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Petroleum reserves and undiscovered resources in the total petroleum systems of Iraq: reserve growth and production implications

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ABSTRACT

Iraq is one of the world's most petroleum-rich countries and, in the future, it could become one of the main producers. Iraq's petroleum resources are estimated to be 184 billion barrels, which include oil and natural gas reserves, and undiscovered resources. With its proved (or remaining) reserves of 113 billion barrels of oil (BBO) as of January 2003, Iraq ranks second to Saudi Arabia with 259 BBO in the Middle East. Iraq's proved reserves of 110 trillion cubic feet of gas (TCFG) rank tenth in the world. In addition to known reserves, the combined undiscovered hydrocarbon potential for the three Total Petroleum Systems (Paleozoic, Jurassic, and Cretaceous/Tertiary) in Iraq is estimated to range from 14 to 84 BBO (45 BBO at the mean), and 37 to 227 TCFG (120 TCFG at the mean). Additionally, of the 526 known prospective structures, some 370 remain undrilled. Petroleum migration models and associated geological and geochemical studies were used to constrain the undiscovered resource estimates of Iraq.

Based on a criterion of recoverable reserves of between 1 and 5 BBO for a giant field, and more than 5 BBO for a super-giant, Iraq has 6 super-giant and 11 giant fields, accounting for 88% of its recoverable reserves, which include proved reserves and cumulative production. Of the 28 producing fields, 22 have recovery factors that range from 15 to 42% with an overall average of less than 30%. The recovery factor can be increased with water injection, improved and enhanced oil recovery methods (IOR and EOR) in various reservoirs, thus potentially increasing Iraq's reserves by an additional 50 to 70 BBO.

Reserve growth is a significant factor that has been observed, to some extent, in nearly all Iraqi oil fields. Historically, producing fields have shown an average growth of 1.6 fold (or 60%) in their recoverable reserves over a 20-year period (1981-2001). With periodic assessments of reservoirs, application of available technology, and an upgrading of facilities, increases in reserves are expected in the future.

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.

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

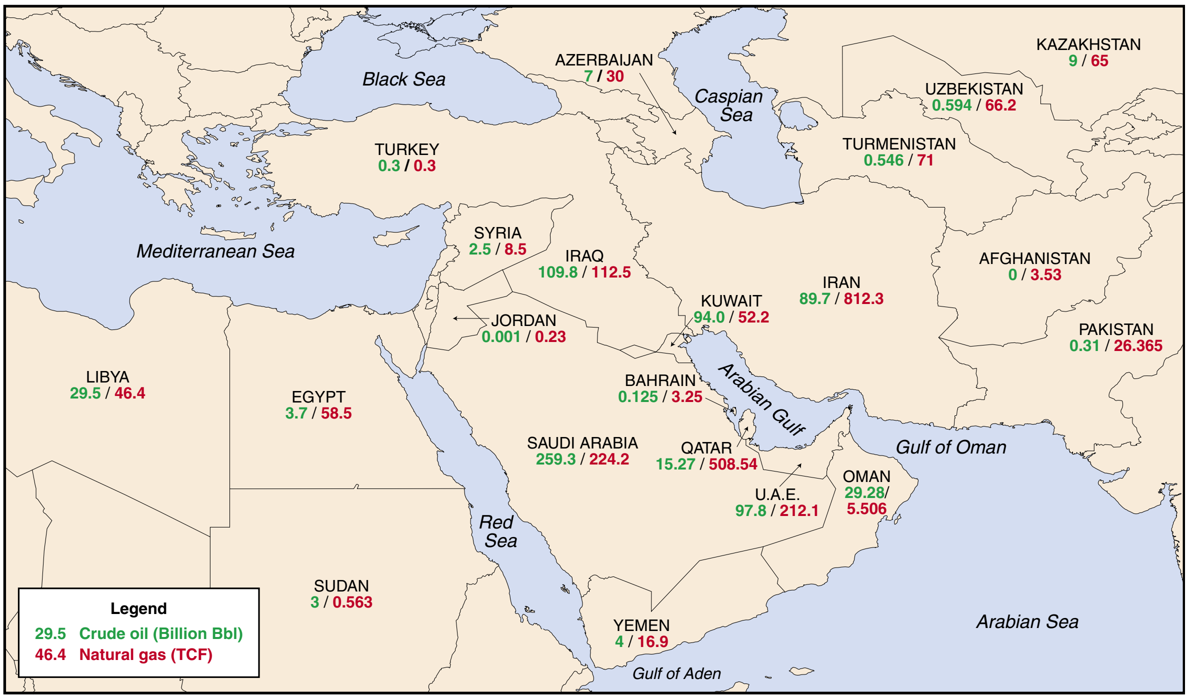


Figure 1: Map showing proved oil and gas reserves in the Middle East countries. Based on reported reserves, Iraq is the second largest in oil reserves in the Middle East and third largest in the world. Data source: Oil and Gas Journal, December 23, 2002.

Table 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.

84.8 BBO, and 11 giant fields with recoverable reserves of 22.6 BBO, for a total of 17 giant and super-giant fields with 107.4 BBO of recoverable reserves (IHS, 2001). These reserves account for about 88% of Iraq's recoverable reserves.

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, Radler, 2002) are compared with the rest of the world in Figure 2 (oil) and Figure 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).

HISTORY OF EXPLORATION IN IRAQ

The first oil and gas exploration in Iraq began in 1902, when a well was drilled on an anticlinal structure at Chia Surkh (Figure 4). In 1919, exploratory appraisal drilling started in the Naft Khaneh area, resulting in the discovery of the first oil field in 1923. The year 1927 was a turning point for exploration in Iraq, when the first well discovered the Kirkuk field (Figure 4). Baba Gurgur No. 1 well struck oil in a dramatic fashion. The uncontrolled oil gusher, which reached 50 ft above the derrick, drenched the surrounding countryside and threatened nearby villages, and the town of Kirkuk. After nearly nine days, the well was brought under control but, before it was capped, it had flowed at 95,000 barrels of oil per day (BOPD) (Yergin, 1991).

Despite success at Kirkuk, Iraqi Petroleum Company's main exploratory effort in the region, prior to World War II, was concentrated to the southeast, in the Iranian Zagros Fold Belt (Dunnington, 1967). The discovery of the giant Greater Burgan field in 1938 in Kuwait, immediately before the outbreak of World War II, focused attention on neighboring southern Iraq. Thus, when exploration resumed after World War II, the increasing exploratory activities by the Iraq Petroleum Company were rewarded by the discovery of the Zubair field in 1948, and the Rumaila field in 1953 (Figure 4). Renewed exploration in the fold belt led to the discovery of oil at Bai Hassan (1953) and Jambur (1954) fields. The next phase of major exploration activity that began in early 1970s led to the discovery of many fields, such as Abu Ghirab (1971), West Qurna (1973), Jabal Fauqi (1974), Sufaiyah (1974), Subba (1976), East Baghdad (1976), Balad (1976), Majnoon (1977), Ajeel (1978, previously Saddam), Amara (1980), Merjan (1983) and West Kifl (1987). Since 1988 exploration in Iraq has been limited in scope, by which time the total number of exploratory wells drilled was 125.

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 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 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 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.

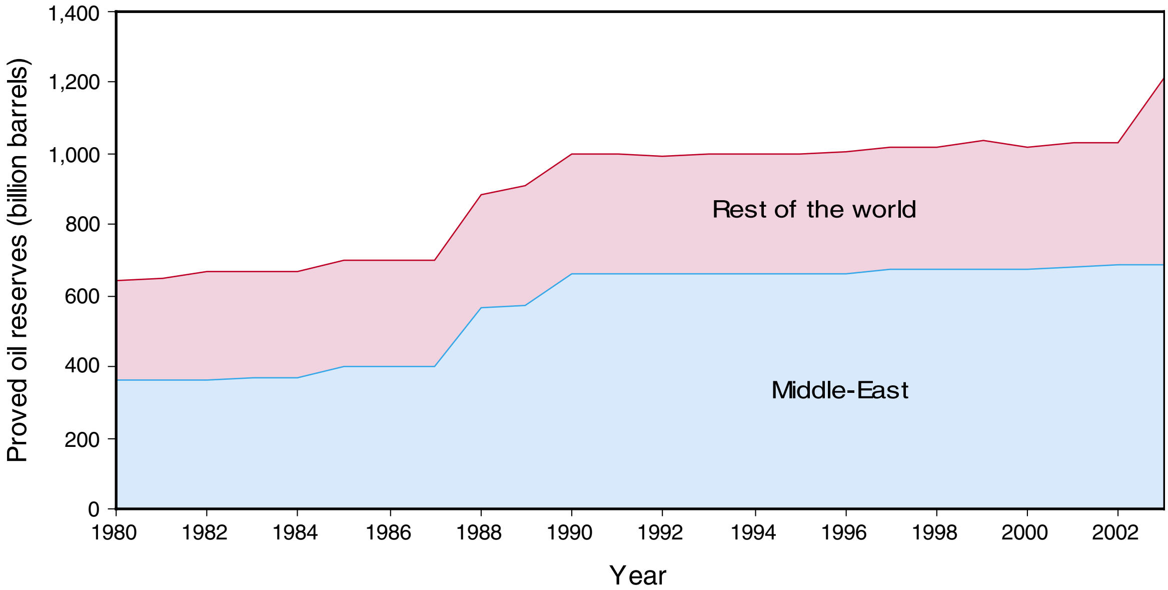


Figure 2: Plot showing comparison of Middle East proved oil reserves and the rest of the world's reserves. The Middle East has historically maintained a two-thirds share of the world's oil reserves, except for 2003 when there was an increase in Canada's oil reserve from 5 to 180 billion barrels through inclusion of Alberta's tar oil sands. Data source: Oil and Gas Journal, December 23, 2002.

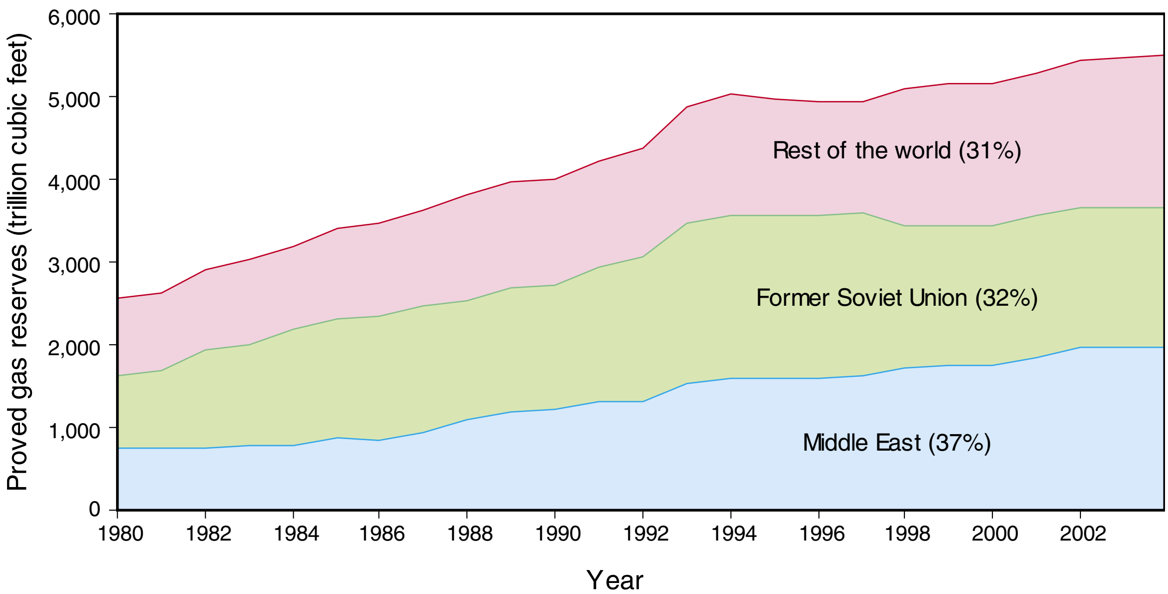


Figure 3: Plot showing comparison of Middle East proved gas reserves and the rest of the world's gas reserves. Data source: Oil and Gas Journal, December 23, 2002.

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 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 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 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

IRAQ : Oilfields and Exploration Blocks

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

Figure 4: Map showing oilfields and exploration blocks in Iraq. Major pipelines are shown in red. Source: GeoDesign Communication, 2003.

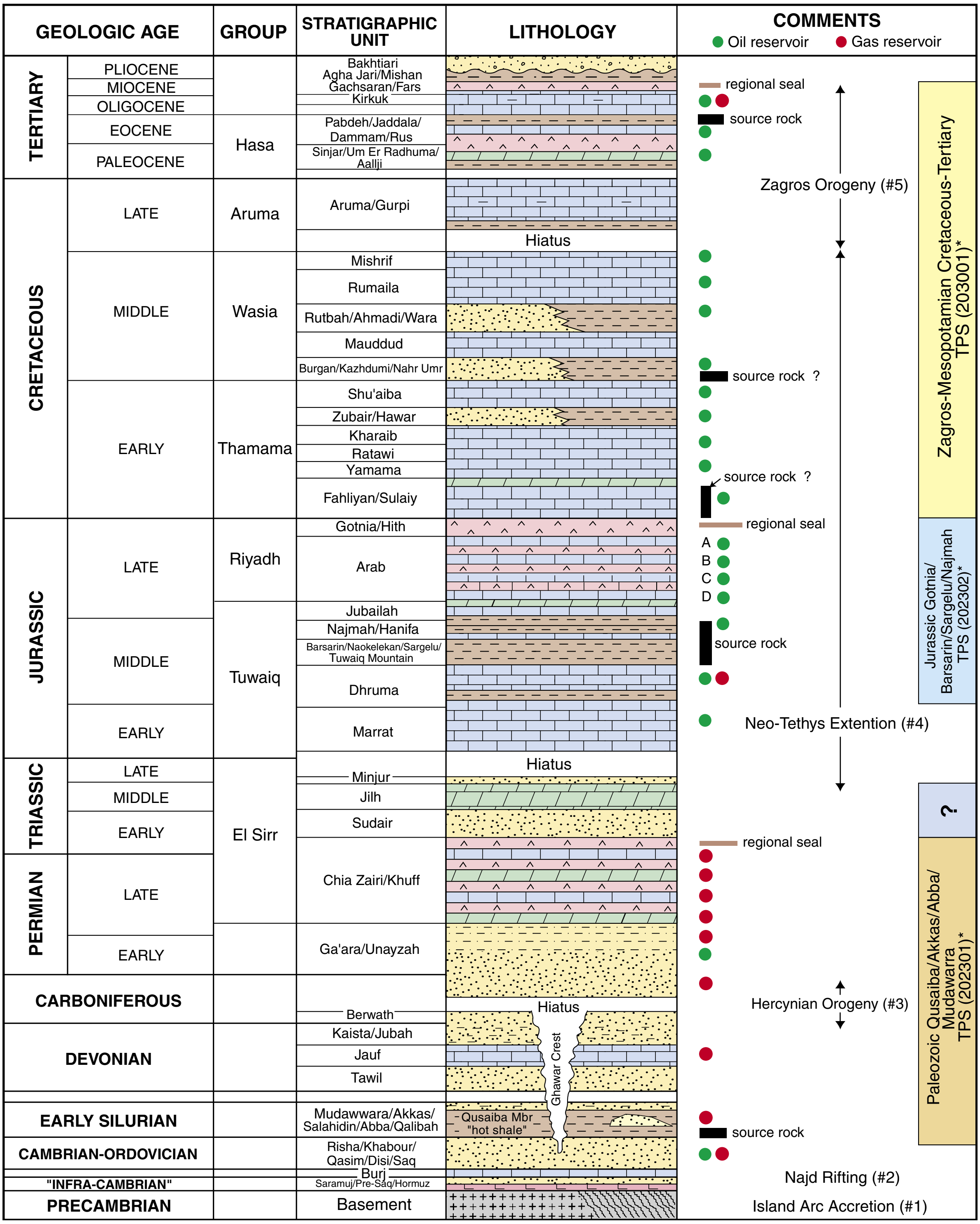


Figure 5: Stratigraphic section and major tectono-stratigraphic phases, relevant to the Paleozoic, Jurassic, and Cretaceous-Tertiary Total Petroleum Systems (TPS) of the northern and eastern Arabian Peninsula and Iraq. Modified from Janahi and Mirza (1991), Chaube and Al-Samahiji (1995), Mendeck and 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.

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 5.

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 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 6) (Al-Gailani, 1996).

Four main structural zones have been defined within the boundaries of Iraq (Figures 6 and 7). The first two are the Near Geosynclinal Flank of the Mesopotamian Foredeep and the Central Faulting zones (Figures 6 and 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 over-thrusted 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 6 and 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 6 and 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 6). A number of major commercial oil fields are situated in this area, including Kirkuk, Bai Hassan, and Jambur (Figures 4, 6 and 7).

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 6 and 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.

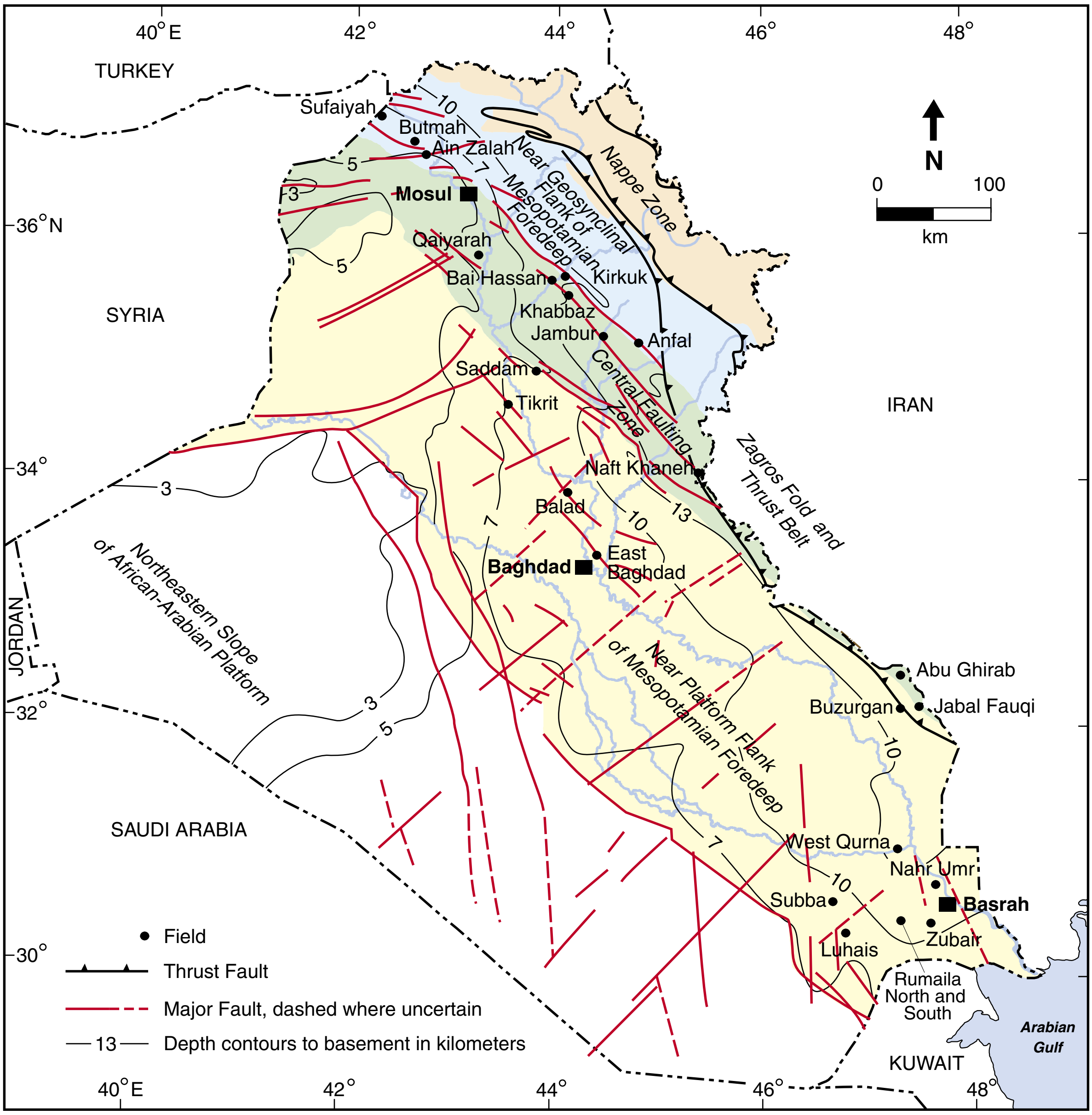


Figure 6: Map showing the structural zones (Near Geosynclinal Flank of the Mesopotamian Foredeep, Central Faulting zone, Near Platform Flank of Mesopotamian Foredeep, and Northeastern Slope of African-Arabian Platform), and isopach contours (sediment thickness to basement). The Zagros thrust fault zone and other major faults are also shown (Buday and Jassim, 1987).

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 (Alsharhan and Nairn, 1997). Prospects in this zone are commonly in older Paleozoic reservoirs (Figure 7).

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.

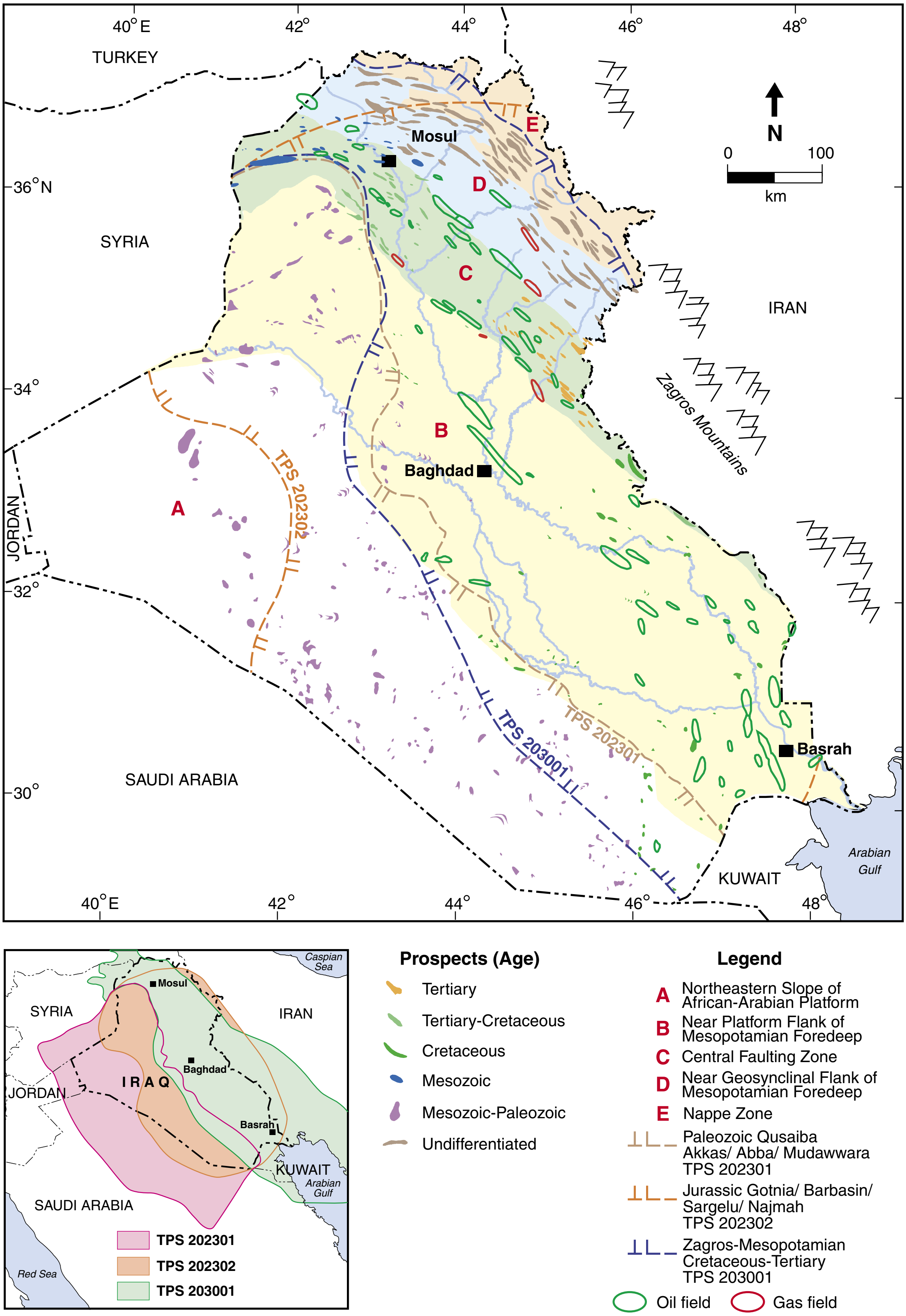


Figure 7: Map showing oil and gas fields, prospects (Al-Gailani, 2003) and the three Total Petroleum Systems (TPS) that have contributed to the petroleum accumulations in Iraq (Ahlbrandt et al., 2000).

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 non-commercial 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.

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 decline-curve analysis (Figure 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.

Table 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	73.290771		

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

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.

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 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 non-producing 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 TCF. Source: GeoDesign dataset, 1999.

Table 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	Raffan	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 non-commercial 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.

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 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 7 and 12a, b; USGS, 2000).

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

Figure 8: Map showing 23 producing (solid black circles) and 41 non-producing (open circles) oil and gas fields in Iraq and their reported oil and gas reserves. Source: GeoDesign, 1999.

numbers of undiscovered fields. The size and number estimates were constrained by potential prospects (Figure 7), and the potential of various stratigraphic horizons was calibrated against petroleum generation, migration and accumulation models. Assessment of the three significant TPS was constrained by the recognition of insignificant hydrocarbon charge by Mesozoic source rocks to western Iraq. Similarly, the Silurian TPS assessment was modified in light of geochemical studies (Ahlbrandt et al., 1997, 2000; Al-Gailani, 1996; Al-Gailani et al., 1998). In addition to modeling studies, data compiled by Louis Christian (Christian, 1997 and MEGMaps, 1998, 2001, Gulf Petrolink, Bahrain) were utilized in the assessment process.

Total Petroleum System 202301: Paleozoic

The geologically-oldest TPS 202301 is the Paleozoic Qusaiba/Akkas/Abba/Mudawwara system (Ahlbrandt et al., 1997, 2000; Fox and Ahlbrandt, 2002) (Figures 5, 7 and 12b), which is located mostly in western Iraq and extends into surrounding portions of eastern Jordan and northern Saudi Arabia (Figures 7 and 12a, b). This TPS's petroleum source rock is a shale facies in the Qusaiba Member of the Qalibah Formation (Saudi Arabia), Mudawwara Formation (Jordan), and Akkas Formation (Iraq);

Table 5
Fields Under Evaluation, Iraq

No.	Field	Discovery Year
1	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
11	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

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.

all of which produce a light gravity (commonly greater than 40°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 7 and 12b) is estimated to contain undiscovered hydrocarbons ranging for oil from 0.5 (F_{95}) to 3.1 (F_5) 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.

Total Petroleum System 202302: Jurassic

The Jurassic Gotnia/Barsarin/Sargelu/Najmah System (TPS 202302, Figures 7 and 12b) consists of Middle and Upper Jurassic source rocks of the Sargelu, Naokelekan and Gotnia formations,

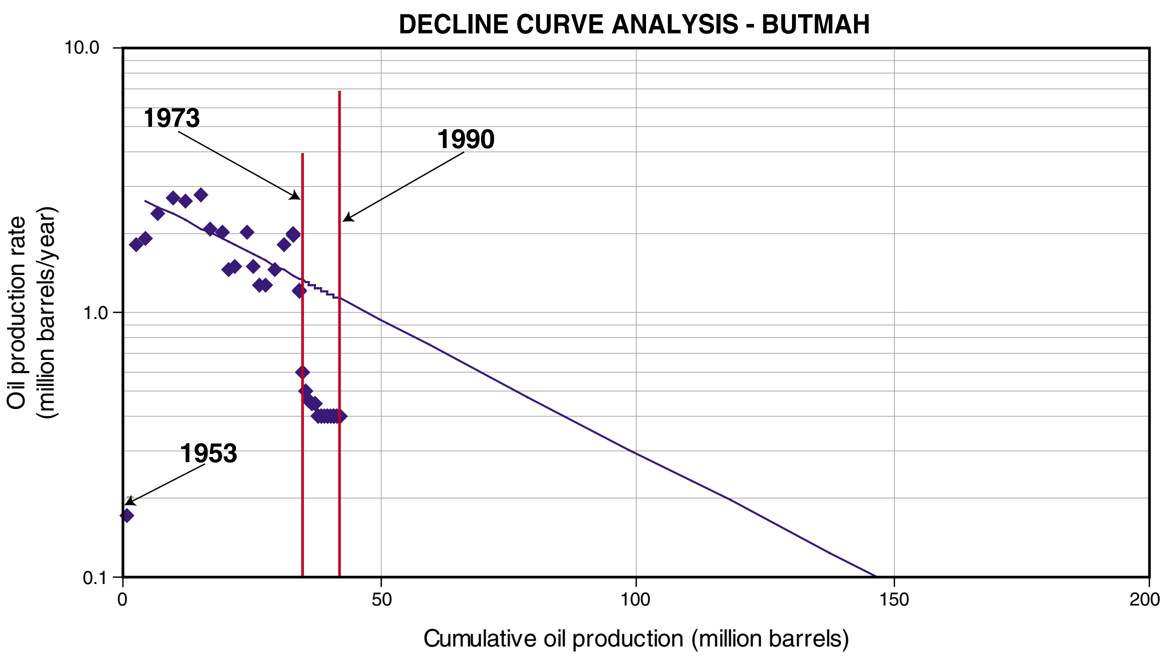


Figure 9: Plot showing the production rate in million barrels per year versus cumulative production in million barrels for the Butmah oil field (discovery year 1953), Iraq. Recoverable reserves were reported as 80 million barrels and cumulative production of 42 million barrels (about 53% of initial reserve) as of year-end 1998. The decline-curve-analysis curve indicates higher reserves than reported. Source: IHS database, 2001.

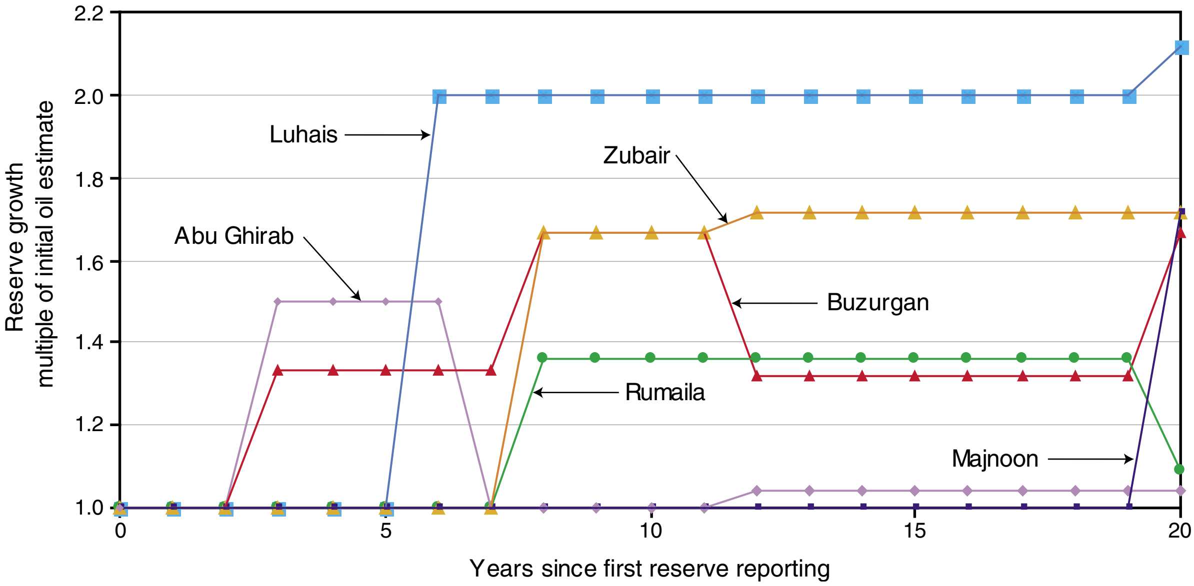


Figure 10: Plot showing the reserve growth of some southern Iraqi fields – Abu Ghirab, Buzurgan, Luhais, Majnoon, Rumaila and Zubair. Source: IHS dataset from 1981 through 2001.

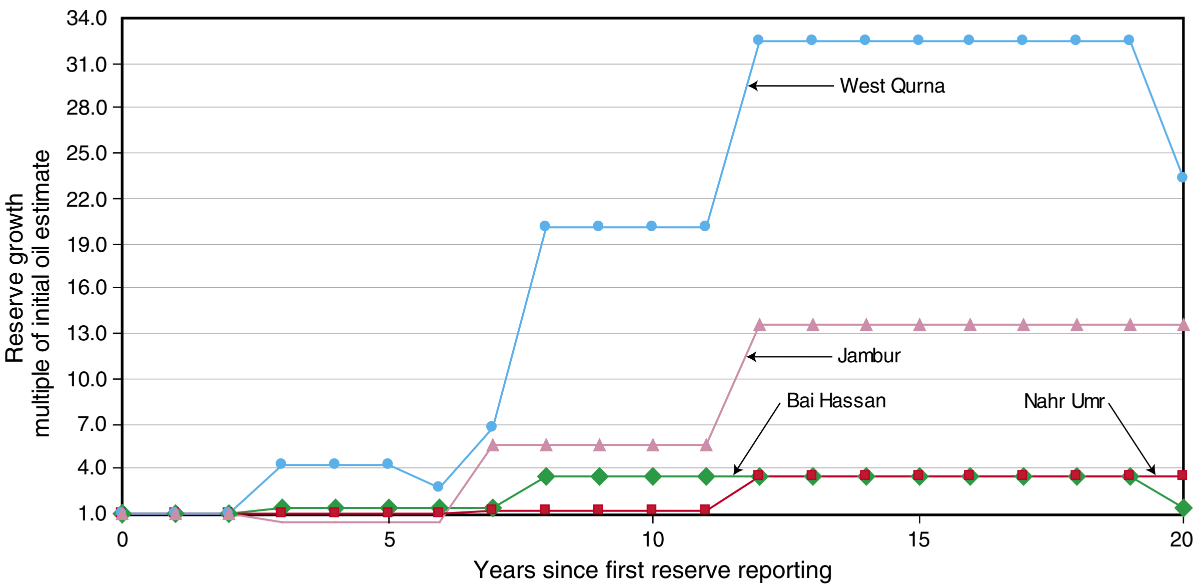
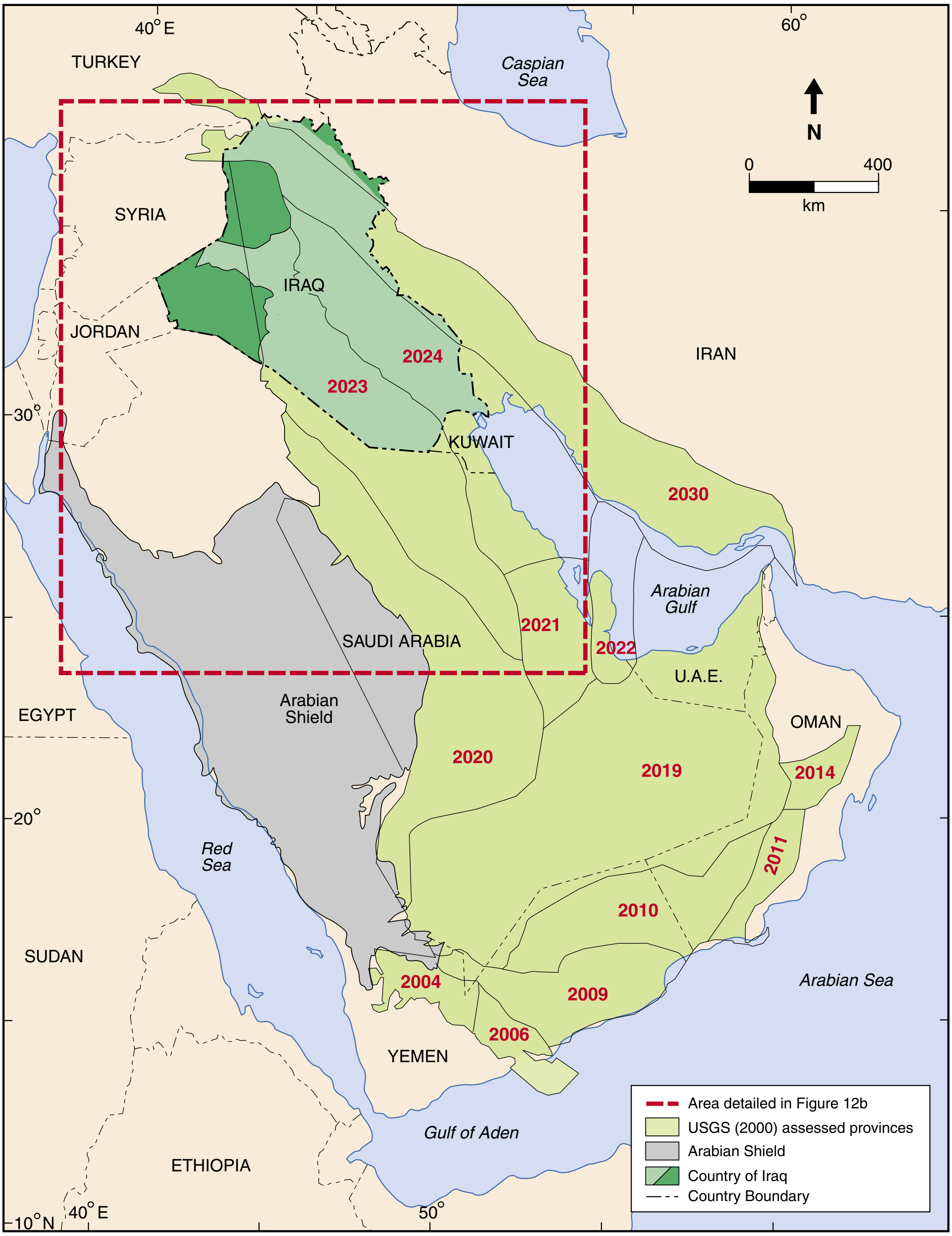


Figure 11: Plot showing the reserve growth of two northern Iraqi fields – Bai Hassan, Jambur, and two southern Iraqi fields, Nahr Umr (now named Bin Umr) and W. Qurna, with large high reserve growth. Field growths in Jambur and W. Qurna are relatively high, whereas the two other fields are similar to the six fields shown in Figure 10. Source: IHS dataset from 1981 through 2001.

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 7 and 12a, b). The Iraqi portion of TPS 202302 (Figures 7 and 12b) is estimated to contain undiscovered hydrocarbons ranging for oil from 1.7 (F_{95}) to 9.2 (F_5) BBO, with a mean of 5.3 BBO; and for gas from 5.0 (F_{95}) to 32.8 (F_5) 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).



Provinces (USGS, 2000)

2004	Ma'Rib-Al Jawf/Masila Basin	2014	Ghaba Salt Basin	2023	Widyan Basin-Interior Platform
2006	Shabwah Basin	2019	Rub' Al-Khali Basin	2024	Mesopotamian Foredeep Basin
2009	Masila-Jeza Basin	2020	Interior Homocline-Central Arch	2030	Zagros Fold Belt
2010	Ghudun-Khasfeh Flank Province	2021	Greater Ghawar Uplift		
2011	South Oman Salt Basin	2022	Qatar Arch		

**Figure 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.**

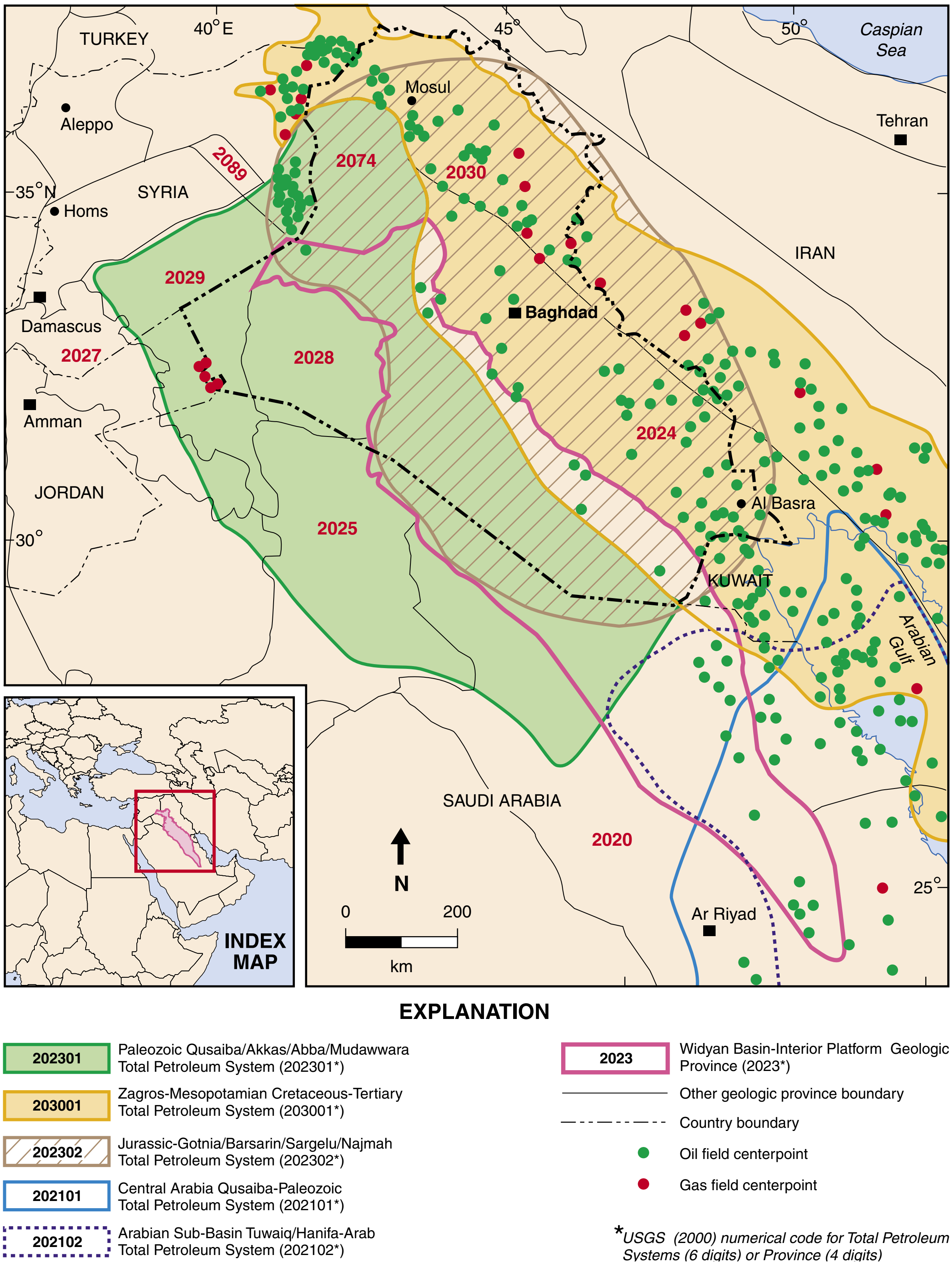


Figure 12: (b) Total Petroleum Systems (TPS, 6-digit code), oil- and gas-field centers, and provinces (4-digit code) in and near Iraq as defined in USGS (2000). The Paleozoic Qusaiba/Akkas/Abba/ Mudawwara TPS (202301) and the Jurassic Gotnia/Barsarin/Sargelu/Najmah TPS (202302, hatched) were formally 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 7 and 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 7 and 12b) is estimated to contain undiscovered hydrocarbons ranging for oil from 12.0 (F_{95}) to 71.7 (F_5) 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).

IRAQ'S PRODUCTION HISTORY AND PRODUCTIVE CAPACITY

Figure 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 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).

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).

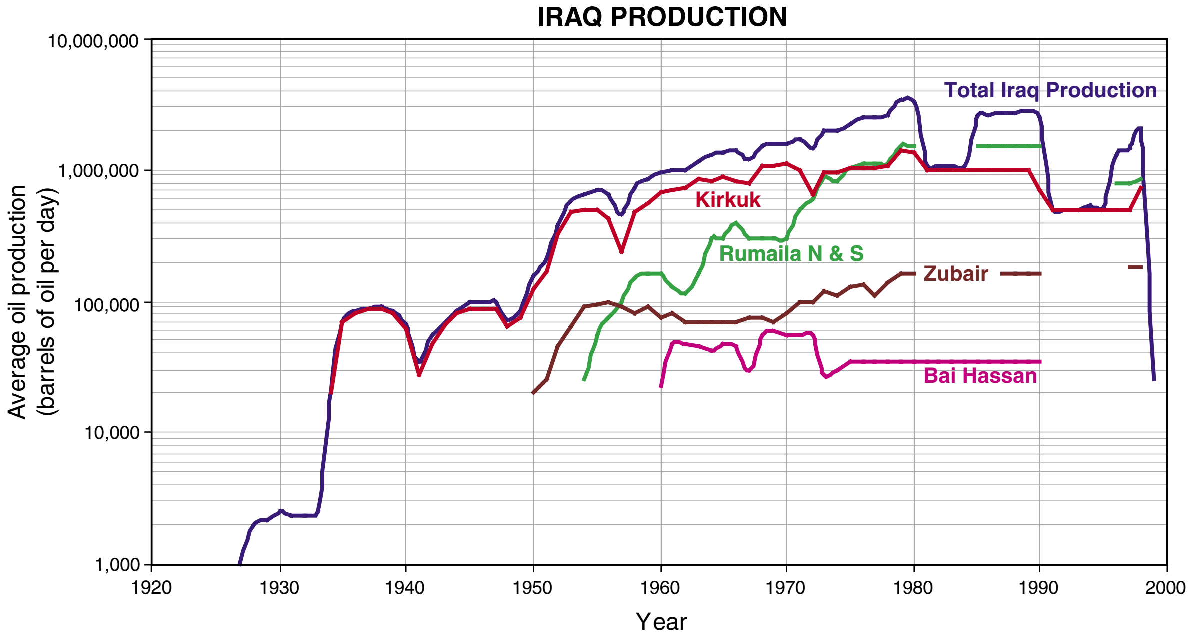


Figure 13: Plot showing production history of major oil fields in Iraq, as well as the combined total production for all fields. Kirkuk is the largest producer. Other important contributors are Rumaila, Zubair, and Bai Hassan fields. Data source: GeoDesign 1999 dataset.

PROSPECTS OF WATERFLOOD, IMPROVED AND ENHANCED OIL RECOVERY

Most Iraqi fields produce either medium- or light-gravity oil (Figure 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.

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

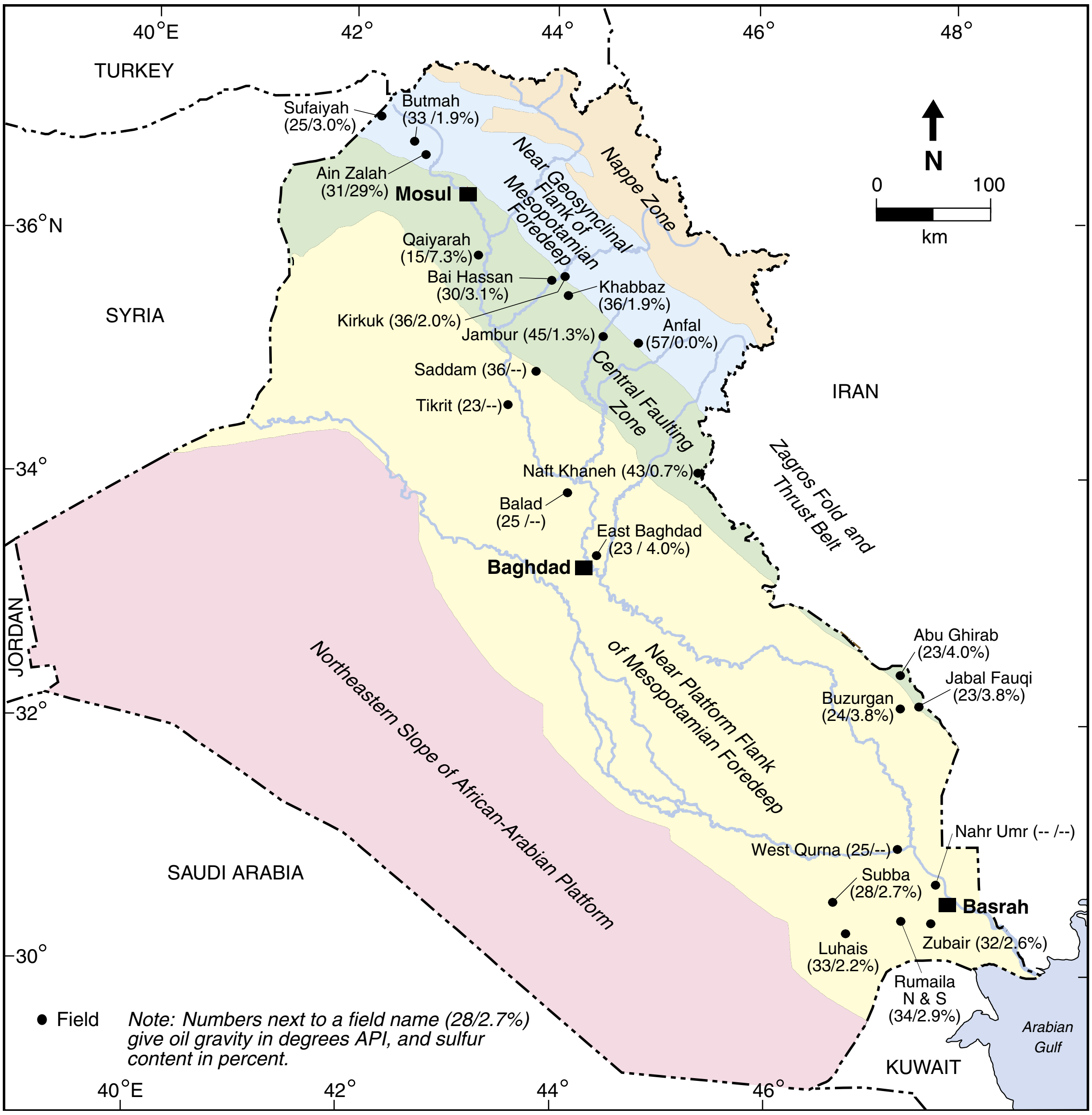


Figure 14: Map showing locations of 23 producing fields with their reported oil gravities and sulfur contents. Data source: GeoDesign 1999 dataset.

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.

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 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 H_2S 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.

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).

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 (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 (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).

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