the operating company and several service companies work together to drill and complete an oil/gas well.

A drilling rig is used to drill a hole, and this requires qualified personnel, different types of equipment the application of a great variety of technology.

When a drilling project is commenced, two goals must be achieved:

1. To drill and finish the well in a safe manner (personal injuries, technical problems) and according to its purpose;
2. To complete the project with minimum cost.

The overall costs of the well must be optimized and this optimization may influence where the well is drilled (onshore – extended reach or offshore above reservoir), the drilling technology applied (conventional or slim-hole drilling) as well as the evaluation procedures run to gather subsurface information for future drilling projects.

Rotary drilling is the most efficient technology applied in the oil and gas industry.

It is a drilling technology that relies on continuous circular rotation of the bit to break rocks, while drilling fluids circulate through the bit and up the wellbore to the surface, making possible to drill safely and efficiently the well.

2.4 Rotary drilling rig

The drilling rig consists of a set of equipment and machinery located on the so-called drilling site and normally the rig is not owned by the oil company but by drilling service companies, which hire out the rig complete with operators and which construct the well according to the client's specifications.

The most important items of equipment are shown in the figure below

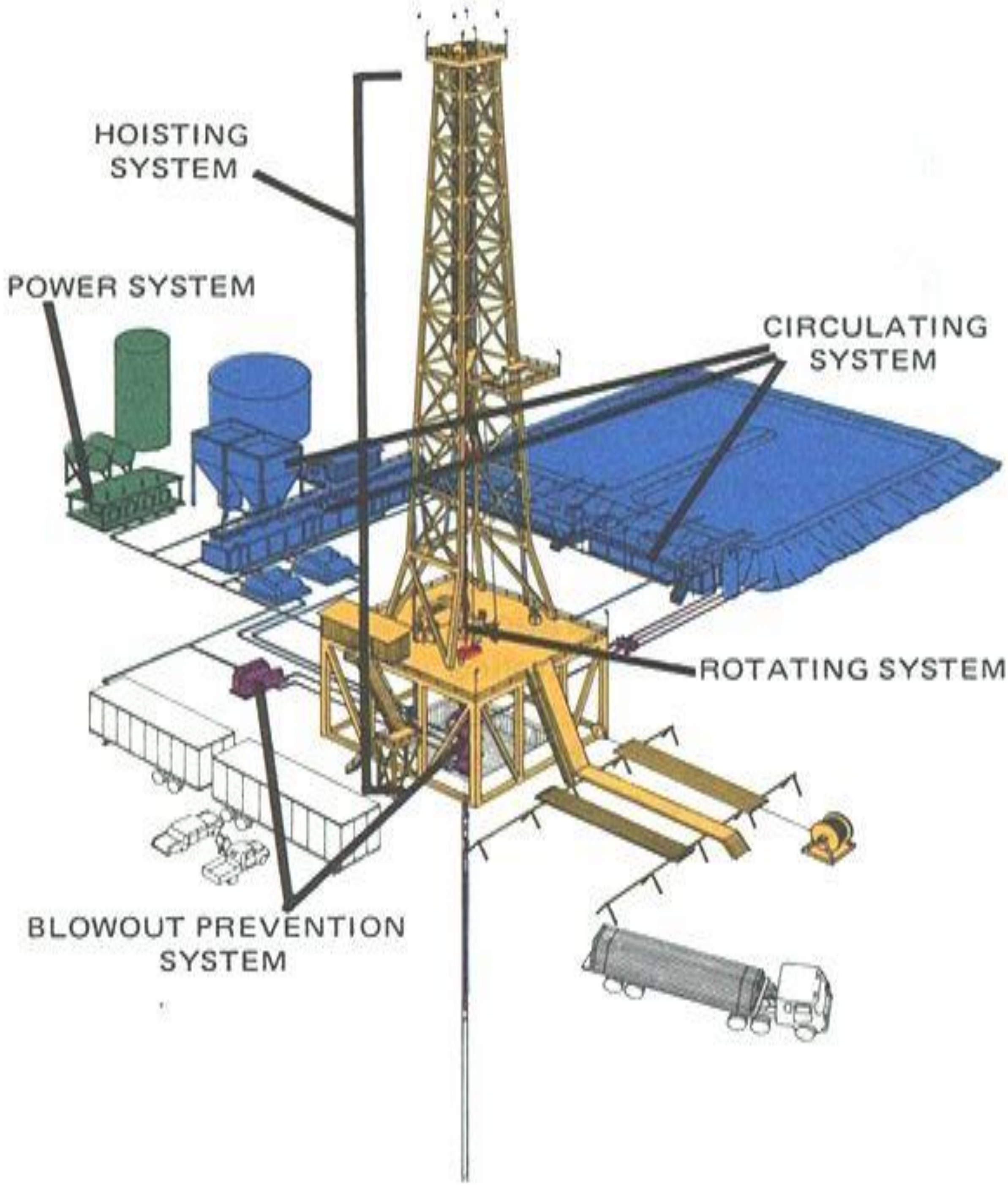


Figure 2.1 - Drilling Rig Systems

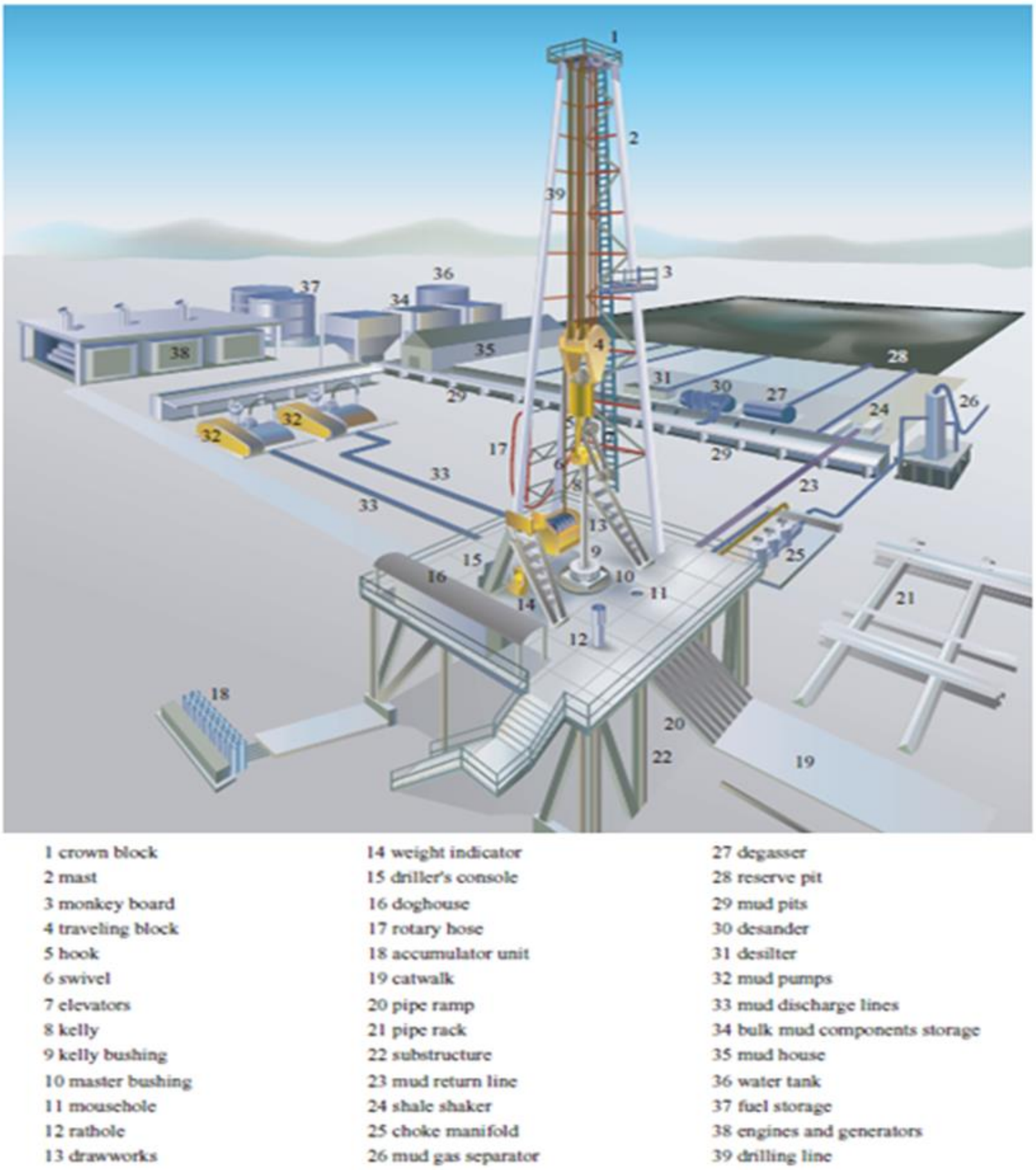


Figure 2.2 - Main Equipment of a Rotary Drilling Rig

A drilling rig is composed of different systems:

- The hosting system
  - It the set of equipment necessary for handling any material inside the well(drill string and the casing);
  - It consists of a structural part (derrick/mast and substructure), the complex of the crown and travelling block, the drawworks (hoist) and the drilling line;
  - The substructure is the supporting base for the derrick, the drawworks and the rotary table, and constitutes the working floor for operations, or drilling floor.

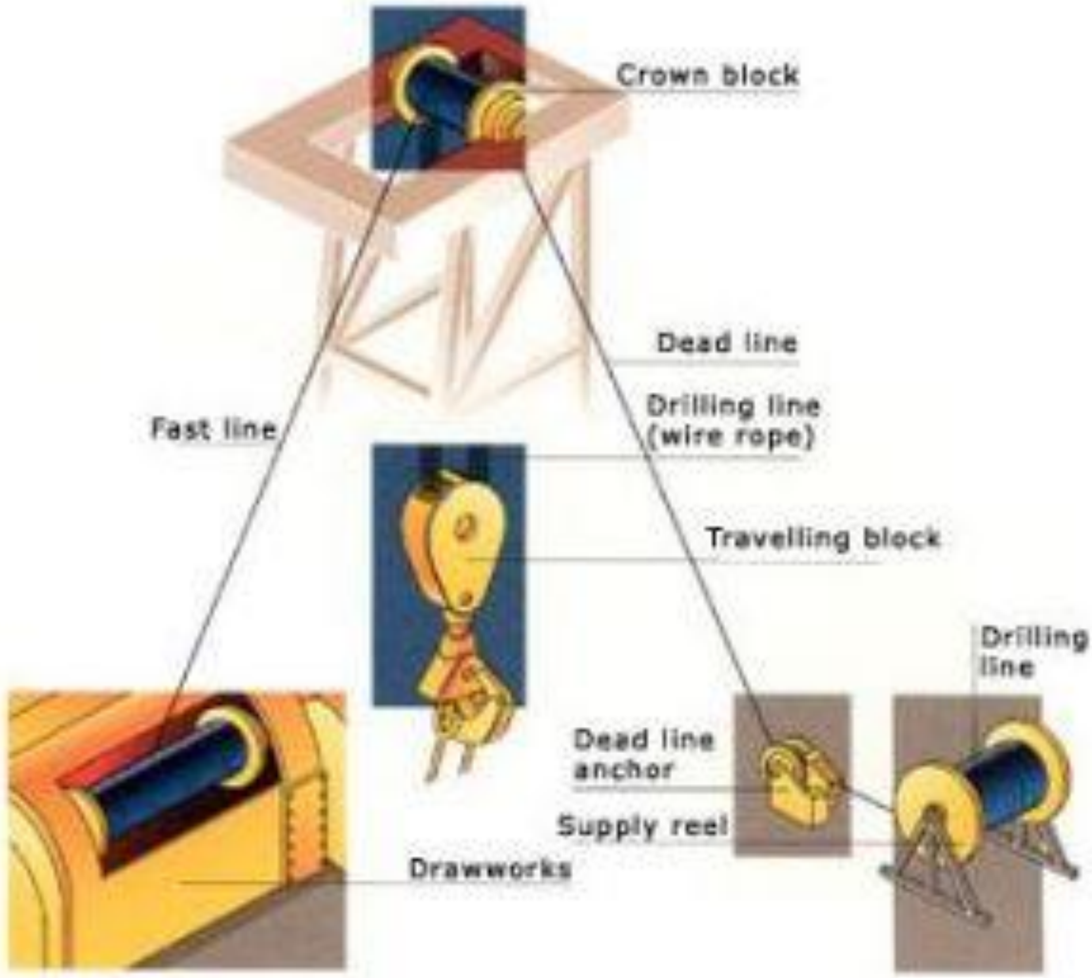


Figure 2.3 - The Hosting System

Figure 2.4 - The Derrick Types

Figure 2.5 - The Mast Types

- The rotating system
  - The rotating system allow the rotation of the drill string, and it consists of the rotary table, the kelly and the swivel;

- In modern rigs, a *top drive* groups together the functions of the above three items of equipment.

Figure 2.6 - The Top Drive System

The Kelly System

- The circulation system
    - The circulation system consists of mud pumps, distribution lines, and the mud cleaning and accumulation system;
    - It is the closed hydraulic circuit which allows the mud to flow from the surface to the bottom of the hole, inside the drill string, and subsequently back to the surface, in the drillstring borehole annulus;
    - The mud from the hole has to have the cuttings removed before being reinjected to the bottom of the hole and the mud pumps supply the energy necessary for circulation;
    - The choice of drilling fluid is dictated mainly by the characteristics of the formations to be drilled, by their drillability and reactivity to water, and by problems of disposing of the spent fluid;
    - Drilling fluids have many functions to perform including:
        - *The removal and transport to the surface of the cuttings produced by the bit;*

- *The control of the formation pressure;*
- *The prevention of caving and collapse of the borehole walls;*
- *The slowing down of the sedimentation of the cuttings when circulation stops;*
- *The cooling and lubrication of the drilling equipment;*
- *The sources of geological and stratigraphic information.*

- Drilling fluids are subdivided into three major classes:
  - Water based muds;
  - Oil based muds;
  - Air -based muds (used to reduce bottomhole pressure, to avoid circulation losses in surface layers, or to limit damage to productive formations).

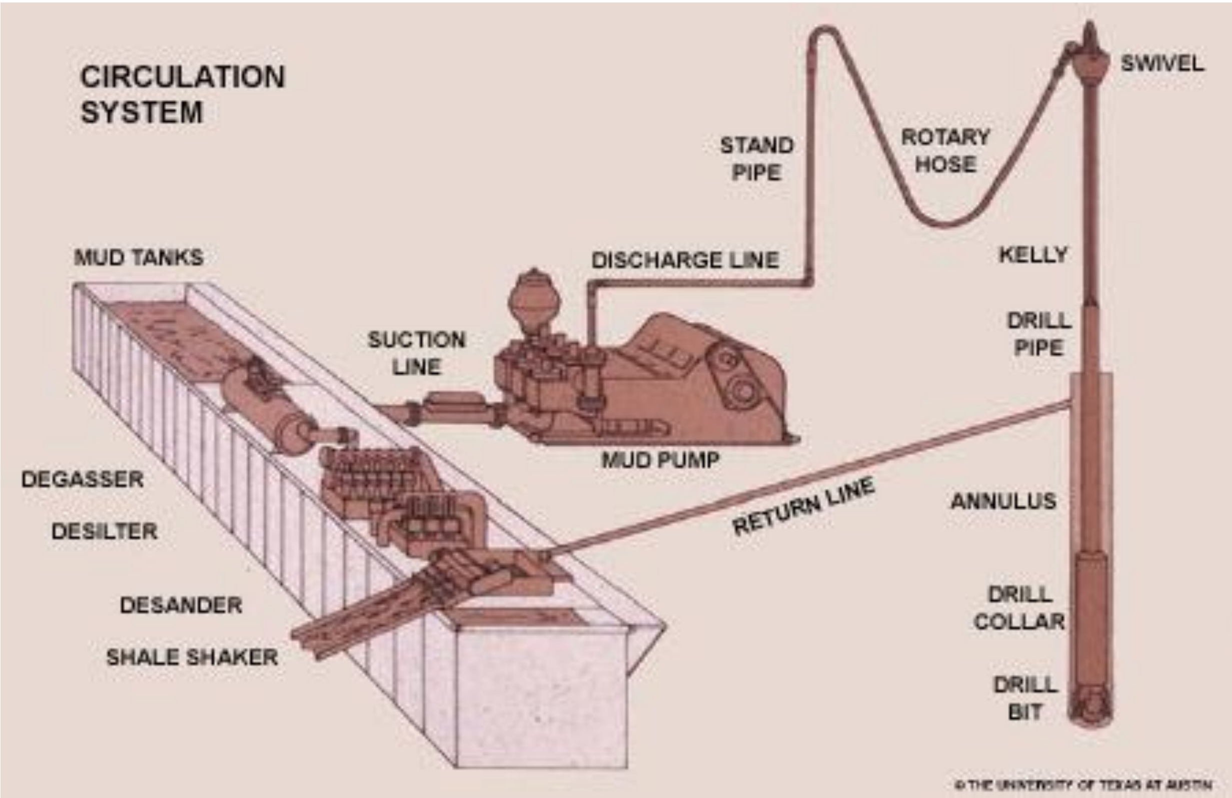


Figure 2.7 - The Circulating System (from University of Texas)

- The power generation system
  - A power generation system is needed to run the machines driving the main components of the rig and it is provided by diesel engines, diesel-electric engines;
  - Power is transferred from the engines to the different rig systems by belts, chains, and drive shafts on a mechanical rig, or by generatedDC electrical power on an electric rig and it is distributed to the rotary table and mud pumps and to the drawworks.

Figure 2.8 - *Drilling Rig Power Generation System*

2.5 The drill string

The drill string is an assemblage of hollow pipes of circular section, extending from the surface to the bottom of the hole.

It has three functions:

- it takes the drilling bit to the bottom of the hole, while transmitting its rotation and its vertical load to it;
- it permits the circulation of the drilling fluid to the bottom of the hole;
- it guides and controls the trajectory of the hole.

Starting from the surface, drill string consists of:

- a kelly, drill pipes, intermediate pipes, drill collars and a number of accessory items of equipment (stabilizers, reamers, jars, shock absorbers, downhole motors, etc.), and it ends with the bit;
- The bit is connected on to the end of the drill string – it is the tool that bores the rock, transforming it into fragments called cuttings, which are then transported to the surface by the drilling fluid;
- The choice of the type of bit depends on the hardness, abrasiveness and drillability of the rock formation.

Figure 2.9 - A PDC Bit An Insert Tricone Bit
Main Components of a Drill String (from National Oilwell Varco)

2.6 Casing

- Casing is a steel tube that starts from the surface and goes down to the bottom of the hole, and is rigidly connected to the rocky formation using cement slurry, which also guarantees hydraulic insulation.
- The casing supports the walls of the hole and prevents the migration of fluids from layers at high pressure to ones at low pressure.
- Furthermore, the casing enables circulation losses to be eliminated, protects the hole against damage caused by impacts and friction of the drill string, acts as an anchorage for the safety equipment (BOPs, Blow Out Preventers) and, in the case of a production well, also for the Christmas tree.
- The dimensions of the tubes, types of thread and joints are standardized (API standards)and the functions and names of the various casings vary according to the depth.
- Starting from the uppermost and largest casing, first comes the conductor pipe, then the surface casing and the intermediate casing, and finally the production casing.

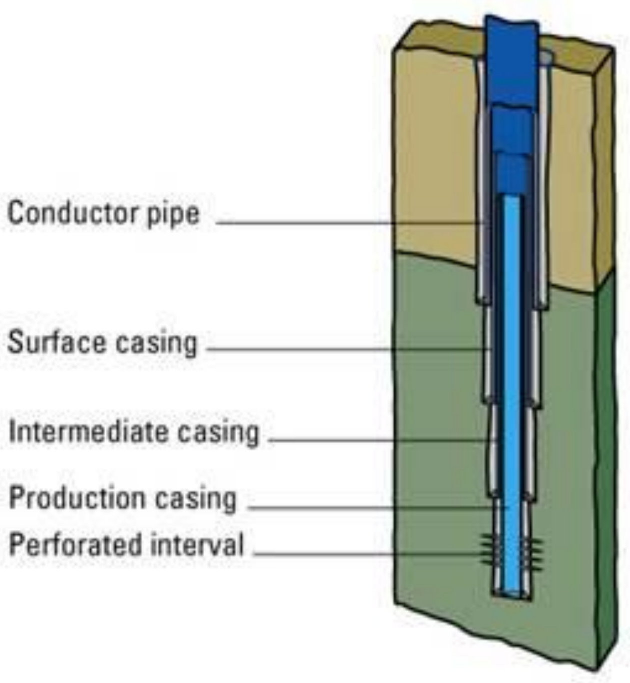


Figure 2.10 - *Casing Strings (from Schlumberger)*

2.7 Cementing

Cementing is the operation of pumping a cement slurry between the casing and the formation, and can be performed by injection into the annulus from inside the casing.

The cementing (primary cementing) serves to rigidly connect the casing to the formation and to guarantee the hydraulic insulation of the various formations, preventing the migration of the fluids from layers at high pore pressure to those at low pressure.

The centralization of the casing is particularly important, as the geometry of the well is seldom regular, but tortuous and with a variable diameter.

All other cementing operations carried out after the primary operation, either to correct an earlier not very effective cementing operation, or for other purposes (repair of a damaged casing, setting cement plugs, squeeze operations, and so on), are called secondary cementing.

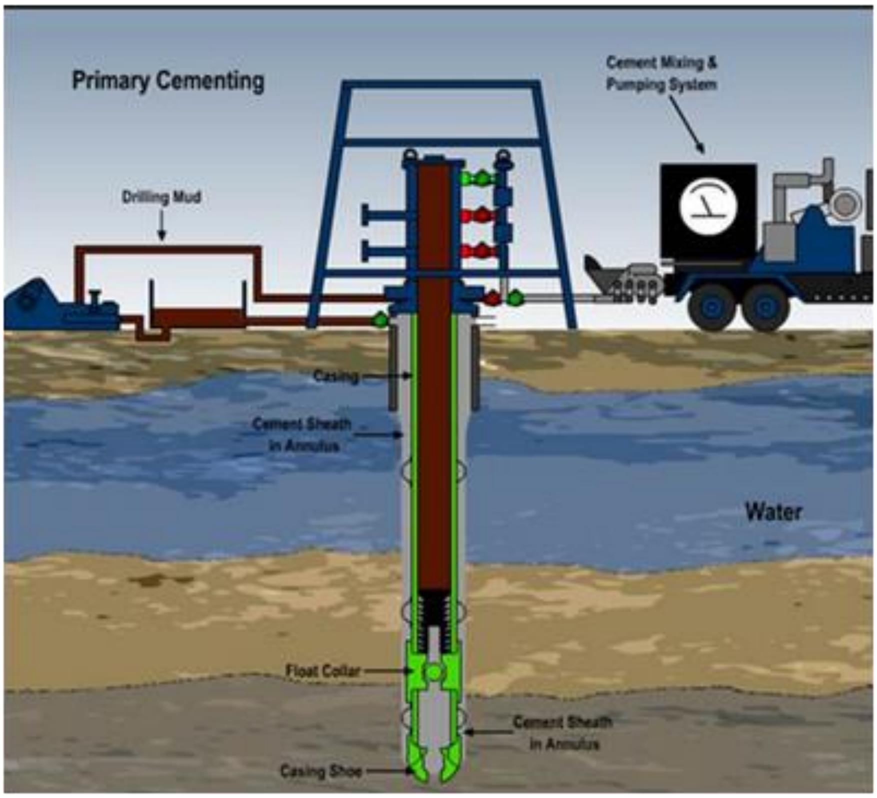


Figure 2.12 - *Primary cementing*

The wellhead and safety equipment (BOP)

The wellhead and the safety equipment are the valve units that allow the well to be insulated from the outside environment.

In this way it is possible to control effectively and safely the pressures that develop in the well when it is in hydraulic communication with the subsurface formations.

The wellhead is a fixed unit that connects the various casings set inside the well.

If it is a producing well, this unit remains there until the end of drilling, and is completed with the production head or Christmas tree.

The safety equipment, known as Blow Out Preventers (BOPs), are large valves located on the wellhead during drilling operations able to fully shut-in the well in case of need (Well control).

BOPs on onshore rigs and fixed offshore rigs (platforms, jack-ups) are installed on the surface wellhead, while for floating rigs they are located on the seabed, on the subsea wellhead.

The shut-in of the well is necessary when hydraulic control is lost, i.e. when the pressure of the underground fluids is greater than that of the bottomhole mud.

A standard BOP stack consists, starting from below, of:

- one or more spools for connection to the wellhead; a dual function ram preventer; a single-function ram preventer; an annular blowout preventer; a lateral tube, which conveys the outgoing mud from the well to the shaker; a number of lateral connections (*kill line* and *choke line*), necessary for operations to restore hydraulic balance after well control problems.

The BOP stack has the following functions:

- to shut-in the well around any type of equipment; to permit pumping of the mud, with the well closed by means of the kill line; to discharge through the choke line any fluids that might have accidentally entered the well; and to allow the vertical movement of the string, upwards or downwards, when the well is closed (*stripping*).

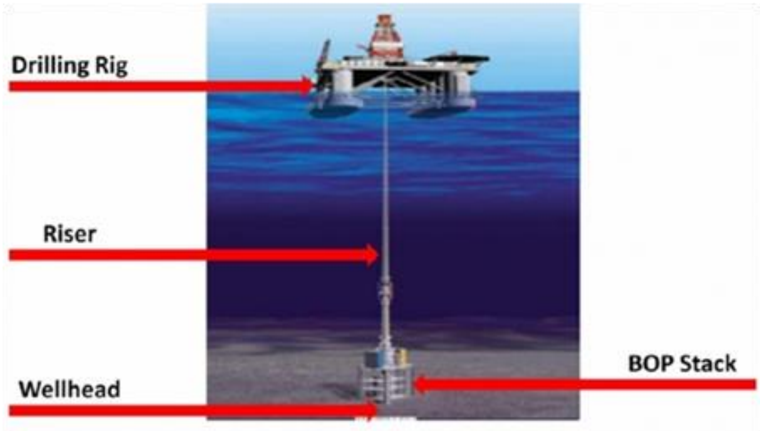


Figure 2.13 - *Land BOP Stack* *A* Subsea BOP Stack

Directional drilling

Directional drilling is the science of deviating a well bore along a planned course to a subsurface target whose location is a given lateral distance and direction from the vertical.

At a specified vertical depth, this definition is the fundamental concept of “controlled” directional drilling even in a well bore which is held as close to vertical as possible as well as a deliberately planned deviation from the vertical.

Directional drilling is, therefore, a technique that makes it possible to reach deep mining targets even at a considerable horizontal distance from the location of the surface rig.

Each of these shapes meets specific operational demands.

During the drilling process, on the basis of the information as and when it is relayed to the drilling engineer, both the inclination and the direction can still be modified (*navigational drilling)*.

2.8 Applications of directional drilling

Directional drilling is used in a number of operational situations, the most recurrent of which are listed below:

- *Sidetracking, Inaccessible Locations, Salt Dome Drilling, Fault Controlling, Multiple Exploration Wells from a Single Well-bore, Offshore Multiwell Drilling, Relief Well, Horizontal Wells*

Configurations of a directional well

Directional and horizontal wells are drilled on the basis of a design that follows precise technical criteria in order to obtain a regular and 'practicable' hole both at the drilling stage and during all of its subsequent productive life.

Broadly speaking, the drilling of a directional or horizontal well has the following operating stages:

*Beginning of the drilling, Deviation of the well, Constant inclination, S-shaped hole(i*f the design envisages an S-shaped hole to reach the target, or a decrease in the inclination angle to a pre-determined value, at the established depth the inclination of the hole path begins to be decreased by a prefixed gradient – Drop-Off Rate).

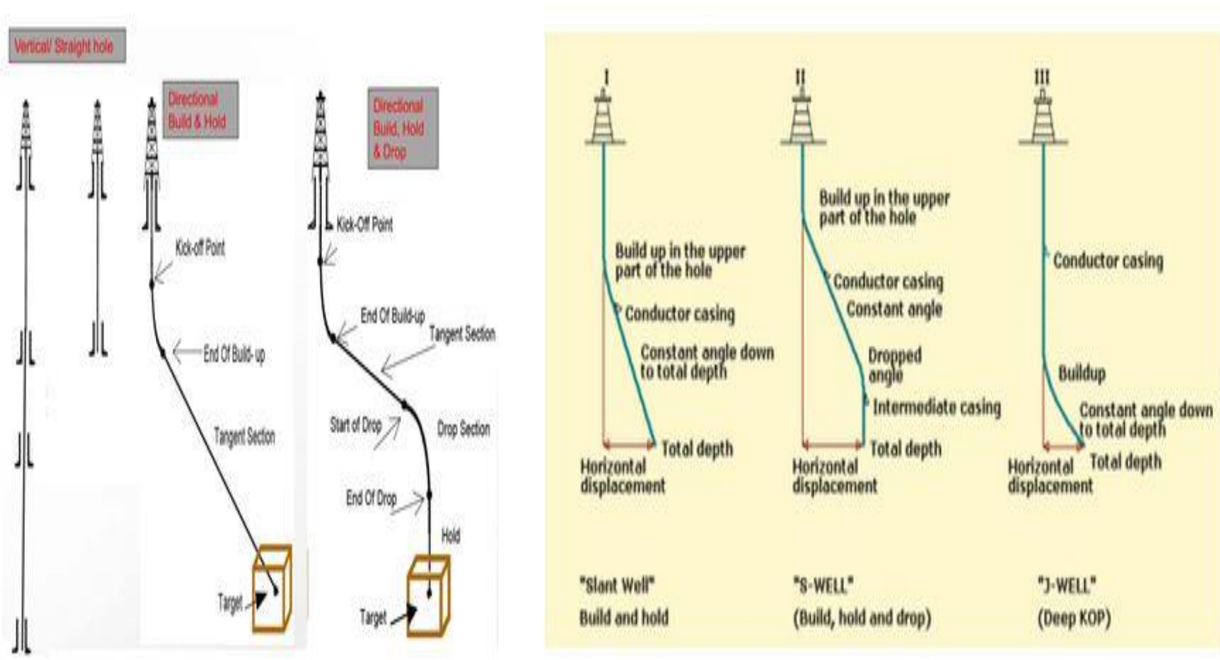


Figure 2.14 - *Typical Well Profiles and Terminology (from National Oilwell Varco)*

Configurations of a horizontal well

Horizontal drilling is the process of drilling a well from the surface to a subsurface location just above the target oil or gas reservoir called the “kickoff point”, then deviating the well bore from the vertical plane around a curve to intersect the reservoir at the “entry point” with a near-horizontal inclination, and remaining within the reservoir until the desired bottom hole location is reached.

Oil companies are often able to develop a reservoir with a significantly smaller number of wells, since each horizontal well can drain a larger rock volume than a vertical well could.

The aggregate surface “footprint” of an oil or gas operation can be reduced by use of horizontal wells.

The use of a horizontal well may reverse or significantly delay the onset of production problems that engender low production rates, low recovery efficiencies, and/or premature well abandonment.

Horizontal wells can schematically be subdivided into three main categories according to the angular gradient with which the horizontal section is reached:

- *Long-radius wells* use standard technology to drill directional wells and the BUR may vary between 3° and 8° every 30 m and requires 2 or 3 sections;
- *Medium-radius wells use* standard equipment, although suitably modified to face the problems arising during horizontal drilling and the BUR increases significantly compared to the preceding case(between 8° and 20° every 30m);
- *Short-radius wells* make possible a build-up rates ranging between 30° and 60° every m and therefore has the possibility to arrive to the horizontal section in less than 3 m.

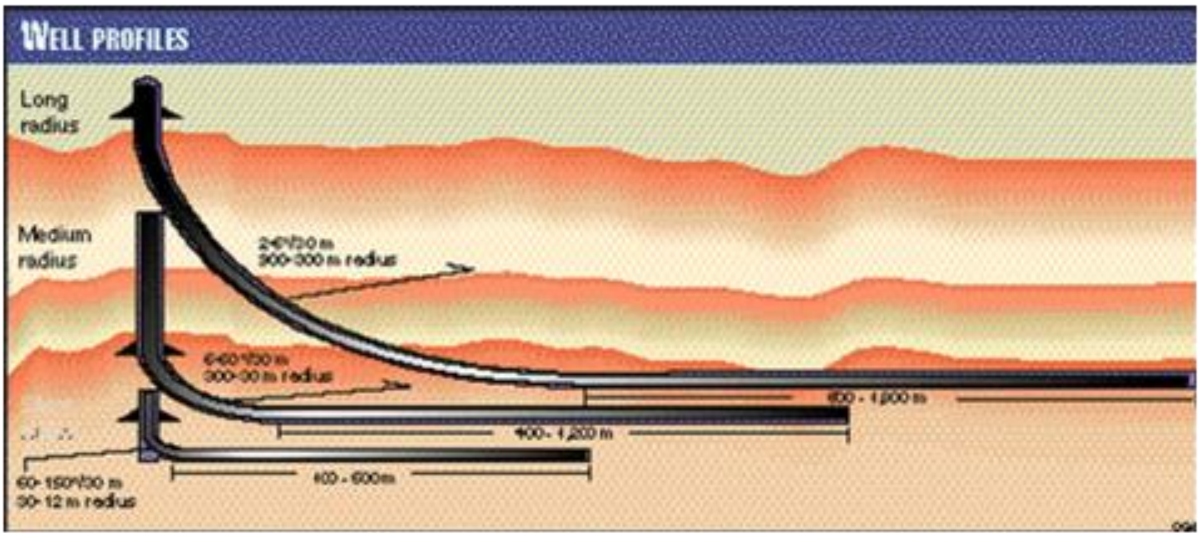


Figure 2.15 - *Typical Horizontal Wells Profiles (from Oil and Gas Journal)*

2.9 Directional drilling tools for deviation

There are several systems to establish and carry out the deviation and some of them have been highly improved in recent times, particularly since the carrying out of extended-reach horizontal wells or those having a particular shape have become more common.

The drilling industry has gone from using the whipstock and jetting to the systematic use of bottomhole motors, steerable systems and the geosteering.

In general, wellbore trajectory is controlled by the type of bottom hole assembly used and the weight on the bit.

The *bottom hole assembly* consists of several components:

- Heavy-weight drill pipe, Drill collars, Stabilizers, Subs

A typical surface rotated bottomhole assembly (BHA) is made of stabilizers, drill collars and measurement-while-drilling (MWD) equipment.

The placement and size of stabilizers control inclination (deviation angle from the vertical).

Assemblies can be designed to build angle, hold it steady or drop angle.

Steerable drilling system and geosteering

Rotary assemblies do not permit close control of wellbore azimuth (compass bearing of the wellbore with respect to magnetic North).

This control is usually achieved with a downhole motor with a bent housing, which allow the rotation to be applied to the bit alone.

Downhole motors are hydraulic machines at the end of the string, screwed directly onto the bit, and the entire mud flow goes through them, part of the mud pressure being converted into rotary motion and torque.

In this way, the rotation necessary for operating the bit is supplied by the downhole motor, while the whole drill string can remain stationary, or may be rotated, if necessary, with the rotary table or the top drive.

The use of such motors is essential both for directional drilling and for the application of modern techniques for controlling the vertical trajectory of wells.

Downhole motors, an integral part of the BHA, are axial-flow machines of tubular shape and are similar in size to a drill collar.

These motors do not form part of the standard equipment of the rig, but are hired from service companies, which also supply the personnel specialized in using them and which look after their maintenance.

Positive Displacement Motors are rotating, closed-type volumetric machines and their internal architecture is in fact they are Moineau pumps made to operate in the opposite direction, whereby the motor shaft is caused to rotate by forcing the mud through it under pressure.

The mud, which is forced past the stator and the rotor, fills these cavities, and causes the rotor to rotate continuously, thus causing the rotation of the bit alone.

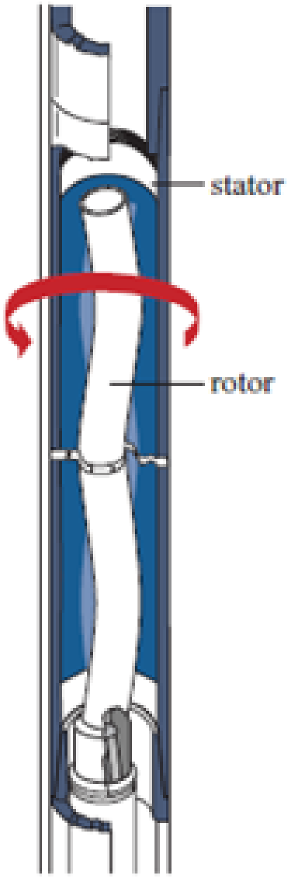
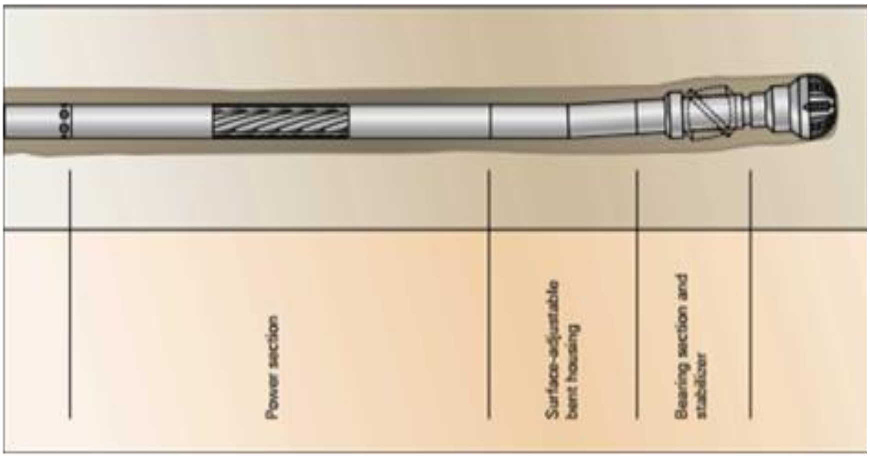


Figure 2.16 - *Schematic of a PDM Motor*



Steerable BHA (from Schlumberger)

A steerable drilling system is made up of a PDM, with a MWD equipment, which provides in real time the data of interest to the driller (such as inclination, direction, pressure, temperature, real weight on the drill bit, torque stress, etc.) or the LWD equipment is installed.

The latter makes it possible to send to the surface, not only the information mentioned above, but also geological data (the gamma ray log, the resistivity, density and sonic logs, etc.).

The coupling of sensors providing information on the course of the well trajectory, in real time and in a continuous way, with logs characterizing the formations from a geological viewpoint, goes under the name of geosteering.

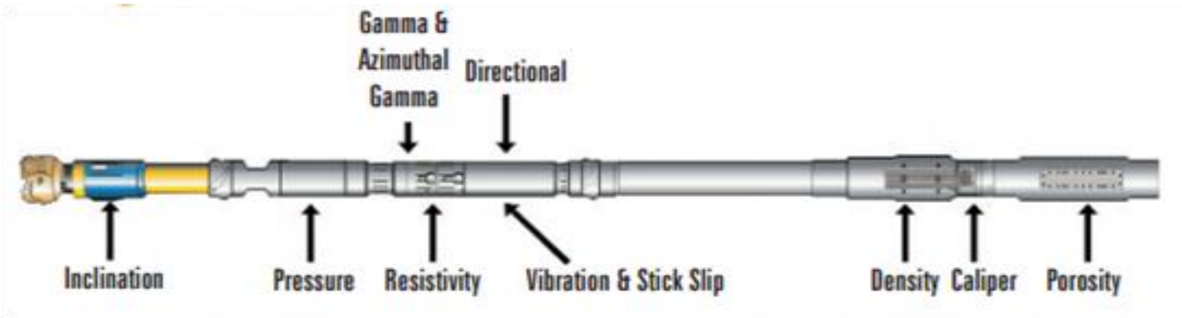


Figure 2.17 - *A Typical Geosteering BHA (from Baker Hughes)*

This technique makes it possible to navigate, in the true sense of the word, in the subsurface following the most suitable route to reach the prefixed targets.

Rotary steereable system – RSS

Conventional directional drilling techniques require the use of bent housing downhole motors to be oriented in the borehole and "slid" along the borehole without rotation of the drillstring to achieve a change in the well's trajectory.

Periods of this "slide" drilling are interspersed with periods of rotary drilling to achieve the desired three-dimensional wellbore trajectory.

Rotary steerable drilling is a technology that enables full three-dimensional directional drilling control to be performed while drilling with continuous drillstring rotation from surface (no "slide" drilling is necessary). This capability requires a special BHA component above the bit to direct the well path in the desired direction, maintaining the orientation of the drilling trajectory independent of the rotation of the BHA and drillpipe above it.

This component is the rotary steering device. How the different available rotary steering devices accomplish their task varies from relatively simple gravity-based orientation systems to more sophisticated flexure of internal drive shafts or flexure of the lower portion of the BHA by application of forces from pads against the borehole wall.

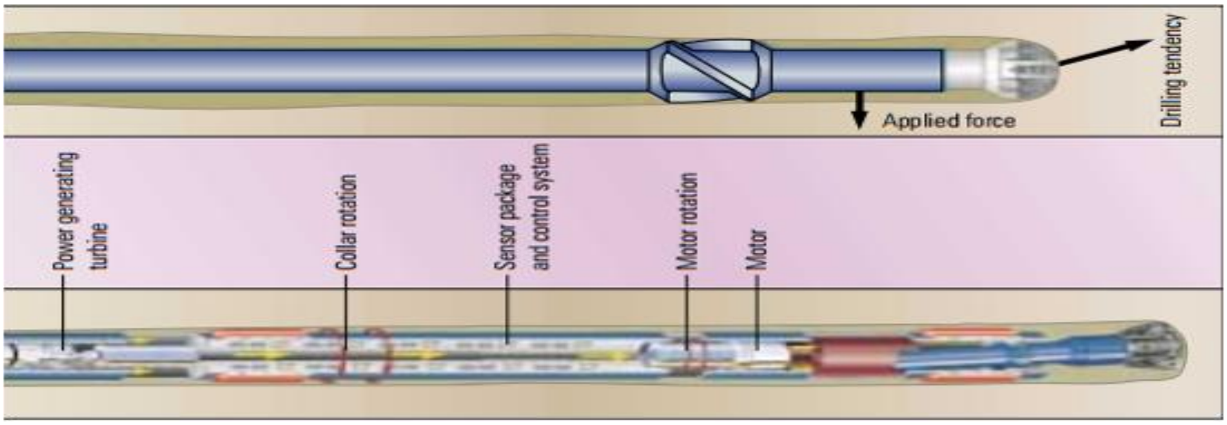


Figure 2.18 - *Rotary steerable system designs*

Some systems also employ automatic drilling modes where the wellbore is automatically steered using closed loop control systems programmed in the down-hole tool.

These systems deliver significant benefits in wellbore placement and overall wellbore quality compared to non automated systems.

They combine the precise directional control of steerable motors with the high penetration rates, hole cleaning advantages, and reduced friction of rotary drilling techniques.

In addition to differences in the mechanisms, which these systems use to physically steer the well, there are also differences in the manner in which systems are communicated with from surface and also the level of integration with the MWD and LWD systems employed in the BHA.

Efficient communication from surface results in significant time savings and a higher level of integration with MWD/LWD systems allows positioning of LWD sensors close to the bit while simultaneously minimizing BHA length and increasing reliability.

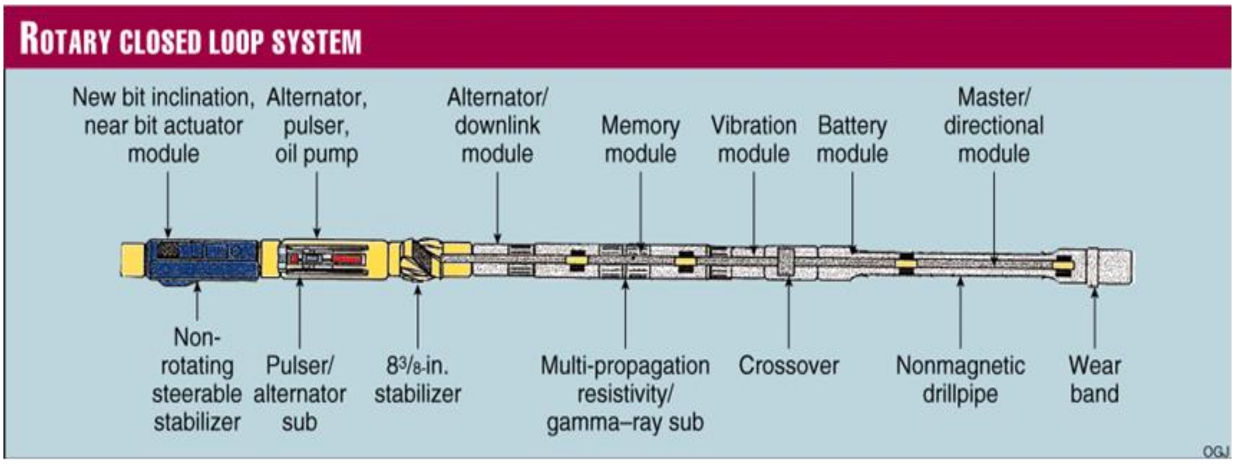


Figure 2.19 - *Example of Rotary Steerable Closed Loop System (from Oil and Gas Journal)*

Section Conclusions

The well will be drilled by a drilling rig Uralmash-3D-76 in four drilling intervals: direction - 426 mm in diameter, conductor - 324 mm in diameter, intermediate string - 245 mm in diameter and for production casing 168/146 mm in diameter, using mud. The drilling process is monitored by the GTI station. Cementing of the well will be carried out using cement mixing machines 2SMN-20, cementing units and a blending tank. Control of the process will be provided by the SKTs-2M cementing control station.

SECTION 3 LABOR PROTECTION

Based on U.S. Department of Labor (DOL), Bureau of Labor Statistics (BLS) reports, it is estimated that employees in the oil and gas field service industries (Standard Industrial Classification (SIC) 138) were injured at about twice the rate of general industry employees from 1972 through 1980. During this study, examination of three separate sources of injury data (Chapter III) indicated that in the oil and gas well drilling! industry (SIC 1381) workers (excluding clerical and administrative support personnel) may have been injured at an even higher rate. Calculations based on these sources of injury data have produced yearly injury incidence rates that range from 11.2 (lost-time injuries only, as computed by the International Association of Drilling Contractors) to 49.4 (compensable injuries recorded by the Texas Workers' Compensation State Board of Insurance) incidents per 100 person-years. The workers involved in drilling activities, the population at risk in this study, increased in number from approximately 25,000 in 1971 to nearly 80,000 in 1980.

Employees who work on drilling rigs may be injured while performing tasks and using equipment unique to well drilling operations; furthermore, these tasks and operations are not specifically addressed by existing Federal occupational safety and health standards. The Occupational Safety and Health Administration (OSHA) General Industry Standards (29 CFR 1910) are applicable to many of the general tasks, equipment, and conditions that are present at well drilling operations; e.g., welding and cutting, scaffolding, handtools, ladders, hydrogen sulfide exposure levels and electrical equipment. However, many of the tasks, equipment, and conditions present at well drilling sites are not specifically regulated by existing Federal safety standards. Some of these include:

- Tongs
- Rotary tables and bushings
- Catheads and catlines
- Elevators and slips
- Drill pipe and casing
- Derrick operations
- Making and breaking drill pipe connections
- Well blowout
- Hydrogen sulfide monitoring.

The scope of this report is to identify the hazards resulting in accidents and injuries during the performance of oil and gas well drilling operations (SIC 1381), and to recommend safe work practices and technologic improvements that will reduce worker exposure to the identified hazards.

The multiplicity of well servicing and completion operations, as performed by SIC 1389 companies, has not been included in the statistical development of this document; however, this is not intended to exclude servicing and completion contractors from utilizing all applicable safety recommendations.

Chapter II discusses the processes and technologies used to drill oil and gas wells and defines the population at risk in the industry. Chapter III defines the problems: injury incidence rates for the population at risk are presented, and hazardous tasks are identified. Chapter IV presents comprehensive safety recommendations for the oil and gas well drilling industry. Appendix A presents representative case histories of oil and gas well drilling accidents that further demonstrate the uniqueness of drilling operations. An evaluation of the applicability of existing standards (State, Federal, international, and consensus) to oil and gas well drilling operations, and specifically to situations involving unique drilling equipment and tasks, is presented in Appendix B. A glossary of general industry terms is also included at the end of this report.

The first section of this chapter briefly describes the oil and gas field industries that interact in developing an oil or gas well; the next section describes the technology and processes used by oil and gas well drilling companies; and the final section assesses the population at risk in the oil and gas well drilling industry.

This document is specifically directed toward tasks associated with oil and gas well drilling and, concomitantly, those industries performing the drilling (SIC 1381). To facilitate an understanding of the development of an oil well, an overview of all tasks necessary to complete a well is presented in the following section.

3.1 General Structure of the Oil and Gas Field Industry

Oil and gas field companies (SIC 138) perform tasks associated with the construction of oil or gas wells and the subsequent maintenance of a producing field. The industry is composed of companies that erect the rig and drill the hole (SIC 1381); companies that provide ancillary services such as well completion, casing, and perforating (SIC 1389); and companies that offer exploratory services (SIC 1382).

The size of the drilling rig, the number of employees, and the duration of the drilling operation depends on the depth of the well to be drilled, which may range from a few hundred feet to over 30,000 feet. Drilling times tend to increase exponentially with well depth and may vary from a week to more than 2 years.

As many as 20 different companies may perform their specialized operations at each well site. The scope of this document is limited to the tasks and operations performed in drilling a well. Figure II-l is a flow chart showing the individual operations (underscored in the section below) required in the construction and maintenance of a producing well, starting from the geological survey.

Once a well site has been selected by a geological survey team, the site preparation will usually be subcontracted to a company specializing in earthmoving operations. This contractor will level the site, dig and dike any required reservoirs, and excavate the cellar. The "spudding-in" of the starter hole and running of conductor casing may be subcontracted to a service company, or the drilling contractor may choose to perform this task itself after it has erected the derrick. The surface casing will then be cemented in place to ensure well integrity and blowout prevention. Meanwhile, a trucking company will be transporting the drilling rig and accessories to the well site for assembly and erection by the drilling contractor. As the well drilling proceeds, it is probable that intermediate protective casings will have to be run and cemented in place. If the drill string breaks and a section is lost in the well bore, then a fishing company may be contracted to remove the portion of broken drill string remaining in the well bore.

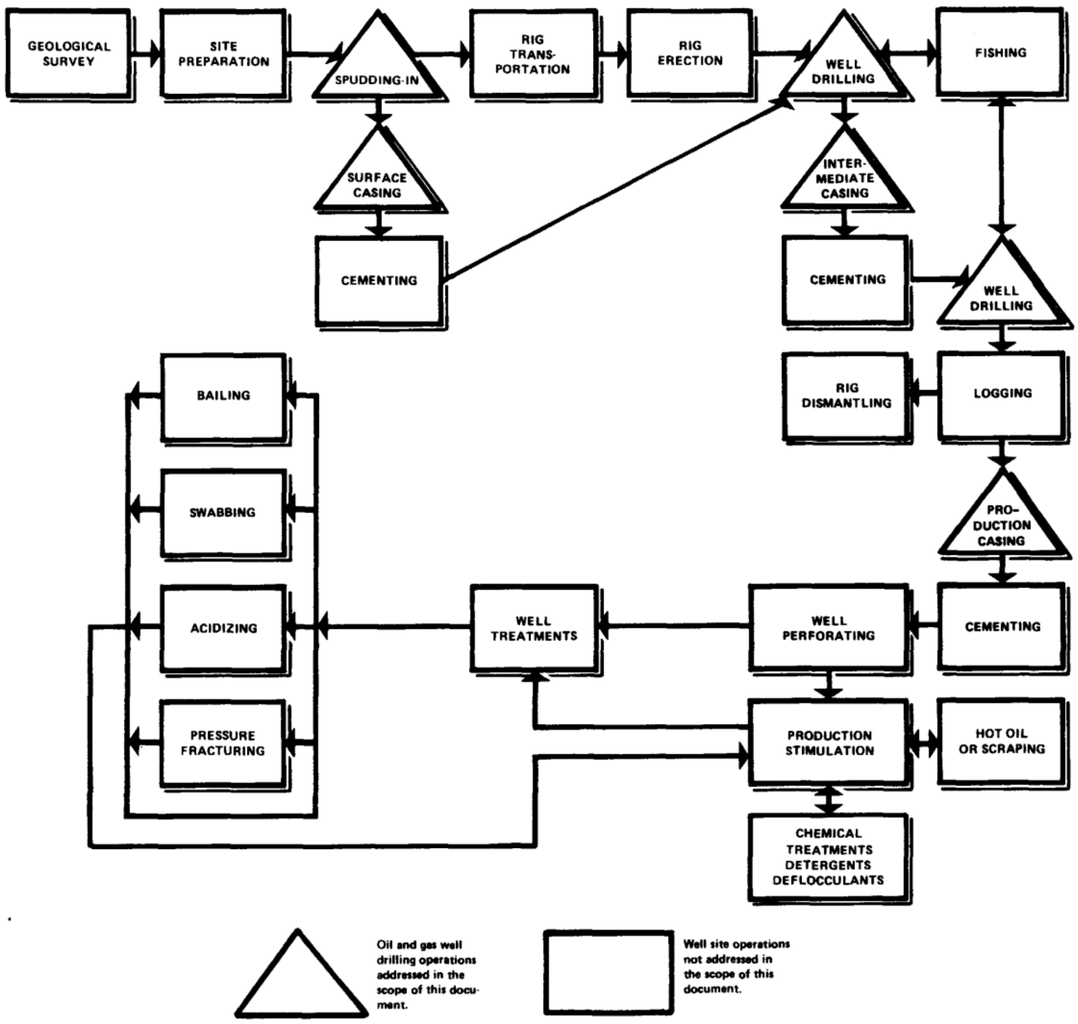


Figure 3.l - Tasks necessary to drill and maintain a producing oil or gas well

When the well depth has reached the hydrocarbon-bearing formation, a logging company may be hired to test the formation for oil and gas production potential. If the well is to be completed—that is, if the well bore has penetrated a formation that contains commercial quantities of oil and/or gas—then production casing will be run, sometimes by a contractor who specializes in this service. Usually the drilling contractor's rig remains onsite during the running and cementing of production casing. Once the casing has been cemented, frequently a company specializing in well perforating is engaged.

Many hydrocarbon-bearing formations can be stimulated to produce at faster rates than initially evidenced. Pressure fracturing or acidizing companies may be used to improve formation channelization. Bailing may be necessary to remove sand from the perforated area, or the well may have to be swabbed. Finally, once well production has been maximized, a "Christmas tree" may be added if the well is a flowing gas well, or a pump may be installed if it is an oil producer. Most new oil wells, like gas wells, will flow on their own.

Additional stimulation and well service may be required throughout the producing life of a well. Hot oil or scraping may be used to remove paraffin buildup in the casing.

The addition of detergents, deflocculants, or other chemicals may be required to maintain the flow rate. Acidizing or pressure fracturing may again be necessary.

B. Well Drilling Technology and Process Descriptions

The following process descriptions concentrate on the activities associated with oil and gas well drilling (SIC 1381).

3.2 Rigging-Up

Before describing the functional components of a drilling operation and their attendant hazards, it is necessary to mention rigging-up; i.e., assembling and erecting the derrick and associated gear. This phase, however, is similar to many other rigging operations with common procedures and hazards and does not require special treatment in this study. Equipment is designed for rapid assembly and economy of labor. In most cases, it is offloaded from trucks by winch and skid techniques. The substructure supporting the drill deck and derrick is either placed intact or assembled over a previously completed cellar.

In many instances, the spudding-in, or augering of the large-diameter starter hole, will have been completed earlier by a contractor using a workover rig. In this case the spud hole will be lined with conductor casing, which is likely to be cemented in place. Then the drilling rig will be assembled (rigged-up) and used to drill the hole below the conductor casing. Surface casing is then run and cemented.

Technically, the derricks in use today are, for the most part, masts in that they are not erected piece by piece. Instead, they are raised either by jackknifing or by hydraulic telescoping. On truck-mounted rigs and small workover rigs, guy lines are strung from the mast to the ground. On large jackknife masts, guy lines are not used as they are self-supporting. An emergency derrick line with escape trolley is strung from the derrick board, also called a "monkey board." The hazards of these operations are those commonly associated with construction sites and are not addressed in this document.

3.3 Rotary Drilling

The functional components of a rotary drilling rig have been grouped under these activities/systems:

- o Power generation and transmission
- o Hoisting the drill string
- o Rotating the drill string
- o Circulating fluid systems
- o Materials handling during drilling operations.

These components, described in more detail below, are shown in a functional diagram.

a. Power Generation and Transmission

The primary power source is normally one or more internal combustion engines. On larger, modern rigs, the engines are frequently located at ground level, 100 or more feet from the derrick. This is to minimize the potential of fires caused by engines igniting gases that could escape from the well bore. On smaller rigs, the engines frequently are mounted immediately next to the derrick. The most common fuel used is diesel; but gasoline, natural gas, liquefied petroleum gas, and purchased electricity are also used. Typically, several hundred horsepower (HP) will be generated and used on a drilling rig, although a larger rig may produce more than 3,000 HP.

The transmission is mechanical or electric. A mechanical transmission, which is more common in older rigs, utilizes a "compound" of clutches, chains and sprockets, belts and pulleys, and a number of driving and driven shafts. An electric transmission is more common in newer equipment.

Most exposures to hazards associated with the power generation and transmission system occur during maintenance, fueling, and lubrication. Inadequate or nonexistent equipment guards and ineffectual (or the lack of) lockout procedures for maintenance operations during continuous drilling increase the risk of physical injury. Other hazards include high voltages, chemical injury to the eyes during fueling, fire, and explosion. The noise levels in power generation areas may be high, with the risk of hearing loss.

b. Hoisting the Drill String

The primary functions of the hoisting apparatus are to raise and lower the drill string components during tripping and drill stem lengthening operations and to support the drill string at the desired bit weight during drilling. The drawworks is essentially a rotating spool, usually located on the drill deck, controlled by a clutch and brake system operated by the driller. The wire rope drill line runs from the drawworks to the crown block at the top of the derrick, and then to the traveling block and hook, which is attached to the drill string during drilling operations. The drilling line diameter and reeving sequence of the blocks are determined by maximum drill string weight.' The deadline anchor, usually located on the derrick substructure, serves as an adjustable terminal anchor point for the wire rope (Figure II-4). Typically, the dead line anchor will be adjustable to allow for the continual addition of new wire rope to the hoisting system.

Employee exposure to hazards associated with hoisting should be slight unless structural defects exist or system overloading occurs. Routine inspection of elevated hoist mechanisms involves the risk of falls. Pinched fingers and injuries from wire rope splinters are other hazards.

c. Rotating the Drill String

In addition to rotating the drill string and bit, the rotary table provides for free vertical motion of the drill as the bit penetrates into the earth. Torque is transmitted from the rotary table to the drill by the kelly, which also conveys the drilling mud that is pumped into it through a swivel connector.

The kelly is a three-, four-, six-, or eight-sided 40-foot-long conduit (i.e., longer than the 30-foot drill pipe sections) that threads into the drill pipe and is connected to the hoist traveling block by the swivel. The swivel supports the buoyed weight of the drill string while allowing the kelly to rotate and the pressurized drilling fluid to enter the drill stem. The kelly is rotated by a suitably structured kelly bushing that transfers rotational force without impeding the continuous downward movement of the kelly. During operations such as tripping, the kelly bushing must be easily removable to permit the drill pipe to be withdrawn from the well. When the kelly is hoisted and stored in the rathole during a trip, the kelly bushing is removed as an integral part of the kelly assembly. To facilitate this maneuver, the kelly bushing sits inside a three-, four-, six-, or eight-sided master bushing that is a fixed portion of the rotary table. The rotary table (and other rotating parts) may turn at rates of up to 400 rpm; however, much slower speeds are usual, perhaps in the range of 25-100 rpm. The driller operates the rotary table clutch controls and hoist controls from the same station. The power source is either an electric motor or mechanical power that is conhected to the rotary table by a compounded chain drive.

A typical drill string consists of 30-foot sections of drill pipe, male and female threaded, that weigh between 14 and 18 pounds/foot (500 pounds/joint). Several heavy, thick-walled joints of pipe, called drill collars, are made up in the drill stem, just above the bit, so the bit will penetrate into the formation being drilled. A single drill collar can weigh between 2,500 and 4,000 pounds (or more) depending on its diameter.

The hazards associated with this equipment are discussed in section e. , Materials Handling During Drilling Operations. However, it should be noted that employee exposure to rotating parts during drilling makes this operation one with a high potential for severe injuries, although the frequency of occurrence is low. The rotary table and kelly bushing are in nearly continuous motion and are not usually provided with any guarding mechanism. Contact with either is likely to cause slips, falls, and bruising accidents; also, there is a risk of being caught between stationary and rotating parts.

d. Circulating Fluid Systems

Drilling fluid, or "mud," is typically a mixture of water and bentonite (an absorbent, gel-forming clay) and sometimes oil or other components. It has four primary functions: cooling, lubricating, and cleaning the bit; removing the cuttings; providing hydrostatic pressure to prevent entry of formation fluids into the well bore; and reducing the risk of hazardous blowouts.

Mud pumps force the mud up a standpipe and through the flexible kelly hose to the swivel, where it enters the drill string via the kelly and eventually emerges at the bit in the well bore. Continuous pressure (up to 3,000 psi) forces the mud up the well annulus and out the mud return pipe, where it is first screened of larger cuttings at a shale shaker and then processed through a series of desanders and desilters prior to recycling (Figure II-5). Cuttings carried by the drilling fluid are taken for analysis to determine the composition of the stratum being drilled.

Hazards associated with working on or around components of circulating fluid systems are various. Mixing of the mud exposes workers to airborne respirable dust and chemical splashes. Tanks in which mud is mechanically stirred are hazardous when unguarded, or when effective lockout procedures are not followed during maintenance operations. Walking surfaces nearby may be slippery, especially in wet or icy weather. Pressure surges causing line rupture are an occasional hazard.

e. Materials Handling During Drilling Operations

On a drill rig, most of the materials handling equipment is unique to the oil field. This equipment is used in the working routines

of raising and lowering the drill string, adding new sections of drill pipe, and tripping. This equipment and its operation are described in operational sequence in this section.

To extend tne length of the drill string, a joint (30-foot section) is hoisted from horizontal pipe storage racks (located at ground level) to the drill deck. The joint is lowered into a hole in the drill deck (known as a mousehole), where it is stored until it is added to the string. This hoisting operation can be performed with a fiber rope, hands-on friction pulley (known as a cathead) that protrudes from each side of the drawworks. Most modern drilling rigs have steel cable air hoists to perform the hoisting of the drill pipe. When the kelly is at the level of the kelly bushing, the rotary table and mud circulating pumps are stopped. The driller raises the drill stem until the bottom of the kelly pipe joint connection is about 2 feet above the level of the rotary table. A set of "slips" is wedged into the space between the master bushing and the drill stem to maintain the drill pipe's position. A large pair of counterweight-suspended wrenches, called tongs, are used to "break out" the torqued kelly pipe joint connection. Once the tongs are clamped above and below the connection, mechanical force is applied to the handle of the breakout tong by a tong pull line originating from a mechanical cathead located on the drawworks. When the connection has been loosened, the joints are "spun out." Some rigs use an air-operated kelly spinner to spin out the kelly from the drill pipe, whereas others spin out the drill pipe with the rotary table after the tool joint has been "broken" with the pipe tongs. When making up a connection, some rigs use a pipe spinner to spin the joint up; then it is tightened with the pipe tongs. Many rigs use the traditional spinning chain to make up a joint of pipe; then it is tightened with the pipe tongs.

Once disengaged, the lower end of the kelly, suspended by the hoist, is pushed/pulled by the floorhands until it is centered over the pipe joint that was temporarily stored in the mousehole. The kelly is "stabbed" into the pipe joint, spun up, and tong tightened. The driller next engages the drawworks and raises the kelly and pipe joint assembly, which in turn is stabbed into the drill stem that is held by the slips. This connection is then spun up and tong tightened. The slips are removed, the mud pumps and rotary table are reactivated, and the drilling operation proceeds.

Tripping is a procedure used when well bore inspections and bit changes are necessary. The entire drill string must be removed from the hole and later returned if the drilling is to proceed. During a "round trip" (cycle of removal and replacement), the kelly is disconnected and stored in the rathole, a hole in the rig floor into which the kelly and swivel are placed during hoisting operations. Elevators, a set of clamps affixed to the bails on the swivel below the traveling block, are attached to the bell portion (tool joint) of the drill pipe and used to raise the drill string from the hole. Pipe tongs and frequently the rotary table are used to disconnect the stands (usually 90 feet of drill pipe) as one unit. The initial breaking of the pipe joint is properly performed by the automatic cathead tensioning the breakout tong. To ensure well control, drilling mud is usually added to the well bore to replace the fluid volume displaced by the drill stem and to maintain hydrostatic pressure when the drill stem is removed. The derrickman, usually using a fall-arresting derrick climber, climbs the derrick and works from the monkey board, which is usually located 90 feet above the rig floor. His task is to coordinate the placement of the triple joints between the fingers of the "finger board" for temporary storage during the trip and to disconnect the drill pipe from the elevators.

Once the bit has been removed from the hole, it is inspected for wear and replaced as necessary. "Logging" devices may be lowered into the hole on a stranded wire electric cable by a cathead power takeoff system or an independent electric winch. If the well drilling operation is to continue, the above sequence is reversed, completing the round trip.

Workers directly involved in these operations are close to moving equipment components, while performing tasks that require substantial exertion and good coordination between individuals. Transferring drill pipe from the rack to the drilling platform may result in the stockpile rolling or in the mishandling of suspended loads, with the risk of crushing injury. Handling of the tongs requires well-coordinated efforts and proper body limb placement. Mistakes in the hands-on spinning chain operations can lead to entanglement that may result in crushing, amputation, and death. Machinery is activated by an operator who depends on visual and/or audible cues; a mistake can lead to premature activation while workers are still in contact with moving parts. Mechanical failure from overloading systems can occur. Lifting and moving heavy items on wet surfaces may lead to slips, falls, and overexertion. Eyes are at risk from material falling off the drill pipe. Potential hazards in these operations can be increased if the drilling crew has not worked together very long; teamwork is necessary to carry out the operations quickly and safely. * •-«

Section Conclusions

Measures to prevent accidents and complications, protection of mineral resources and the environment.

SECTION 4 ENVIROMENT PROTECTION

4.1 General

Before drilling or construction, and, in some instances, before modification of onshore oil and gas production facilities, it may be necessary to obtain approvals from one or more government agencies. In addition to drilling and building permits, permits may be required because of air emissions, discharges to surface waters or sewer systems, injection activities, stormwater discharges (including during construction activities), impacts to threatened or endangered species or their critical habitat, impacts to wetlands and other environmental impacts, or impacts to other cultural resources. Operators should ensure that all necessary permits have been obtained before commencing operations. Operators should ensure that operations are conducted in accordance with local, state or federal regulatory requirements.

4.2 Surface Owners and Users

The footprint of drilling and production operations for oil and gas projects is variable and dependent upon the operator's equipment and operational needs, and the mutual objectives established by the operator, appropriate regulatory agencies, and the owner of the surface rights. Operators will need to be familiar with land use plans, regulations and ordinances that have been adopted by federal, state, and (in certain cases) local governments. Different land uses may require operators to adjust their approaches during site preparation, construction, development or production to avoid or minimize impacts to existing land uses. The development of surface use plans will allow for more efficient use of the land while balancing protection of important local resources, by minimizing surface disturbance and mitigating those impacts that are unavoidable.

Before drilling or construction on lands on which the surface estate is privately held, it is recommended that the operator communicate with land owners or surface users concerning activities planned for the site and measures to be taken for safety, protection of the environment, and for minimization of impacts to surface uses. Additional recommendations may be found in API 75L, Annex B—"Good Neighbor Guidelines." Operators of federal oil and gas leases under private surface ownership are encouraged to consult the BLM publication, *Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development* (*The Gold Book*) for BLM guidance with respect to communication and recommended practices to address concerns of surface owners.

4.3 Lease Roads

Lease roads are constructed and used to support various exploration and production (E&P) operations. The environmental impact of the construction of a roadway can have long lasting effects well beyond the limits of the right-of-way. Existing roads should be utilized, where feasible, to limit the extent of new road construction, when they meet regulatory standards, transportation and development needs, and safety and environmental objectives. When it is necessary to build new roadways, they should be developed in an environmentally acceptable manner consistent with landowner recommendations.

4.4 Planning

Road alignment and right-of-way selection is a multidisciplinary process. Goals of the planning effort should include affected resource values and safety, and avoidance of haphazard or unnecessary development of roads and associated utility corridors. The total infrastructure that may later be developed should be considered during the selection process. Government agencies, landowners, tenants, and other users may need to be consulted during the planning process.

Standards should be established for the road based on its short-term and long-term function considering geography, traffic density, and load expectations.

Alternative alignments should be developed considering the following parameters as appropriate:

topography;

hydrology, drainage, and watercourses, whether intermittent or permanent;

engineering properties of soils, erodible soils;

location and amounts of excavation and fill materials;

type and location of materials for road construction;

air, water, and noise pollution;

wetlands and wetland drainage;

consistency with community character and local government needs and plans;

proximity to dwellings or other permanent structures occupied or used by the public;

visual sensitivity;

power lines and pipelines;

other geotechnical factors, particularly in areas of complex terrain, such as landslide areas, subgrade conditions indicating a need for surfacing, potential cut slope problems, and subsurface or surface water problem areas.

Road alignments and potential environmental impacts should be reviewed. Routes and alignment should be selected to minimize erosion. Environmentally significant areas should be identified and avoided to the maximum extent practical, including:

sensitive wildlife and critical habitats;

areas with endangered and threatened animals and plants;

cultural and historical sites;

federal, state, or local areas of concern;

areas with the potential for flooding or snow drifting;

wetlands.

When required, mitigation strategies should be developed in the planning process, including:

road operation schedules and/or use of special designs to minimize any adverse impacts in areas with sensitive wildlife and fish habitats, wetlands, existing facilities, crops;

plans to take appropriate action on cultural and historic resources before changes are made;

maintenance of existing traffic patterns on highways and local access roads.

Interim reclamation plans and final restoration plans should be developed and incorporated into the planning process.

Stormwater and air (dust) permit requirements should be considered during the planning phase of the roadway.

4.5 Primitive or Nonconstructed Roads and Routes

Where site conditions are appropriate, and where approved by a surface owner or surface management agency, the establishment and use of "primitive," two-track roads or overland route corridors may be appropriate for an operator's needs and to facilitate later reclamation of the site. Primitive roads and route corridors may serve as appropriate access to exploration drilling locations where it is not certain if the well will be productive, or to producing wells where vehicle traffic is infrequent due to the use of off-site production facilities and automated well monitoring. Traffic and load expectations for primitive roads should be evaluated. If the expectations are exceeded during the project, the road should be evaluated for upgrades.

The appropriateness of primitive roads and routes is both site-specific and use-specific and is typically based on many factors, such as anticipated dry or frozen soil conditions, seasonal weather conditions, flat terrain, low anticipated traffic, service company’s/driller’s/operator’s access needs.

Primitive roads or routes necessitate low vehicle speeds and are typically limited to four-wheel drive or high- clearance vehicles. They can consist of existing or new roads with minor or moderate grading; two-track roads created by the operator’s direct vehicle use with little or no grading; overland routes with a defined travel corridor leaving no defined roadway beyond crushed vegetation; or any combination along the route. Operators should not flat-blade roads. Drainage must be maintained, where appropriate, to avoid erosion or the creation of a muddy, braided course of vehicular travel.

Primitive or two-track roads and routes must be used and established in a safe and environmentally responsible manner and are not intended for use as all-weather access roads. Resource damage must be repaired as soon as possible and the operator must consult with the surface management agency to determine if all or a portion of the road needs to be upgraded to an all-weather access road. When used and maintained appropriately, nonconstructed roads and routes have the advantage of reducing construction, maintenance and reclamation costs and reducing resource impacts.

Approval of a surface resource agency is generally required for use of nonconstructed roads on other than privately owned lands.

4.6 Maintenance

Proper road maintenance is critical for the performance of the road and to prevent and control erosion and sedimentation. Maintenance personnel should be made aware of environmentally difficult and sensitive areas.

Maintenance work should be scheduled and the use of special designs and maintenance programs should be considered to minimize undesirable effects on sensitive wildlife and fish habitats, wetlands, and designated federal, state, or local recreational areas.

When performing scraping and leveling operations, care should be exercised to avoid disrupting ditches and shoulders, and creating undesirable berms with the bladed material.

Ditches, culverts, and drains should be regularly cleaned of debris and sediment to allow the free passage of water. Periodic inspections of all culverts should be conducted. Culverts found to be blocked should be cleared.

Borrow and surface materials should be readily accessible to be utilized during maintenance operations. Pits opened during construction should be used as a source for maintenance material, where feasible.

The use of dust control materials or measures should be evaluated before their utilization. The materials should not be detrimental to health, vegetation, wildlife, or water quality.

Cutting back weed and hedge growth is essential for road safety. This maintenance operation should be done with light equipment. Critical review should occur before herbicides or other chemicals used for weed control are applied.

There should be continuous monitoring of drainage and erosion control structures. They should be maintained and revised, as required, to provide for the intended function.

Erosion should be prevented and controlled. Areas should be revegetated, and slopes and soils should be stabilized.

There should be an environmental emergency response plan ready to be placed in action during construction and maintenance operations. The plan should include emergency procedures to be followed in the event major drainage ways are blocked, fail, or do not perform as required during or immediately after major storm events.

4.7 Reclamation and Abandonment

Abandonment procedures should comply with regulatory requirements, contractual obligations, and lessor and landowner requirements. Consideration should be given to cost-effective measures that will minimize environmental impacts. Interim reclamation should be undertaken for portions of the road or areas disturbed during construction of the road that are not required for vehicle travel. In interim or final reclamation, wherever possible, cut slopes, fill slopes, and borrow ditches should be recontoured, covered with topsoil and revegetated to restore habitat, forage and scenic resources, and to reduce soil erosion.

Abandonment procedures may include the following considerations: restoration; abandonment in place; restoration of original or improved drainage; agreement on maintenance requirements, if any, after discontinued use, to be reached between the operator and new user; agency approval requirements.

Restoration plans should be prepared in detail and should consider methods such as: priority of stabilization and revegetation of disturbed areas, use of native plant species, stockpiling soils where reclamation would be enhanced, use of agency approved designs and seed mixes.

Section Conclusions

The industry has been under continuous and growing legal pressure to address environmental imperatives by improving its performance. The introduction of increasingly strict environmental requirements has led to changes in investment conditions and capital and operating costs. Corporate liability for environmental damage has a tendency to evolve towards greater stringency and higher ceiling of compensation. Surging environmental fines and taxes further augment financial burden on the oil and gas operators.

Environmental considerations affect corporate structure and operational practices which have to adjust by introducing environmental management systems, special personnel and new pollution abatement and control procedures. Management of environmental, and associated legal risks, has become an integral part of corporate strategies. With the further anticipated expansion of O&G operations into environmentally sensitive areas, such as deep-water offshore zones and the Arctic and Sub-Arctic regions, or to traditional territories of indigenous peoples, these risks will only increase.

CONCLUSIONS

In this work, drilling and casing of a production well at oil and gas field with the development of measures to prevent violations of the integrity of the walls of the well.

In the general part, the following is given: the geographical location, an overview of previously conducted geological and geophysical studies and the geological characteristics of the area of work. Described: stratigraphy, tectonics andphysico-chemical properties of formation fluids in a given area.

The well will be drilled by a drilling rig in four drilling intervals: direction - 426 mm in diameter, conductor - 324 mm in diameter, intermediate string - 245 mm in diameter and for production casing 168/146 mm in diameter, using mud. The drilling process is monitored by the GTI station. Cementing of the well will be carried out using cement mixing machines, cementing units and a blending tank. Control of the process will be provided by the cementing control station.

The work provides all the necessary life safety measures, Considered measures to prevent accidents and complications, protection of mineral resources and the environment.

BIBLIOGRAPHY

1 Aqrawi, A.A.M. 1998. Paleozoic stratigraphy and petroleum systems of the western and southwestern deserts of Iraq. GeoArabia, v. 3, no. 2, p. 229-248.

2 Ahlbrandt, T.S., O.A. Okasheh and M.D. Lewan 1997. A Middle East basin center hydrocarbon accumulation in Paleozoic, eastern Jordan, western Iraq and surrounding regions. American Association of Petroleum Geologists Bulletin, Abstract, v. 81, no. 8, p. 1359-1360.

3 Ahlbrandt, T.S., R.M. Pollastro, T.R. Klett, C.J. Schenk, S.J. Lindquist and J.E. Fox 2000. Region 2 Assessment Summary-Middle East and North Africa, Chapter R2 in United States Geological Survey World Petroleum Assessment 2000—Description and Results, DDS-60, 46 p.

4 Al-Gailani, M. 1996. Iraq's significant hydrocarbon potential remains relatively undeveloped. Oil and Gas Journal, v. 94, issue 31, p. 108-112.

5 Al-Gailani, M., M.D. Lewan and T.S. Ahlbrandt 1998. Sulfur versus API gravity relationships of crude oils. GeoArabia, Abstract, v. 3, no. 1, p. 40-41.

6 Al-Gailani, M. 2003. Assessing Iraq's oil potential. Geotimes, v. 47, p. 16-20.

7 Al-Husseini, M.I. 1997. Jurassic sequence stratigraphy of the western and southern Arabian Gulf.

8 GeoArabia, v. 2, no. 4, p. 361-382.

9 Al-Husseini, M.I. 2000. Origin of the Arabian Plate structures: Amar collision and Najd rift. GeoArabia, v. 5, no. 4, p. 527-542.

10 Al-Naqib, K.M. 1967. Geology of the Arabian Peninsula - southwestern Iraq. United States Geological Survey, Professional Paper 560-6, 54 p.

11 Al-Naqib, F.M., R.M. Al-Debouni, T.A. Al-Irhayim and D.M. Morris 1971. Water Drive Performance of the Fractured Kirkuk Field of Northern Iraq. SPE Paper no. 3437, presented at 46th Annual Meeting of the Society of Petroleum Engineers in New Orleans, Lousiana, October 1971, 19 p.

12 Alsharhan, A.S. and A.E.M. Nairn 1997. Sedimentary Basins and Petroleum Geology of the Middle East. Amsterdam, The Netherlands, Elsevier Science, 942 p.

13 Beydoun, Z.R. 1991. Arabian Plate Hydrocarbon Geology and Potential, A Plate Tectonic Approach. American Association of Petroleum Geologists, Studies in Geology, no. 33, 77 p.

14 Bishop, R.S. 1995. Maturation history of the lower Palaeozoic of the eastern Arabian platform. In, M.I. Al-Husseini (Ed.), Middle East Petroleum Geosciences Conference, GEO'94. Gulf PetroLink, Bahrain, v. 1, p. 180-189.

15 Bordenave, M.L. 2000. Zagros domain of Iran holds exploration, EOR opportunities. Oil and Gas Journal, May 8, 2000, 4 p.

16 Buday, T. and S.Z. Jassim 1987. The Regional Geology of Iraq. v. 2. Tectonism, Magmatism and Metamorphism. In, I.I.M. Kassab and M.J. Abbas (Eds.), State Establishment of Geological Survey and Mineral Investigation. Baghdad, Iraq, 352 p.

17 Chaube, A.N. and J. Al-Samahiji 1995. Jurassic and Cretaceous of Bahrain: geology and petroleum habitat. In, M.I. Al-Husseini (Ed.), Middle East Petroleum Geosciences Conference, GEO'94. Gulf PetroLink, Bahrain, v. 1, p. 292-305.

18 Christian, L. 1997. Cretaceous subsurface geology of the Middle East region. GeoArabia, v. 2, no. 3, p. 239-256.

19 Cole, G.A., M.A. Abu-Ali, S.M. Aoudeh, M.J. Carrigan, H.H. Chen, E.L. Colling, W.J. Gwathney, A.A. Al-Hajii, H.I. Halpern, PJ. Jones, S.H. Al-Sharidi and M.H. Tobey 1994a. Organic geochemistry of the Paleozoic petroleum system of Saudi Arabia. Energy and Fuels, v. 8, p. 1425-1442.

20 Cole, G.A., H.H. Carrigan, E.L. Colling, H.I. Halpern, M.R. Al-Khadhrawi and PJ. Jones 1994b. Organic geochemistry of the Jurassic petroleum system in Eastern Saudi Arabia. In, A.F. Embry, B. Beauchamp and D.J. Closs (Eds.), Pangea, Global Environments and Resources. Canadian Society of Petroleum Geologists Memoir 17, p. 413-438.

21 Cole, G.A., H.I. Halpern and S.M. Aoudeh 1994c. The relationships between iron-sulfur-carbon and gamma-ray response, Silurian basal Qusaiba shale, northern Saudi Arabia. Saudi Arabia Journal of Technology, p. 9-19.

22 Dunnington, H.V. 1967. Stratigraphical distribution of oilfields in the Iraq-Iran-Arabia Basin. Journal of the Institute of Petroleum, v. 53, p 129-161.

23 Fanchi, J.R. 1984. An evaluation of the Wilmington field Micellar/Polymer project. Society of Petroleum Engineers/United States Department of Energy, SPE/DOE 12681, p. 27-39.

24 Farouq, A. 1995. Improved/enhanced oil recovery - what is the reality. Presented at the Regional Symposium on Improved Oil Recovery, Abu Dhabi, UAE, December 17-19, 1995, 7 p.

25 Fox, J.E. and T.S. Ahlbrandt 2002. Petroleum Geology and Total Petroleum Systems of the Widyan Basin and Interior Platform of Saudi Arabia and Iraq. United States Geological Survey Bulletin 2202E, 26 p.

26 GeoDesign Report 1999. Iraq Hydrocarbon Reserves and Production.

27 GeoDesign Communication 2003. Iraq's reserve estimates by year from 1906 through 2002.

28 Glennie, K.S. 2000. Cretaceous tectonic evolution of Arabia's eastern plate margin: a tale of two oceans. In, A.S. Alsharhan and R.W. Scott (Eds.), Middle East Models of Jurassic/Cretaceous Carbonate Systems. Society of Economic

Paleontologists and Mineralogists, Special Publication no. 69, p. 9-20.

29 Ibrahim, M.W. 1978. Petroleum Geology of Southern Iraq. PhD thesis, Imperial College, University of London, 479 p.

30 Ibrahim, M.W. 1983. Petroleum geology of southern Iraq. American Association of Petroleum Geoleogists Bulletin, v. 67, no. 7, p. 97-130.

31 IHS Database 2001. IHS Energy Group (includes current data as of September 2001), PI/Dwights plus US production data. IHS Energy Group, Englewood, Colorado.

APPENDIX A

The type of materials in the quality of works

No.	Format	Designation	Names	Number of pages	Note
1					
2			Documentation		
3					
4	A4	OGEB.22.03.EN	Explanatory note	75	
5					
6			Demonstration material	15	
7					
8					