Total Petroleum Systems of the Pelagian Province, Tunisia, Libya, Italy, and Malta—The Bou Dabbous–Tertiary and Jurassic-Cretaceous Composite

By T.R. Klett

U.S. Geological Survey Bulletin 2202-D

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

Version 1.0, 2001

This publication is only available online at:
http://geology.cr.usgs.gov/pub/bulletins/b2202-d/

Manuscript approved for publication August 3, 2001
Published in the Central Region, Denver, Colorado
Graphics by the author and Gayle M. Dumonceaux
Photocomposition by Gayle M. Dumonceaux
Edited by L.M. Carter

Contents

Figures

Tables

Total Petroleum Systems of the Pelagian Province, Tunisia, Libya, Italy, and Malta—The Bou Dabbous–Tertiary and Jurassic-Cretaceous Composite

By T.R. Klett

Foreword

This report was prepared as part of the U.S. Geological Survey World Petroleum Assessment 2000 (U.S. Geological Survey World Energy Assessment Team, 2000). The primary objective of World Petroleum Assessment 2000 is to assess the quantities of conventional oil, natural gas, and natural gas liquids outside the United States that have the potential to be added to reserves in the next 30 years. Parts of these assessed volumes reside in undiscovered fields whose sizes exceed the stated minimum-field-size cutoff value for the assessment unit; the cutoff varies, but it must be at least 1 million barrels of oil equivalent. Another part of these assessed volumes occurs as reserve growth of fields already discovered. However, the contribution from reserve growth of discovered fields to resources is not covered for the areas treated in this report.

In order to organize, evaluate, and delineate areas to assess, the Assessment Methodology Team of World Petroleum Assessment 2000 developed a hierarchical scheme of geographic and geologic units. This scheme consists of regions, geologic provinces, total petroleum systems, and assessment units. For World Petroleum Assessment 2000, regions serve as organizational units and geologic provinces are used as prioritization tools. Assessment of undiscovered resources was done at the level of the total petroleum system or the assessment unit.

The world was divided into 8 regions and 937 geologic provinces. These provinces have been ranked according to the discovered known (cumulative production plus remaining reserves) oil and gas volumes (Klett and others, 1997). Then, 76 "priority" provinces (exclusive of the United States and chosen for their high ranking) and 26 "boutique" provinces (exclusive of the United States) were selected for appraisal of oil and gas resources. Boutique provinces were chosen for their anticipated petroleum richness or special regional economic or strategic importance.

A geologic province is an area having characteristic dimensions of hundreds of kilometers that encompasses a natural geologic entity (for example, a sedimentary basin, thrust belt, or accreted terrane) or some combination of contiguous geologic entities. Each geologic province is a spatial entity with common geologic attributes. Province boundaries were drawn as logically as possible along natural geologic boundaries, although in some places they were located arbitrarily (for example, along specific water-depth contours in the open oceans).

Total petroleum systems and assessment units were delineated for each geologic province considered for assessment. It is not necessary for the boundaries of total petroleum systems and assessment units to be entirely contained within a geologic province. Particular emphasis is placed on the similarities of *petroleum fluids* within total petroleum systems, unlike geologic provinces and plays in which similarities of *rocks* are emphasized.

The total petroleum system includes all genetically related petroleum that occurs in shows and accumulations (discovered and undiscovered) generated by a pod or by closely related pods of mature source rock. Total petroleum systems exist within a limited mappable geologic space, together with the essential mappable geologic elements (source, reservoir, seal, and overburden rocks). These essential geologic elements control the fundamental processes of generation, expulsion, migration, entrapment, and preservation of petroleum within the total petroleum system.

An assessment unit is a mappable part of a total petroleum system in which discovered and undiscovered oil and gas fields constitute a single relatively homogeneous population such that the methodology of resource assessment based on estimation of the number and sizes of undiscovered fields is applicable. A total petroleum system might equate to a single assessment unit. If necessary, a total petroleum system may be subdivided into two or more assessment units such that each assessment unit is *sufficiently* homogeneous in terms of geology, exploration considerations, and risk to assess individually. Differences in the distributions of accumulation density, trap styles, reservoirs, and exploration concepts within an assessment unit were recognized and *not* assumed to extend homogeneously across an entire assessment unit.

A numeric code identifies each region, province, total petroleum system, and assessment unit. The criteria for assigning codes are uniform throughout the project and throughout all publications of the project. The numeric codes used in this study are:

Unit	*Name*	*Code*
Region	Middle East and North Africa	**2**
Province	Pelagian	2**048**
Total Petroleum Systems	Bou Dabbous–Tertiary	2048**01**
	Jurassic-Cretaceous Composite	2048**02**
Assessment Units	Bou Dabbous–Tertiary Structural/Stratigraphic	204801**01**
	Jurassic-Cretaceous Structural/Stratigraphic	204802**01**

A graphical depiction that places the elements of the total petroleum system into the context of geologic time is provided in the form of an events chart. Items on the events chart include (1) the major rock-unit names; (2) the temporal extent of source-rock deposition, reservoir-rock deposition, seal-rock deposition, overburden-rock deposition, trap formation, generation-migration-accumulation of petroleum, and preservation of petroleum; and (3) the critical moment, which is defined as the time that best depicts the generation-migration-accumulation of hydrocarbons in a petroleum system (Magoon and Dow, 1994). The events chart serves only as a timeline and does not necessarily represent spatial relations.

Probabilities of occurrence of adequate charge, rocks, and timing are assigned to each assessment unit. Additionally, an access probability is assigned for necessary petroleum-related activity within the assessment unit. All four probabilities, or risking elements, are similar in application and address the question of whether at least one undiscovered field of minimum size has the potential to be added to reserves in the next 30 years somewhere in the assessment unit. Each risking element thus applies to the entire assessment unit and does not equate to the percentage of the assessment unit that might be unfavorable in terms of charge, rocks, timing, or access.

Estimated total recoverable oil and gas volumes (cumulative production plus remaining reserves, called “known” volumes hereafter) quoted in this report are derived from Petroconsultants, Inc., 1996 Petroleum Exploration and Production database (Petroconsultants, 1996a). To address the fact that increases in reported known volumes through time are commonly observed, the U.S. Geological Survey (Schmoker and Crovelli, 1998) and the Minerals Management Service (Lore and others, 1996) created a set of analytical “growth” functions that are used to estimate future reserve growth (that, when added to known volumes, is called “grown” volumes hereafter). The set of functions was originally created for geologic regions of the United States, but the assumption is that these regions can serve as analogs for the world. This study applied the Federal offshore Gulf of Mexico growth function (developed by the U.S. Minerals Management Service) to known oil and gas volumes, which in turn were plotted to aid in estimating undiscovered petroleum volumes. These estimates of undiscovered petroleum volumes therefore take into account reserve growth of fields yet to be discovered.

Estimates of the minimum, median, and maximum number, sizes, and coproduct ratios of undiscovered fields are made based on geologic knowledge of the assessment unit, exploration and discovery history, analogs, and, if available, prospect maps. Probabilistic distributions are applied to these estimates and combined by Monte Carlo simulation to calculate undiscovered resources.

Illustrations in this report that show boundaries of the total petroleum systems, assessment units, and extent of source rocks were compiled using geographic information system (GIS) software. The political boundaries and cartographic representations were taken, with permission, from the Environmental Research Institute’s ArcWorld 1:3 million digital coverage (1996), have no political significance, and are displayed for general reference only. Oil and gas field center points were provided by, and reproduced with permission from, Petroconsultants (1996a, 1996b).

Abstract

Undiscovered conventional oil and gas resources were assessed within total petroleum systems of the Pelagian Province (2048) as part of the U.S. Geological Survey World Petroleum Assessment 2000. The Pelagian Province is located mainly in eastern Tunisia and northwestern Libya. Small portions of the province extend into Malta and offshore Italy. Although several petroleum systems may exist, only two “composite” total petroleum systems were identified. Each total petroleum system comprises a single assessment unit. These total petroleum systems are called the Bou Dabbous–Tertiary and Jurassic-Cretaceous Composite, named after the source-rock intervals and reservoir-rock ages.

The main source rocks include mudstone of the Eocene Bou Dabbous Formation; Cretaceous Bahloul, Lower Fahdene, and M’Cherga Formations; and Jurassic Nara Formation. Known reservoirs are in carbonate rocks and sandstone intervals throughout the Upper Jurassic, Cretaceous, and Tertiary sections. Traps for known accumulations include fault blocks, low-amplitude anticlines, high-amplitude anticlines associated with reverse faults, wrench fault structures, and stratigraphic traps.

The estimated means of the undiscovered conventional petroleum volumes in total petroleum systems of the Pelagian Province are as follows:

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids]

Total Petroleum System	MMBO	BCFG	MMBNGL
Bou Dabbous–Tertiary	667	2,746	64
Jurassic-Cretaceous Composite	403	2,280	27

Introduction

Undiscovered conventional oil and gas resources were assessed within total petroleum systems of the Pelagian Province (2048) as part of the World Energy Project being conducted by the U.S. Geological Survey (USGS). The Pelagian Province is a geologic province delineated by the USGS. This study documents the geology, undiscovered oil- and gas-resource potential, exploration activity, and discovery history of this geologic province.

The Pelagian Province is located mainly in eastern Tunisia and northwestern Libya (fig. 1). A portion of the province extends into Malta and offshore areas of Italy. The province area encompasses approximately 294,000 km^2. Neighboring geologic provinces as delineated by the USGS include the Tyrrhenian Basin (4069), Sicily (4066), Mediterranean Basin (2070), Sirte Basin (2043), Nefusa Uplift (2049), Hamra Basin (2047), Trias/Ghadames Basin (2054), Atlas Uplift (2053), and Tellian Foredeep (2052) (Persits and others, 1997).

Several total petroleum systems may exist in the Pelagian Province, but only two "composite" total petroleum systems are described in this report. Data available for this study are insufficient to adequately determine the relative contribution of every total petroleum system to individual accumulations and therefore preclude further subdivision. The described systems are called the Bou Dabbous–Tertiary (204801) and Jurassic-Cretaceous Composite (204802) Total Petroleum Systems, named after the source-rock intervals and reservoir-rock ages. Both total petroleum systems coincide with the extent of proven source rocks within the province and the hypothesized extent of petroleum migration from their respective source rocks (figs. 2, 3, and 4). Due to insufficient data, province and total petroleum system boundaries can only be approximately delineated and therefore are subject to future modification.

One assessment unit was defined for each total petroleum system; the assessment units coincide with the total petroleum systems (figs. 2, 3). The assessment units are named after the total petroleum system with a suffix of "Structural/Stratigraphic." This suffix refers to the progression from a structural and combination trap exploration strategy to a stratigraphic trap exploration strategy.

Volumes of petroleum discovered in each of the total petroleum systems of the Pelagian Province are shown in table 1. The Pelagian Province as a whole contains more than 2,300 million barrels (MMB) of known petroleum liquids (estimated total recoverable volume, which is cumulative production plus remaining reserves and includes approximately 2,240 million barrels of oil, MMBO, and 70 million barrels of natural gas liquids, MMBNGL) and approximately 17,200 billion cubic feet of known natural gas (17.2×10^{12} CFG or 17.2 TCFG) (Petroconsultants, 1996a). These volumes are greater than those shown in table 1 in that the volumes include those from neighboring total petroleum systems that slightly extend into the province. The Bou Dabbous–Tertiary Total Petroleum System contains a greater volume of known petroleum (approximately 2,100 MMBO, 15,500 BCFG, and 44 MMBNGL) than the Jurassic-Cretaceous Composite Total Petroleum System (approximately 103 MMBO, 1,300 BCFG, and 23 MMBNGL).

Table 1. Number and sizes of discovered fields for each assessment unit in the Pelagian Province (2048) through 1995.

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; NGL, natural gas liquids; MMBNGL, million barrels of NGL. Volumes reported are summed for oil and gas fields (USGS defined). Oil and gas fields containing known volumes below 1 million barrels of oil or 6 billion cubic feet of gas (BCFG) are grouped. Data from Petroconsultants (1996a)]

USGS Code	Number of fields	Known (discovered) volumes		
		Oil (MMBO)	Gas (BCFG)	NGL (MMBNGL)
204801	**Bou Dabbous-Tertiary Total Petroleum System**			
20480101	Bou Dabbous-Tertiary Structural/Stratigraphic Assessment Unit			
Oil fields	27	2,097	12,859	19
Gas fields	14	16	2,635	25
Fields < 1 MMBOE	5	1	15	0
All fields	46	2,114	15,509	44
204802	**Jurassic-Cretaceous Composite Total Petroleum System**			
20480201	Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit			
Oil fields	11	101	105	1
Gas fields	6	0	1,181	21
Fields < 1 MMBOE	9	3	15	0
All fields	26	103	1,301	23
2048	***Total***			
Oil fields	38	2,198	12,964	20
Gas fields	20	16	3,816	46
Fields < 1 MMBOE	14	4	30	0
All fields	72	2,217	16,810	67

Acknowledgments

I thank Ali M'Rabet of Entreprise Tunisienne d'Activités Pétrolières (ETAP) and David Boote and Marc Traut of Occidental Oil and Gas Corporation for their suggestions, and Lorna Carter, William Keefer, Katharine Varnes, Gregory Ulmishek, and Janet Pitman for their editorial review. I also thank Margarita Zyrianova for help in drafting some of the figures.

Province Geology

The Pelagian Province generally coincides with the offshore shelf area of east-central Tunisia and northern Libya (figs. 1, 2). However, the western and southern boundaries are onshore. The western boundary is along the North-South Axis (fig. 1), a basement-related structural feature bounded by normal faults separating the Pelagian Province in eastern Tunisia from the Mesozoic fault basin farther west (Bobier and others, 1991).

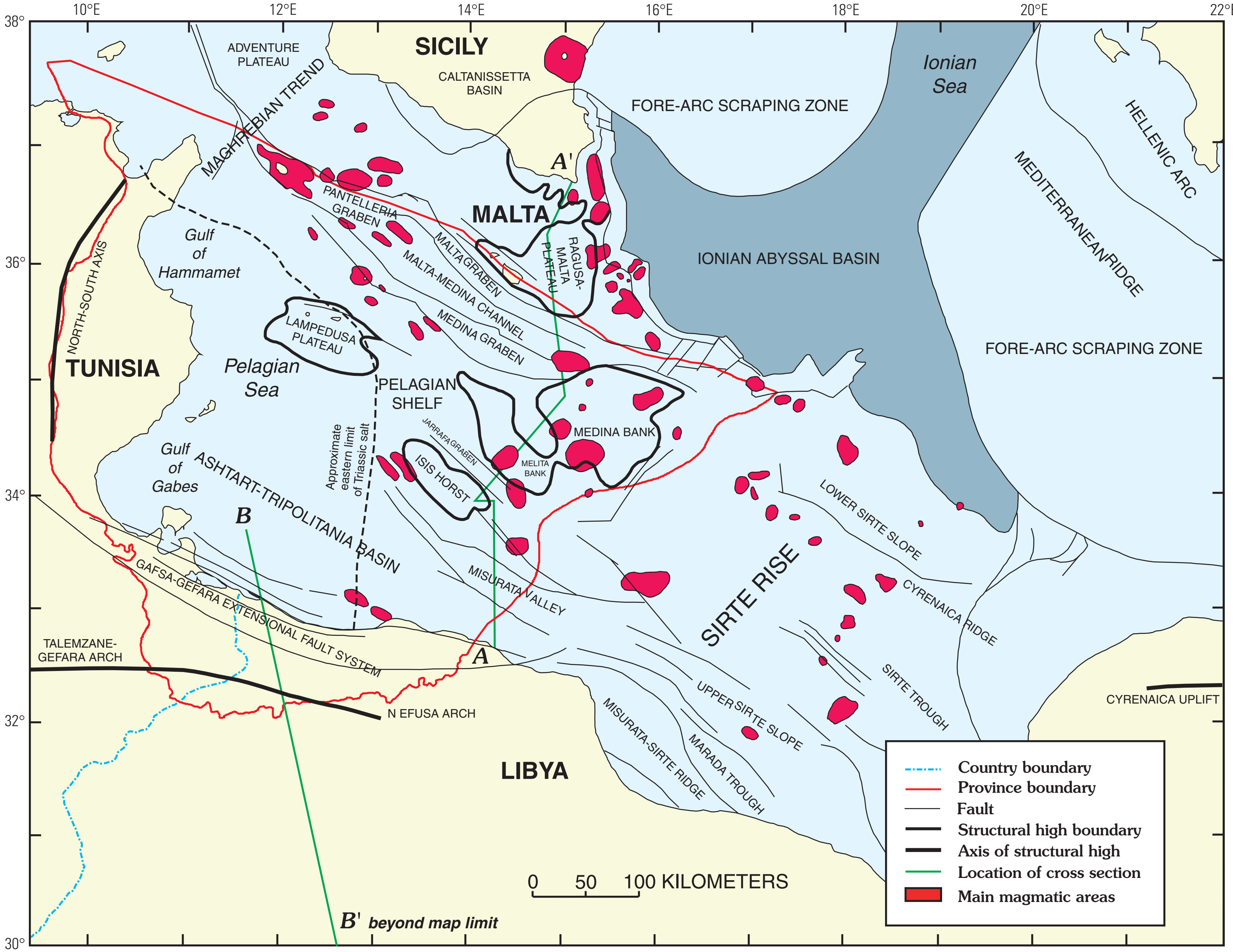


Figure 1. Central Mediterranean Sea, showing USGS-defined Pelagian Province (2048), major geologic structures, and location of cross sections. Boundaries of structural highs (for example, Isis Horst) are based on seismic data and drawn on 1.0 and 1.8 second two-way travel time intervals (modified from Finetti, 1982; Burollet, 1991; Bishop, 1988; Jongsma and others, 1985).

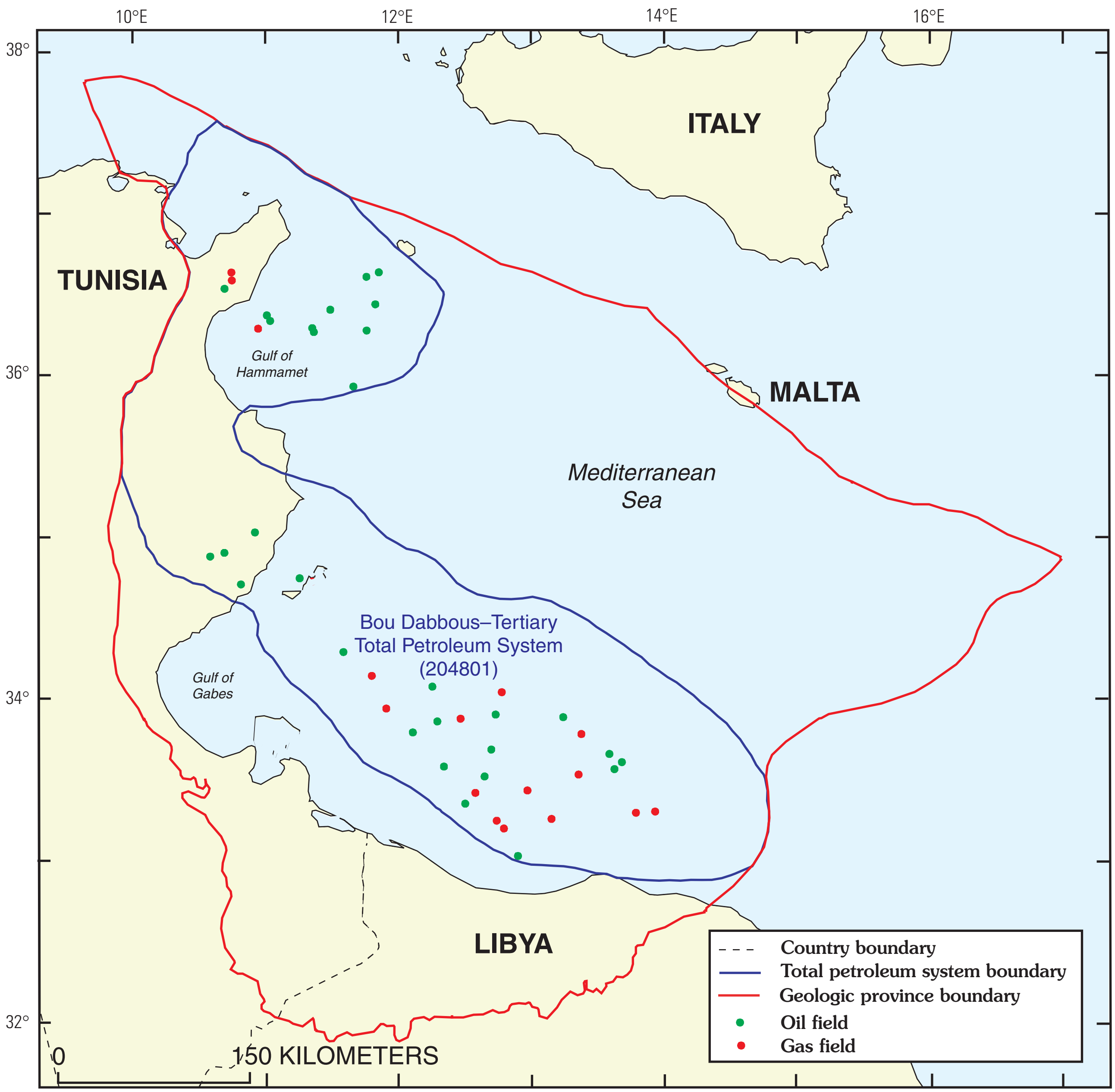


Figure 2. Areal extent of Bou Dabbous–Tertiary Total Petroleum System (204801) and coinciding Bou Dabbous–Tertiary Structural/Stratigraphic Assessment Unit (20480101) in the Pelagian Province (modified from Petroconsultants, 1996b; Persits and others, 1997).

The southern boundary was delineated along an escarpment that resulted from uplift of the Talemzane-Gefara and Nefusa Arches (fig. 1). The eastern boundary corresponds approximately with a fault zone and escarpment that marks the boundary between the Pelagian Shelf and Ionian Sea. The northern boundary follows a rift zone between the African and European continental plates (fig. 1).

Several major geologic structures exist within the Pelagian Province (fig. 1). Among the more pronounced structural highs are the Lampedusa Plateau, Medina Bank, Melita Bank, and Isis Horst. The Ashtart-Tripolitania Basin (also called Gabes-Tarābulus Basin), Misurata Valley, Jarrafa Graben, and grabens associated with the rift zone to the north are major depressions. These structures are oriented northwest to southeast. Cross section *A–A′* (fig. 5*A*) shows the major structural style as alternating horsts and grabens separated by normal faults.

Tectonic History

The tectonic evolution of the Pelagian Province controlled source- and reservoir-rock deposition, source-rock maturation, and petroleum migration and accumulation (Bédir and others, 1992).

The Paleozoic record is not well known in the Pelagian Province, but based on better known Paleozoic sections of the Saharan Platform (partly shown in fig. 5*B*) in southern Tunisia, the area was part of a passive continental margin, containing

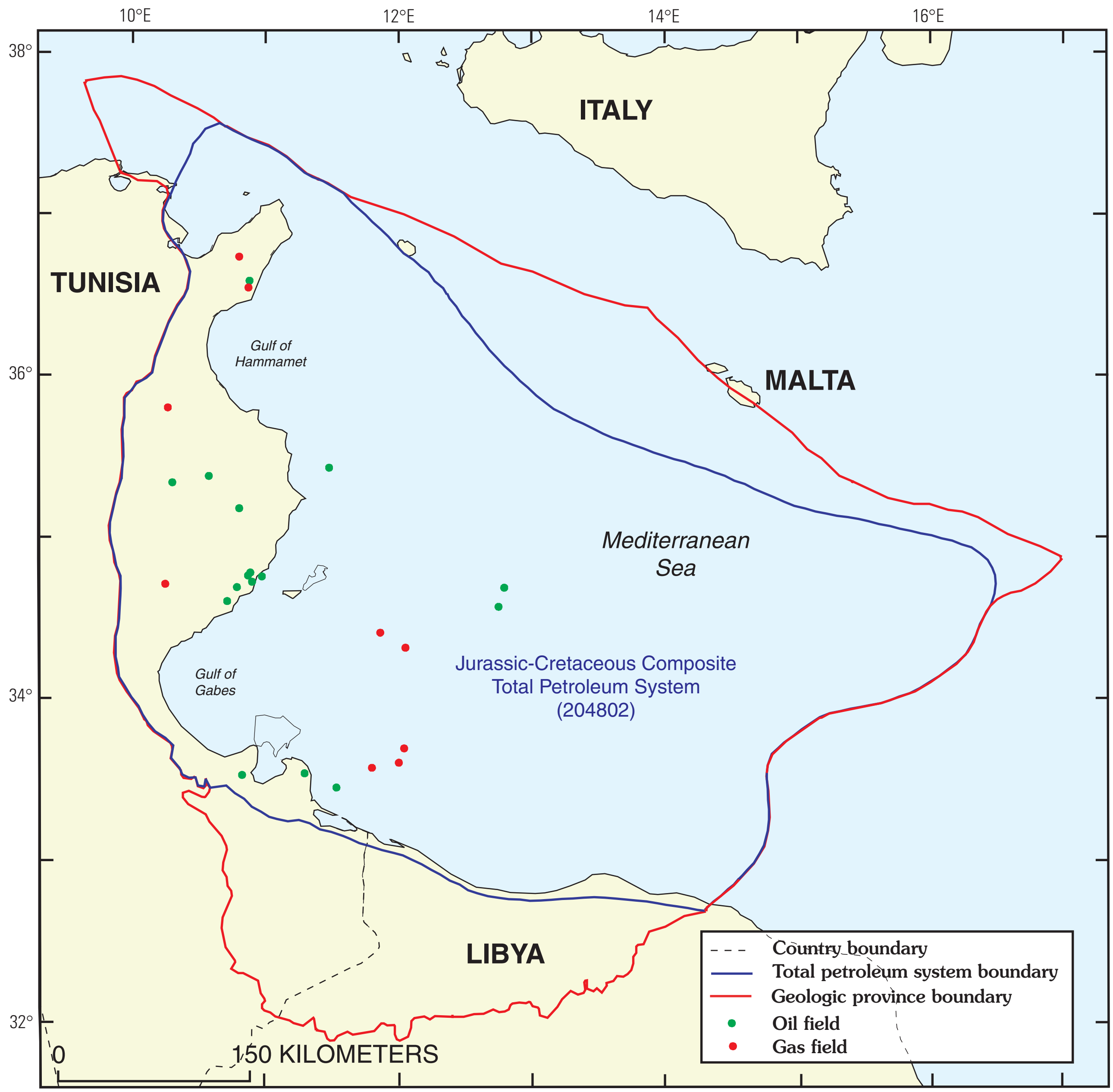


Figure 3. Areal extent of Jurassic-Cretaceous Composite Total Petroleum System (204802) and coinciding Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit (20480201) in the Pelagian Province (modified from Petroconsultants, 1996b; Persits and others, 1997).

Cambrian to Carboniferous clastic rocks. During the Carboniferous, Laurasia collided with Gondwana, marking the Hercynian event, resulting in the older Paleozoic section being folded, uplifted, and eroded (Aliev and others, 1971; Burollet and others, 1978; Boote and others, 1998). In the Late Carboniferous and Permian, several rift basins and grabens formed along the northern margin of the African plate by extension as a result of the initial breakup of Gondwana and the opening of the Tethyan seaway (Guiraud, 1998). Step faulting and subsidence occurred north of the Talemzane-Gefara Arch, where Upper Carboniferous and Permian sediments were deposited (fig. 1) (Burollet and others, 1978; Guiraud, 1998).

Extension and subsidence continued into the Triassic and Early Jurassic (Morgan and others, 1998). North-south-trending normal faults and east-west-trending transfer faults developed at this time, particularly along the North-South Axis in eastern Tunisia (Ouali, 1985; Morgan and others, 1998). Clastic and carbonate sediments were deposited in the Triassic (fig. 5*B*), as well as evaporites consisting of halite and sulfates (Burollet, 1991). Flowage of the evaporites due to sedimentary loading resulted in vertical migration and formation of diapirs and subsurface “salt walls” (Burollet, 1991). During the Early Jurassic, turbidites, as well as shelf and pelagic carbonates, were deposited.

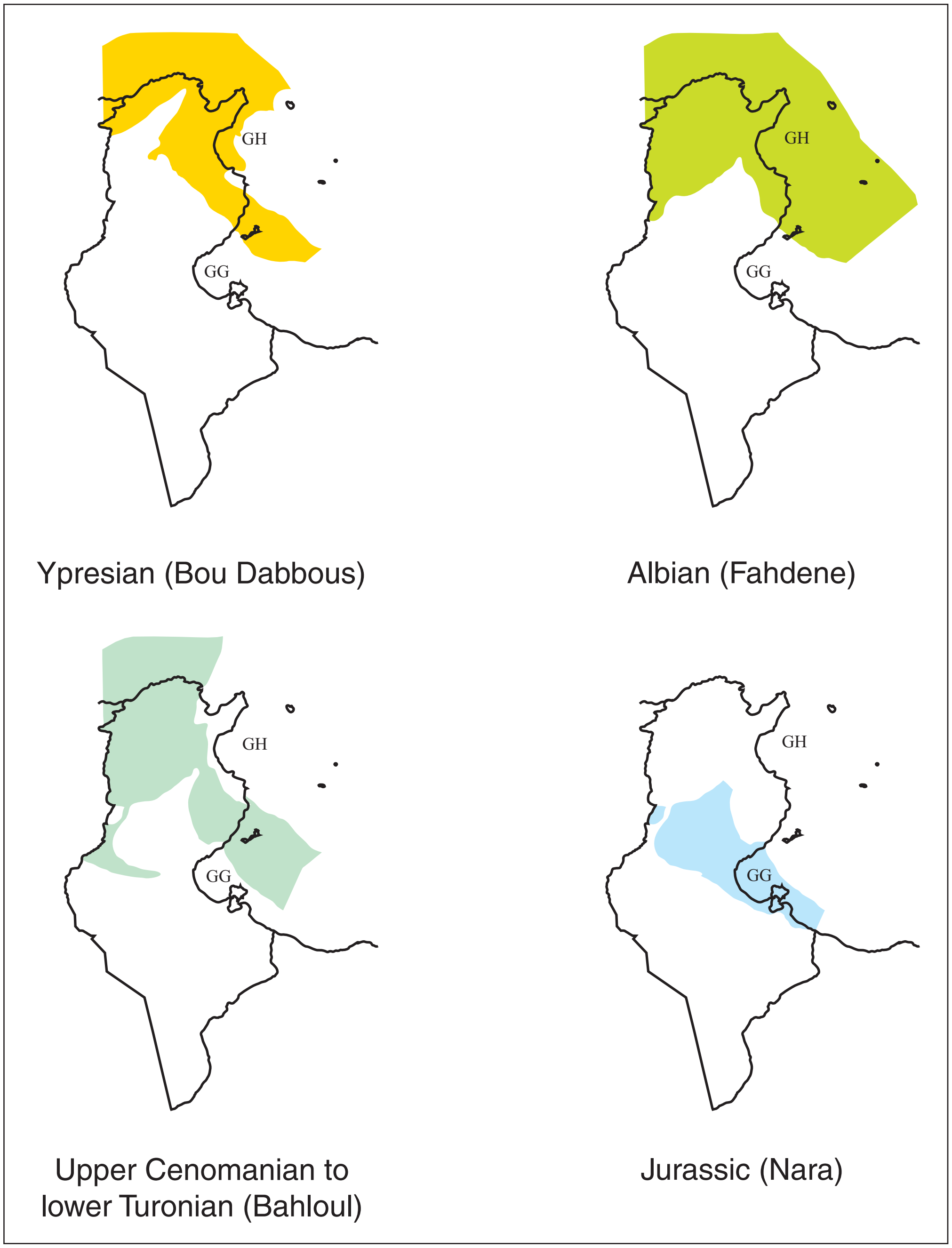


Figure 4. Distribution of proven Mesozoic and Cenozoic source rocks in Tunisia (modified from Entreprise Tunisienne d'Activités Pétrolières, 2000). GH, Gulf of Hammamet; GG, Gulf of Gabes.

In Middle and Late Jurassic time, the central Atlantic Ocean opened between Laurasia and Africa, developing a rift zone between the African and European continents. Shelf carbonates were deposited in the Pelagian Province area at this time (Burollet and others, 1978; Morgan and others, 1998). Faults associated with the opening of the Tethys Ocean and rifting between the European and African plates controlled sedimentation from the Middle Jurassic to the present (Morgan and others, 1998). The depocenter that developed north of the Talemzane-Gefara Arch during the Permian shifted northward (Burollet and others, 1978).

During the Early Cretaceous, rifting continued along the northern margin of the African plate, resulting in subsidence of the Saharan Atlas and the Aures trough of northern Algeria and Tunisia (Vially and others, 1994; Guiraud, 1998). Faults associated with rifting continued to control sedimentation (Morgan and others, 1998). Clastic alluvial sediments from the Saharan Platform were deposited in the southern portion of the Pelagian Province whereas open-marine clastic and carbonate sediments were deposited in the northern portion (Burollet and others, 1978). In some areas, sediment thickness was sufficient to initiate flowage of Triassic evaporites that continued into the Late Cretaceous (Morgan and others, 1998). The late Paleozoic depocenter that developed north of the Talemzane-Gefara Arch migrated northward with the development of a trough in the area of the Gafsa-Gefara extensional fault system during the Aptian

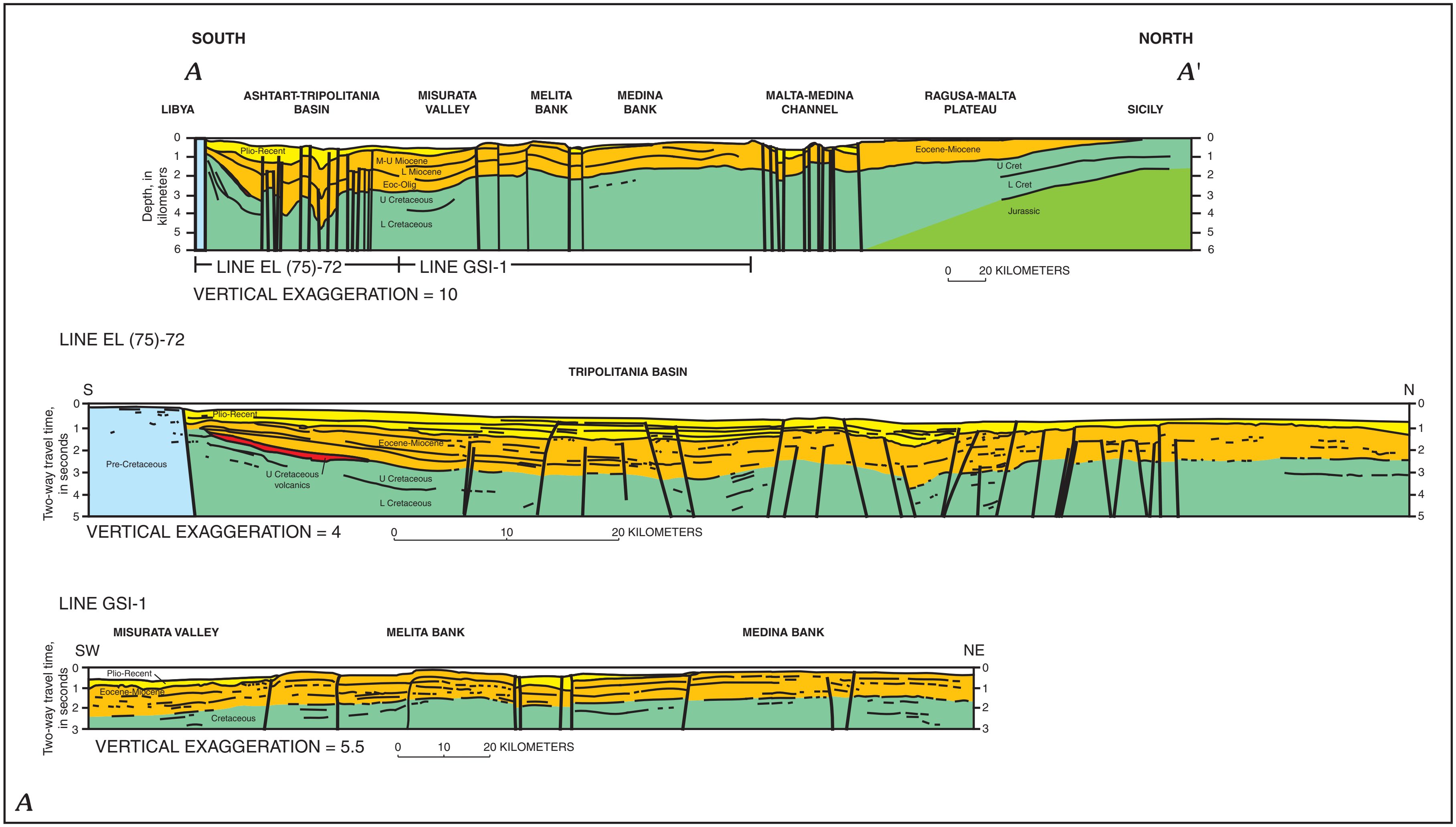


Figure 5. Cross sections through Pelagian Province (2048). *A*, South-to-north cross section *A–A′* through Pelagian Basin (modified from Jongsma and others, 1985). An expanded scale of the cross section is shown in seismic lines EL (75)-72 and GSI-1. Heavy vertical line, fault. Location of section, figure 1.

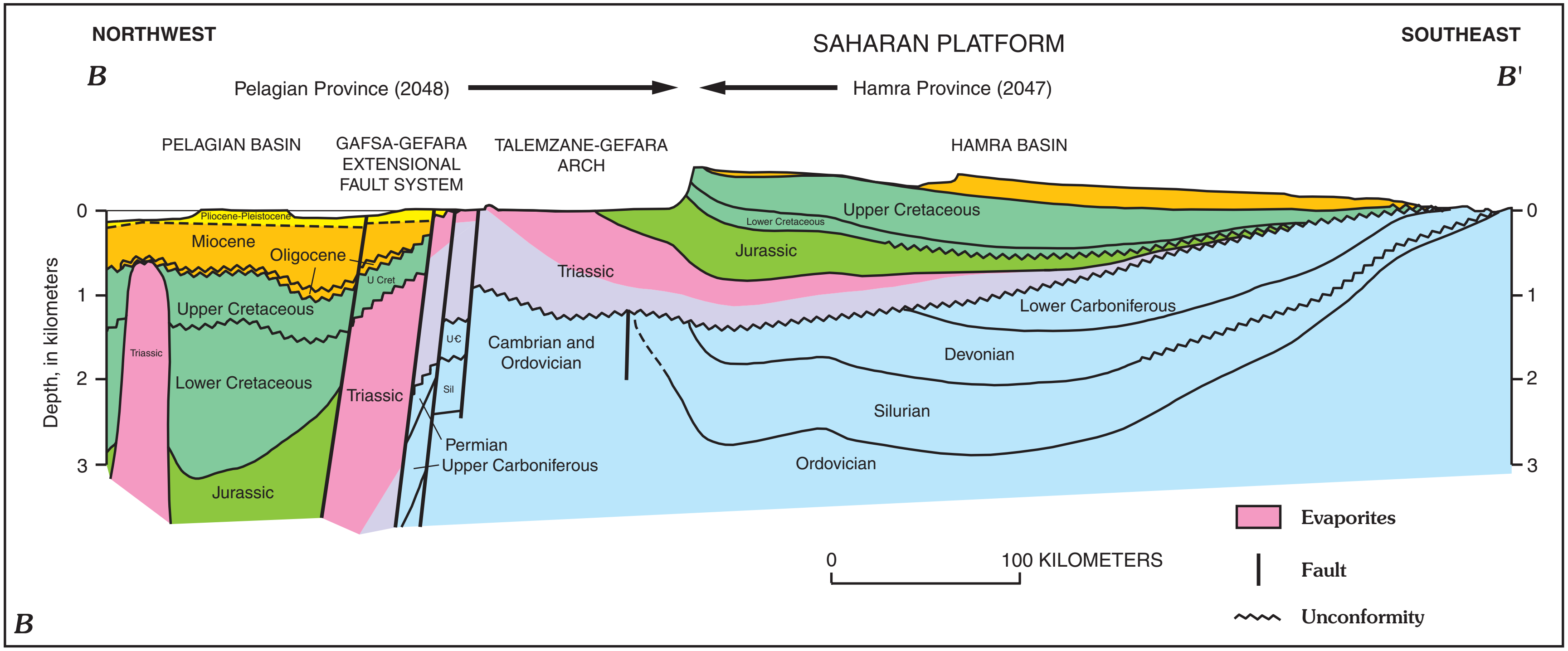


Figure 5—Continued. Cross sections through Pelagian Province (2048). *B*, Northwest-to-southeast cross section *B–B′* through Pelagian and Hamra Basins (modified from Burollet and others, 1978; Boote and others, 1998). Dashed lines, approximate position. Location of section, figure 1.

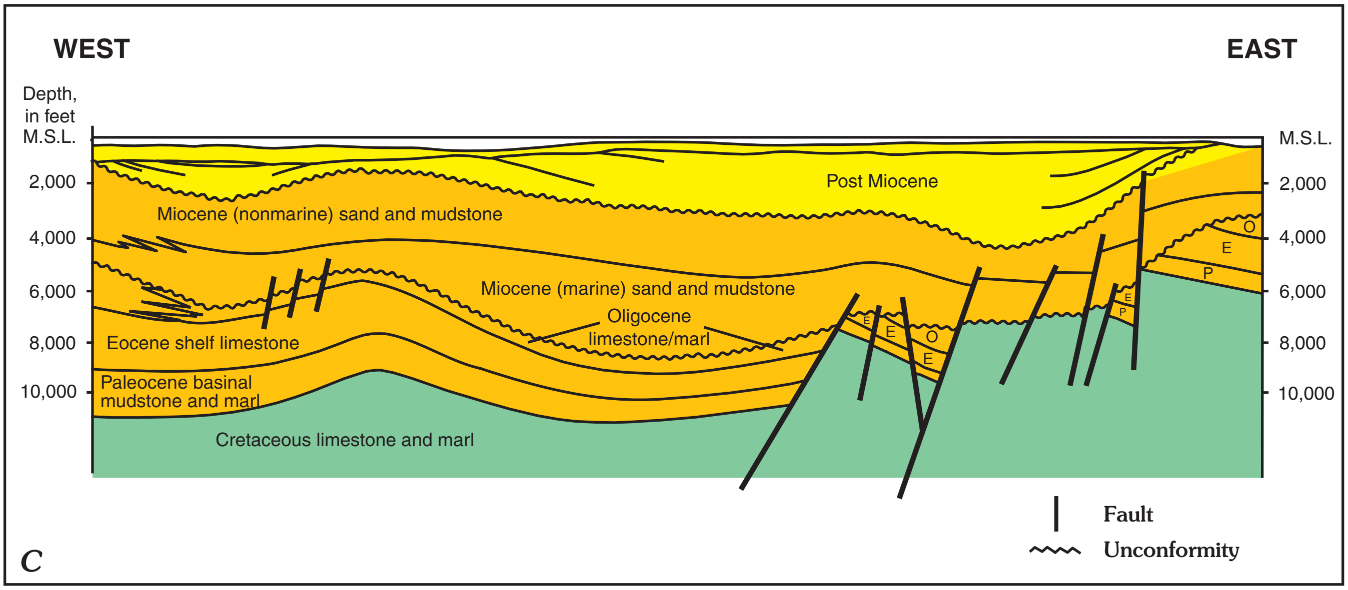


Figure 5—Continued. Cross sections through Pelagian Province (2048). *C*, Generalized west-to-east cross section through Gulf of Hammamet (modified from Long, 1978).

(fig. 1) (Burollet and others, 1978). Additionally, uplift and erosion occurred, particularly along the North-South Axis (Burollet and others, 1978), resulting in the Austrian Unconformity.

The African plate began to drift northward during the early Late Cretaceous, and this movement has continued to the present (Morgan and others, 1998). Rifting occurred along the northern margin of the African plate as a result of dextral shearing between the African and European plates, developing a complex horst and graben system. The grabens trend northwest to southeast and include the Ashtart-Tripolitania Basin and the Misurata Valley, and Jarrafa Graben (fig. 1) (Jongsma and others, 1985; Hammuda and others, 1991; Guiraud, 1998). Associated fault displacements and uplift of horst blocks controlled sedimentation (Morgan and others, 1998). In the Santonian (Late Cretaceous), structural inversion, reverse or thrust faulting, and folding occurred (Guiraud, 1998; Morgan and others, 1998). Fold belts along the Saharan Atlas, west of the North-South Axis, were initiated, whereby Triassic evaporites provided a décollement surface (Guiraud, 1998). Gentle uplift occurred during the latest Cretaceous to Paleocene (Burollet, 1967a).

In the early Eocene, west-to-east or west-northwest-to-east-southeast transfer faults were reactivated (Morgan and others, 1998). Sedimentation was controlled by this faulting activity, and facies boundaries of Ypresian (lower Eocene) rocks reflect the orientation of these strike-slip faults (Bishop, 1988; Morgan and others, 1998). The Kabylie microplate collided with the African margin in the Oligocene (Jongsma and others, 1985; Morgan and others, 1998), marked by an angular unconformity at the base of the Oligocene section (Morgan and others, 1998). Additionally, a fractured mobile terrane developed along the north edge of the Pelagian area, leaving the southern portion (most of the Pelagian Province, fig. 1) a passive platform attached to the African plate (Jongsma and others, 1985). Tectonic activity in late Oligocene to Miocene time resulted in nondeposition or erosion over much of the area (Burollet, 1967a and b). A disconformity between Miocene and older beds is present in eastern Tunisia, whereas an angular unconformity exists elsewhere (Burollet, 1967b). In some areas, the entire Paleogene section was removed (fig. 5*C*).

Deformation due to crustal shortening occurred north and west of the North-South Axis from late Miocene until early Pleistocene (Burollet, 1991; Morgan and others, 1998). Uplift of areas east of the North-South Axis resulted in erosion (Bishop, 1975; Salaj, 1978). The fault systems of the Pantelleria Graben, Malta Graben, Malta-Medina Channel, and Medina Graben (fig. 1) began to develop in the late Miocene to early Pliocene; and deformation continues to the present, resulting from rifting and east-to-west dextral movements (Jongsma and others, 1985). Fault systems, developed earlier in the Pelagian Province area (south of the Pantelleria Graben, Malta Graben, Malta-Medina Channel, and Medina Graben), continued to subside and control deposition. Locally, relatively greater amounts of subsidence occurred, such as in the Gulf of Hammamet (Burollet and others, 1978). Orogenic movement is presently occurring in northern Tunisia (Burollet and others, 1978).

Magmatic activity has occurred throughout the area (fig. 1), much of it occurring in the Aptian to Paleocene due to rifting on the Pelagian Shelf and in the Neogene to Quaternary due to the Alpine (Atlassic) collision and subsequent opening of the western Mediterranean (Finetti, 1982; Wilson and Guiraud, 1998; Guiraud, 1998).

The present-day geothermal gradients are variable across the Pelagian Province, but observed trends correspond to the recent structural evolution of the area. Values in offshore areas range from about 3.5° to 4.5°C/100 m (Lucazeau and Ben Dhia, 1989) and are higher than values in onshore areas.

Stratigraphy

The regional stratigraphy is variable across the Pelagian Province, and stratigraphic nomenclature varies among authors and countries. Throughout the Mesozoic and Cenozoic, open-marine conditions existed generally in the northern part of the province, whereas neritic shelf conditions existed in the southern part (Burollet and others, 1978). Little information exists for rocks older than Triassic or Jurassic (Burollet, 1990). This study uses primarily the nomenclature given by Entreprise Tunisienne d'Activités Pétrolières (1997) for the Tunisian portion of the province and Hammuda and others (1991) for the Libyan portion. Columnar sections, stratigraphic nomenclature, and correlations are shown in figure 6.

Triassic rocks can be separated into two main intervals, a lower clastic interval and an upper evaporite interval (Bishop, 1975). The lower clastic interval includes sandstone and mudstone of the Bir El Jaja, Ouled Chebbi, and Kirchaou or Trias Argilo-Greseux Inferieur Formations (fig. 6). Depositional facies were continental in the southern portion of the Pelagian Province, grading into shallow marine facies northward. The northern limit of the clastic interval is not known (Bishop, 1975). The Kirchaou or Trias Argilo-Greseux Inferieur Formation provides major oil and gas reservoirs in the Saharan Platform basins of Libya, Tunisia, and Algeria. Between the clastic and evaporite intervals is a dolomitic section equivalent to the Azizia, Trias Carbonate, and Trias Argilo-Greseux Superieur (TAGS) Formations (fig. 6). The upper evaporite interval contains interbedded anhydrite, salt, and dolostone (Busson, 1967; Bishop, 1975).

The Jurassic and Lower Cretaceous sections contain mostly carbonate rocks, representing increasingly deeper marine to pelagic deposition northwestward (Burollet and others, 1978). Lagoonal, deltaic, and terrigenous facies were present in the south and southwest, which migrated northward through time until the Aptian (Bishop, 1975; Burollet and others, 1978; M'Rabet, 1984). These landward deposits include sandstone of the Upper Jurassic M'Rabtine Formation, Upper Jurassic to Lower Cretaceous Meloussi Formation, and Lower Cretaceous Boudinar Formation (fig. 6). Marine deposits include limestone, dolostone, and marl (Salaj, 1978) of the Jurassic Nara Formation and Upper Jurassic to Lower Cretaceous Sidi Khalif and M'Cherga Formations (fig. 6). Micrite and mudstone were deposited in the deep marine environments (Bishop, 1975).

Deposition of condensed sections, as well as the development of shoal facies and some reefs, occurred along the North-South Axis during the Jurassic and Early Cretaceous (Bishop, 1975; Salaj, 1978; Burollet and others, 1978). Farther east and to the south, pelagic sediments were deposited in a subsiding depositional trough that existed in the present-day Gulf of Gabes area (fig. 1) (Salaj, 1978; Burollet and others, 1978).

A maximum flooding event occurred during the Barremian to Aptian (Early Cretaceous; Bishop, 1975; Salaj, 1978). Barremian rocks consist of limestone, marl, and interbedded sandstone and shale of the Bouhedma and M'Cherga Formations, and the Sidi Aïch sandstone (Bishop, 1975; Salaj, 1978; Entreprise Tunisienne d'Activités Pétrolières, 1997).

Aptian and Albian rocks include limestone, dolostone, sandstone, mudstone, marl, and some evaporites of the Orbata, Serdj, Hameima, and Lower Fahdene Formations (Burollet and others, 1978; Salaj, 1978). The Orbata Formation (or Orbata member of the Gafsa Formation in earlier publications) is limestone and dolostone (Bishop, 1975). The Serdj Formation is a reef limestone that is laterally equivalent to the Orbata Formation and overlain by clastic sediments of either the deeper marine Hameima Formation or Lower Fahdene (also called the Mouelha) Formation (fig. 6) (Burollet and others, 1978).

Unconformably overlying the Orbata Formation is the Albian to Turonian Zebbag Formation (fig. 6). Zebbag sediments were deposited on a shallow marine carbonate platform in the Gulf of Gabes area and central Tunisia (Bishop, 1988). Subtidal conditions existed in central Tunisia and in the area of the present-day Gulf of Gabes coast, where lagoonal mudstone, dolostone, and anhydrite were deposited (Bishop, 1975; Bishop, 1988). Reefs, reefoid facies, and rudist banks are also present (Bishop, 1975; Burollet and others, 1978). In the Pelagian Province, the Zebbag Formation is limestone, dolostone, and bioclastic rocks, and is laterally equivalent to basinal mudstone and argillaceous limestone of the Fahdene and Bahloul Formations (Bishop, 1988). The Fahdene Formation is a dark-gray mudstone and the Bahloul Formation is a dark-colored, laminated, euxinic, argillaceous limestone (Burollet and others, 1978; Bishop, 1988).

The Turonian to Campanian Aleg Formation overlies the Fahdene, Bahloul, and Zebbag Formations. Rocks of the Aleg Formation include mudstone, limestone, and marl (Bishop, 1975; Salaj, 1978). The Bireno, Miskar, and Douleb Formations are equivalent to some intervals of the Aleg Formation (fig. 6). Both the Bireno and Douleb Formations are, in part, laterally equivalent to, or are members of the Miskar Formation. These formations consist of limestone, dolostone, and marl (Salaj, 1978; Entreprise Tunisienne d'Activités Pétrolières, c. 1999). The Miskar Formation represents a rudist bank or banks on the shelf edge or slope (Bishop, 1988; Knott and others, 1995).

During the Campanian to Maastrichtian (latest Cretaceous), chalky limestone, micrite, and marl of the Abiod Formation were deposited over the Aleg Formation (Burollet and others, 1978; Salaj, 1978; Bishop, 1975). The Santonian Jamil Formation and Campanian to Maastrichtian Bu Isa Formation are laterally equivalent, in part, to the Aleg and Abiod Formations (fig. 6).

Overlying the Abiod and Bu Isa Formations is the Maastrichtian to Thanetian (Paleocene) El Haria Formation, a gray, black, or brown mudstone, containing some thin limestone beds in the lower part (Burollet, 1967b; Bishop, 1975). The El Haria Formation covers much of the Pelagian Province but is absent in the southern and southwestern portions, as a result of either nondeposition or removal by erosion (Bishop, 1975). The Al Jurf, Ehduz, and part of the Bilal Formations are laterally equivalent to the El Haria Formation (fig. 6).

The Thanetian to Lutetian Metlaoui Group overlies the El Haria Formation and consists of rocks representing lagoonal, carbonate ramp, and marine deposition. The lowermost beds are the Tselja (oldest) and Chouabine Formations (fig. 6). The Tselja Formation is represented by evaporites (including gypsum) and dolomitic rocks; the Chouabine Formation is

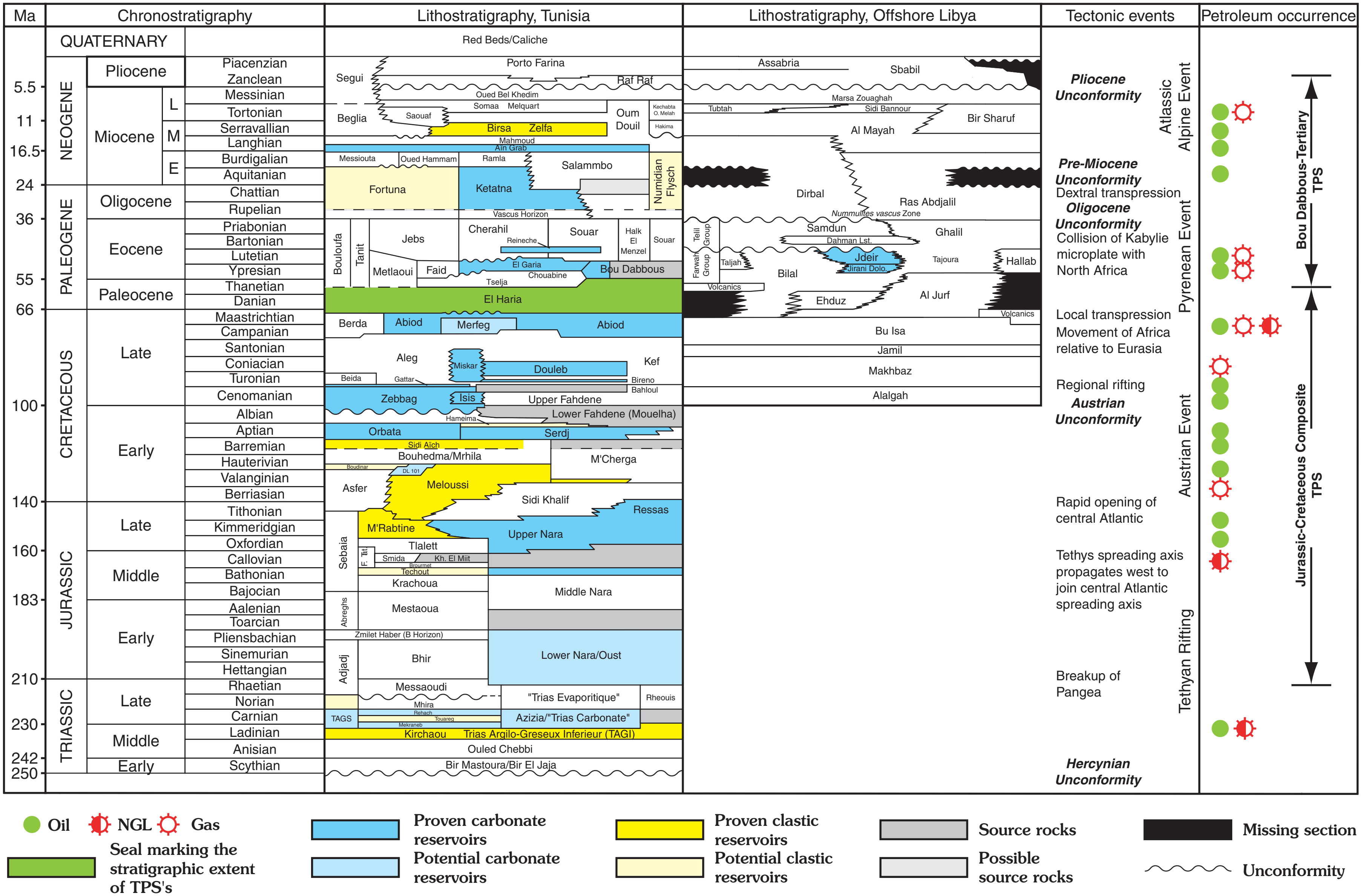


Figure 6. Columnar section, stratigraphic nomenclature, tectonic events, and petroleum occurrence for Tunisia and offshore Libya (modified from Entreprise Tunisienne d'Activités Pétrolières, 1997; Hammuda and others, 1991). Stratigraphic column for Tunisia represents all areas of Tunisia, including the Pelagian Province (2048). Dashed lines, approximate position. TPS, total petroleum system.

represented by glauconitic and phosphatic beds (Burollet and others, 1978; Bishop, 1988). Above and partially equivalent to the Chouabine Formation are rock units that represent a continuous set of lagoonal to open-marine depositional facies. These units include the Faid Formation, representing an evaporitic anhydrite and dolostone facies; the Ain Merhotta Formation, restricted shelf gastropod facies (not shown in fig. 6); the El Garia Formation, shallow-shelf nummulitid facies; and the Bou Dabbous Formation, deep-water globigerinid facies (Bishop, 1988; Loucks and others, 1998). The Libyan Jirani Dolomite and Jdeir Formation are laterally equivalent to the Metlaoui Group (fig. 6).

Rocks of the middle to upper Eocene are mudstone and limestone of the Souar Formation, and are laterally equivalent to evaporites of the Jebs Formation (Bishop, 1988). Some coquinoid nummulitic carbonate rocks are present in the Souar Formation, such as the Lutetian Reineche Formation (fig. 6) (Bishop, 1975). The Oligocene Unconformity marks the top of the Souar and laterally equivalent formations.

Immediately overlying the Oligocene Unconformity is mudstone with interbedded fine-grained sandstone containing some nummulitic limestones, called the *Nummulites vascus* horizon (Bishop, 1975; Burollet and others, 1978; Salaj, 1978; Hammuda and others, 1991).

Rocks representing a succession of terrigenous to marine depositional facies overlie the *Nummulites vascus* horizon (Bishop, 1975; Burollet and others, 1978; Salaj, 1978). Each depositional facies type carries a different formation name. The most landward formation is the Fortuna Formation, capped by continental rocks of the Messiouta Formation. Nearshore marine rocks are represented by limestone of the Ketatna Formation, which interfingers with offshore mudstone of the Salammbo Formation (Schwab, 1995). The Libyan equivalents to the Ketatna and Salammbo Formations are the Dirbal and Ras Abdjalil Formations (Hammuda and others, 1991) (fig. 6). The ages of all these formations range from Rupelian to Burdigalian (Oligocene to Miocene; fig. 6). Tectonic activity during the late Oligocene and early Miocene resulted in erosion and nondeposition. Basal Miocene sediments are commonly conglomeritic and unconformably overlie older sediments (Burollet, 1967b).

Upper Miocene rocks include (1) the transgressive limestone of the Aïn Grab Formation; (2) marls of the Mahmoud Formation; (3) a sandy sequence represented by the Beglia, Saouaf, Birsa, Oum Douil, and part of the Segui Formations; and (4) lagoonal and brackish-water sediments (including anhydrite; Jongsma and others, 1985) of the Messinian Oued Bel Khedim and Marsa Zouaghah Formations (Burollet and others, 1978; Salaj, 1978) (fig. 6). The top of the Miocene is marked by an angular unconformity, above which lower Pliocene sediments were deposited during marine transgression (Bishop, 1975; Burollet and others, 1978).

During the Pliocene, strong local subsidence occurred in troughs and basins, into which thick accumulations of terrigenous and marine clastic sediments were deposited (Bishop, 1975; Burollet and others, 1978). Formations include the Raf Raf and Porto Farina Formations, both laterally equivalent to parts of the Segui and Sbabil Formations (fig. 6).

Quaternary deposits include clastic terrigenous and marine sediments (Burollet and others, 1978).

Regional Exploration Activity

As of 1996, more discoveries were made in reservoirs of the Bou Dabbous–Tertiary Total Petroleum System than in reservoirs of the Jurassic-Cretaceous Composite (figs. 2 and 3). Most of the larger oil and gas fields in both total petroleum systems were discovered since 1970 (Appendices 1 and 2), although a few earlier discoveries had been made in the Jurassic-Cretaceous Composite Total Petroleum System.

Most of the exploration in Tunisia was in the Pelagian Province, beginning in the early 1950's. Fewer than 10 new-field wildcat wells were drilled in most years until the early 1970's. Since the early 1970's, however, the number of new-field wildcat wells drilled per year increased, and the number peaked in the early 1980's to more than 20 new-field wildcat wells per year; drilling then generally decreased until the middle 1990's. Exploration by foreign companies in Tunisia between the early 1960's and the 1970's was limited. Throughout the 1970's and 1980's, however, Tunisia revised its legislation and introduced measures to encourage foreign companies to explore and develop oil and gas resources (Davies and Bel Haiza, 1990; Montgomery, 1994).

In the Libyan portion of the Pelagian Province, exploration activity appeared greatest in the early 1960's with about six to seven new-field wildcat wells per year and again from the late 1970's to early 1980's with as many as six new-field wildcat wells per year. Few new-field wildcat wells were drilled from the mid 1980's to 1996.

In 1955, the Libyan government implemented the Libyan Petroleum Law, designed to attract foreign interest (Nelson, 1979). In the early 1970's, however, the Petroleum Law was amended as a result of nationalization of oil companies, thereby reducing the control of oil- and gas-related activities by foreign companies. Furthermore, U.S. and U.N. sanctions imposed on Libya in the late 1980's and early 1990's discouraged foreign participation and restricted the available resources required for exploration and development (Arab Petroleum Research Center, 1998; Petzet, 1999). In the late 1980's, however, new terms to encourage foreign interest were introduced, which were still in effect as of 1996.

From the late 1970's until the late 1980's, the exploration and production of fields in a portion of offshore Tunisia and Libya were suspended pending adjudication of the Tunisian-Libyan demarcation line in the Gulf of Gabes (Nelson, 1979). The conflict was resolved in 1988 when Libya and Tunisia agreed to create a joint oil exploration company to operate in this area (called the 7th November concession) (Arab Petroleum Research Center, 1998).

A large portion of the Pelagian Province is offshore (fig. 1), and water depths in that portion are generally less than 400 m. The greatest water depth is in the Malta Trough, which has a maximum depth of 1,715 m (Jongsma and others, 1985). As of 1996, wells were drilled in water as deep as 351 m (Petroconsultants, 1996a).

A basic infrastructure has been established in the Pelagian Province whereby tanker terminals and a pipeline network are capable of transporting petroleum from most of the major producing fields to port cities in Tunisia and Libya (Arab Petroleum Research Center, 1998).

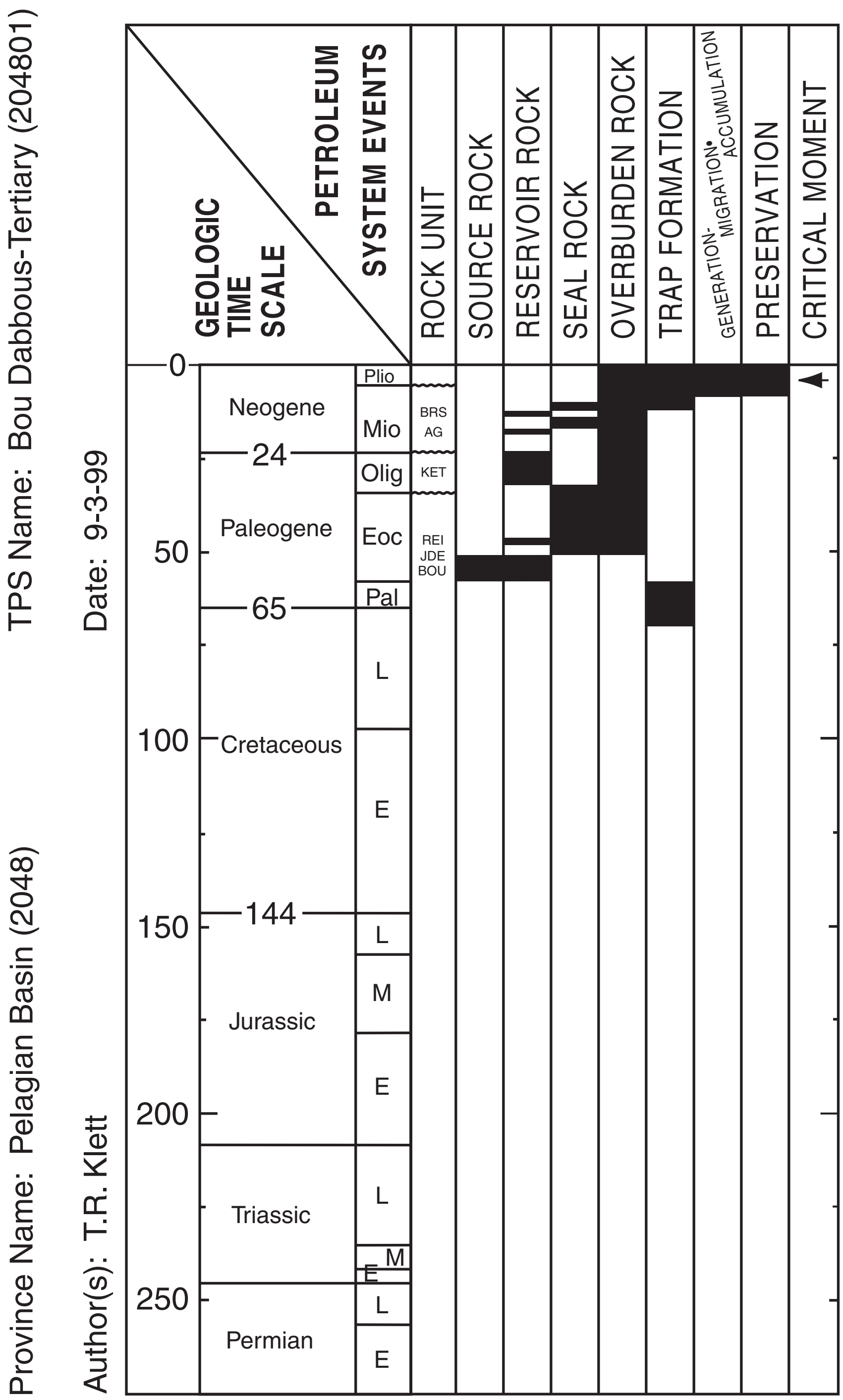


Figure 7. Events chart for Bou Dabbous–Tertiary Total Petroleum System (204801). BRS, Birsa; AG, Aïn Grab; KET, Ketatna; REI, Reineche; JDE, Jdeir, BOU, Bou Dabbous.

The Bou Dabbous–Tertiary Total Petroleum System (204801)

The Bou Dabbous–Tertiary Total Petroleum System extends from northern Tunisia to offshore Libya, from the northwest to the southeast portion of the Pelagian Province (figs. 1 and 2). This total petroleum system and corresponding assessment unit generally coincide with the potential extent of petroleum being generated by, and migrating from, Eocene (Bou Dabbous) source rocks. Where present, the Upper Cretaceous to Paleocene El Haria mudstone separates this total petroleum system from the underlying Jurassic-Cretaceous Composite Total Petroleum System. An events chart (fig. 7) summarizes the ages of source, reservoir, and seal rocks; the timing of trap development; and generation and migration of petroleum.

Eocene extension and fault reactivation controlled the distribution of depositional facies of the Metlaoui Group (Morgan and others, 1998). Neogene subsidence resulted in deposition of turbidite-fan deposits and invoked maturation of Cretaceous and Eocene source rocks and petroleum migration (Bédir and others, 1992). Petroleum migration most likely occurred from late Miocene to Quaternary (Bédir and others, 1992). Potential traps for petroleum accumulations were developed in the late Miocene and Quaternary as a result of compression by reactivating older structures (Bédir and others, 1992).

Several fields with reported production from Oligocene and Miocene reservoirs exist in the Gulf of Hammamet where the Bou Dabbous source rocks have not been mapped (figs. 2, 4, and 8). Although the Bou Dabbous Formation is assumed to be the most likely source rock, Cretaceous source rocks may have been a major supply of petroleum to these fields. If this is the case, then a portion of the discovered and undiscovered petroleum included with the Bou Dabbous–Tertiary Total Petroleum System (approximately 8 to 10 percent of the known oil and 3 to 5 percent of the known gas; approximately 10 to 25 percent of the undiscovered oil and 5 to 25 percent of the undiscovered gas) should be included with the Jurassic-Cretaceous Total Petroleum System.

Source Rocks

The primary source rock is dark-brown marl and mudstone of the lower Eocene (Ypresian) Bou Dabbous Formation (or lateral equivalents) (Macgregor and Moody, 1998; Entreprise Tunisienne d'Activités Pétrolières, c. 1999). Various authors have mapped the extent of the Bou Dabbous Formation differently (compare figs. 4 and 8). However, this formation generally follows an arcuate and elongate trend extending from the northwest to the southeast portions of the province (fig. 2).

The Bou Dabbous Formation contains type I and II kerogen and ranges in thickness from 50 to 300 m (Entreprise Tunisienne d'Activités Pétrolières, c. 1999). Total organic carbon content (TOC) of the Bou Dabbous ranges from 0.4 to 4 percent, and maturation is described as early mature to mature (Entreprise Tunisienne d'Activités Pétrolières, c. 1999). This source rock most likely became mature in the Miocene to Pleistocene (Bédir and others, 1992), and the generated petroleum migrated laterally into adjacent, juxtaposed reservoirs and vertically along faults or fractures.

The API gravity of oil generated from the Bou Dabbous source rock ranges from 18º to 53º; the mean is 36º (Petroconsultants, 1996a; GeoMark, 1998). Sulfur content ranges from 0.2 to 0.6 percent; the mean is 0.4 percent (GeoMark, 1998).

Overburden Rocks

Overburden rocks are variable across the Pelagian Province area mainly due to erosion and nondeposition during the Oligocene and Pliocene deformation (fig. 5*C*). Eocene, Miocene, and Pliocene rocks make up most of the overburden. In some areas, large portions of the Paleogene section (Paleocene, Eocene, and Oligocene) were removed by erosion during pre-Miocene deformation (fig. 5*C*). Smaller portions of Miocene rocks were removed, in turn, by erosion before and during the Pliocene. Both Mesozoic and Cenozoic rocks are thickest in the Ashtart-Tripolitania Basin and in the central part of the Gulf of Hammamet. A Quaternary section of variable thickness covers much of the area.

Reservoir Rocks

Known reservoir rocks include members of the lower Eocene Metlaoui Group (the laterally equivalent members of Bou Dabbous Formation), such as the El Garia fractured limestone; Jirani dolostone, Jdeir limestone, and Reineche limestone, as well as the Oligocene to Miocene Ketatna limestone and the middle Miocene Aïn Grab limestone and Birsa sandstone. The Oligocene to Miocene Fortuna sandstone may be a potential reservoir. Figure 8 shows the distribution of the Metlaoui Group reservoirs and source rock, as well as locations of fields having reported oil and gas in reservoirs of the Bou Dabbous–Tertiary Total Petroleum System. Names of laterally equivalent rock units are given in figure 6, and known reservoir properties are given in table 2.

Volumetrically, most of the discovered petroleum, as of 1996, is in Metlaoui Group reservoirs (approximately 1,900 MMBO and 15,000 BCFG), although a significant volume of petroleum was discovered in Miocene-age reservoirs (approximately 175 MMBO and 400 BCFG).

Seal Rocks

Seals include Eocene and Miocene mudstone and carbonate rocks (compact micrite, for example) (Entreprise Tunisienne d'Activités Pétrolières, c. 1999). Mudstone of the Cherahil and Souar Formations and their lateral equivalents provide seals for many of the Eocene reservoirs (Macgregor and Moody, 1998).

Trap Types in Oil and Gas Fields

Generally, traps were developed by the formation of horst blocks and associated pinchouts during the Cretaceous to Paleocene, by reactivation of these horsts during the Miocene to Quaternary (fig. 9*A*), and by folding and subsequent faulting (fig. 9*B*) (Bédir and others, 1992; Entreprise Tunisienne d'Activités Pétrolières, c. 1999). Most of the discovered oil and gas fields (having reported petroleum in reservoirs within the Bou Dabbous–Tertiary Total Petroleum System as of 1996) are associated with low-amplitude anticlines, high-amplitude anticlines associated with reverse faults (inversion anticlines), wrench fault structures, and stratigraphic features (Petroconsultants, 1996a; Entreprise Tunisienne d'Activités Pétrolières, c. 1999). Accumulations in combination structural-stratigraphic traps are also common. Potential traps may be associated with

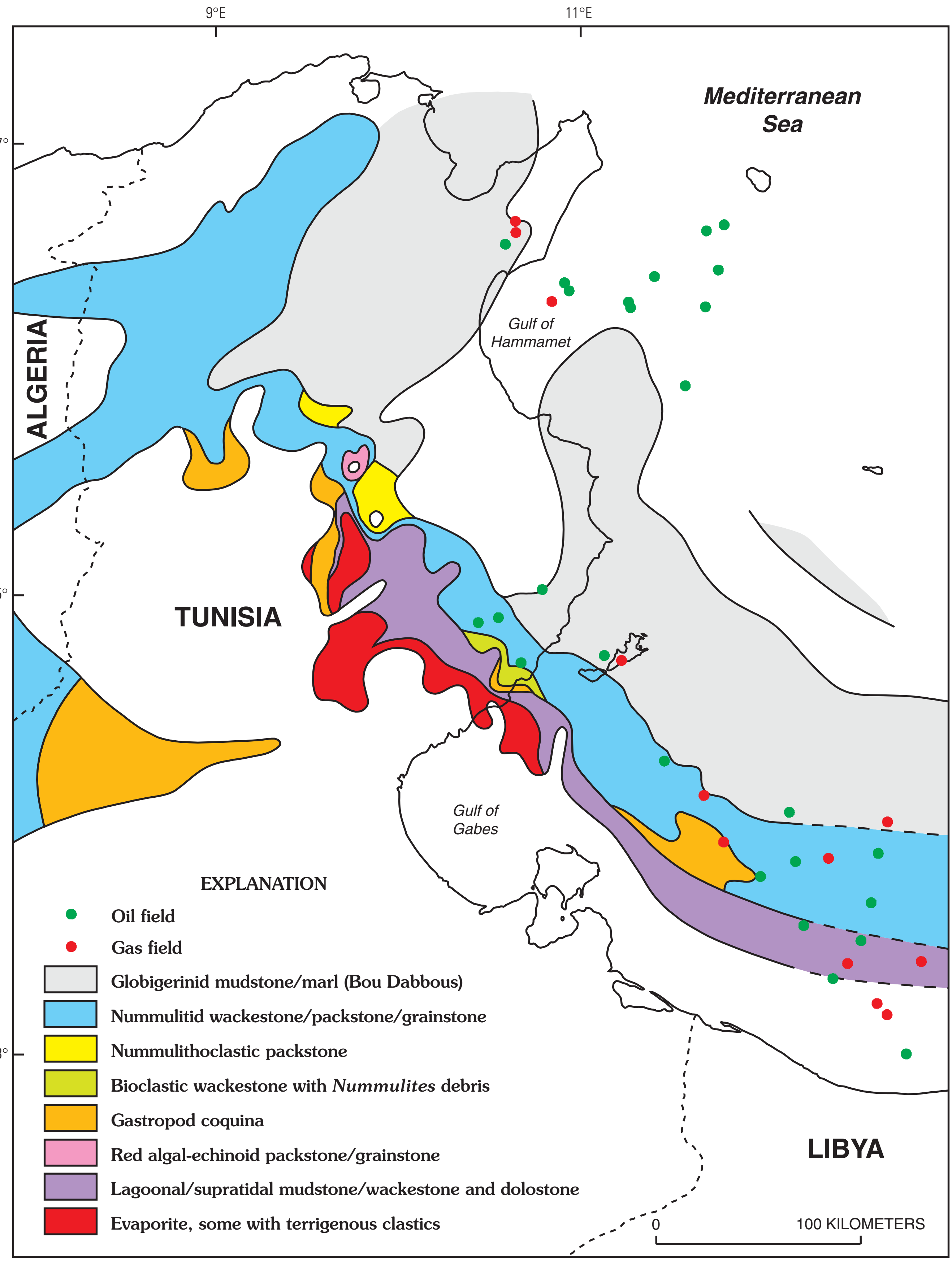


Figure 8. Lithofacies map of the Metlaoui Group (excluding the Chouabine and Tselja Formations) and locations of fields with reported oil and gas volumes in Bou Dabbous–Tertiary Total Petroleum System (204801) (modified from Bishop, 1988; Petroconsultants, 1996b). Dashed lines, approximate location. White areas, rock section is absent.

Table 2. Reservoir properties of discovered accumulations for each assessment unit in the Pelagian Province (2048) through 1995.

[nd, either no data or insufficient data. Data from Petroconsultants (1996a)]

USGS Code	Depth (meters)				Gross thickness (meters)				Porosity (percent)				Permeability (millidarcies)			
	Minimum	Mean	Maximum	Number	Minimum	Mean	Maximum	Number	Minimum	Mean	Maximum	Number	Minimum	Mean	Maximum	Number
204801	**Bou Dabbous-Tertiary Total Petroleum System**															
20480101	Bou Dabbous-Tertiary Structural/Stratigraphic Assessment Unit															
Metlaoui/El Garia	820	2,230	3,390	13	8	73	190	11	7	18	28	13	<0.1	530	3,000	9
Jdeir	2,280	2,530	3,370	20	150	176	200	18	nd	25	nd	nd	nd	500.0	nd	nd
Birsa	640	1,260	1,980	8	5	60	100	5	30	31	32	7	400	860	1,000	7
204802	**Jurassic-Cretaceous Composite Total Petroleum System**															
20480201	Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit															
Nara	2,870	3,400	4,350	3	nd	nd	nd	nd	8	14	30	4	nd	98	nd	nd
M'Rabtine	nd	2,190	nd	nd	nd	17	nd	nd	nd	17	nd	nd	nd	130	nd	nd
Zebbag	950	2,470	3,960	7	30	75	200	6	12	18	26	4	400	522	1,000	6
Bireno	2,530	2,880	3,350	7	7	45	76	4	15	28	32	7	40	306	350	7
Aleg	3,170	3,490	3,600	5	nd	12	nd	nd	nd	20	nd	nd	nd	nd	nd	nd
Abiod	1,500	2,510	3,200	6	16	68	150	5	8	19	30	5	0.5	1,430	3,000	5

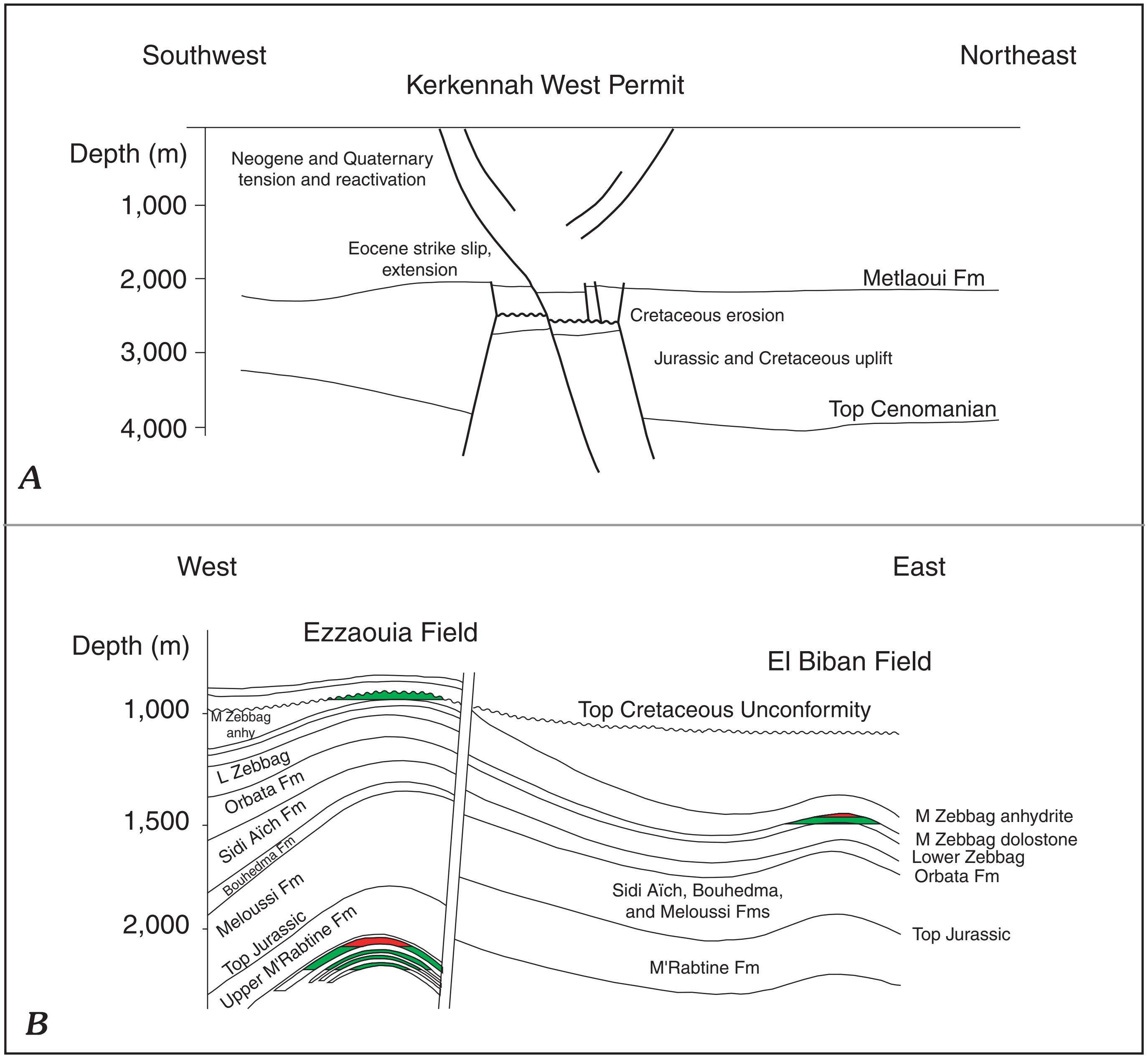


Figure 9. Diagrams illustrating selected trap styles in Pelagian Province (2048). *A*, Schematic cross section through Kerkennah West Permit, onshore eastern Tunisia (modified from Bishop, 1988). *B*, Schematic cross section through Ezzaouia (onshore) and El Biban (offshore) fields, southern Tunisia (modified from Entreprise Tunisienne d'Activités Pétrolières, c. 1999). Red, gas accumulation; green, oil accumulation. No horizontal scale.

salt ridges and diapirs (Entreprise Tunisienne d'Activités Pétrolières, c. 1999), as well as Paleogene stratigraphic pinchouts and turbidites above and below the Oligocene Unconformity (Bédir and others, 1992). The locations of major faults (mostly extensional) and major anticlines in Tunisia and offshore areas to the east, as well as field locations, are shown in figure 10. Fault systems in the Gulf of Gabes area trend generally northwest-to-southeast, whereas fault systems in the Gulf of Hammamet area trend generally west-to-east.

Assessment of Undiscovered Petroleum

One assessment unit was identified for the Bou Dabbous–Tertiary Total Petroleum System, the Bou Dabbous–Tertiary Structural/Stratigraphic Assessment Unit (20480101) (fig. 2). As of 1996, forty-six fields reported petroleum volumes in reservoirs of the corresponding total petroleum system, and these fields are allocated to this assessment unit. Of these, 27 are oil

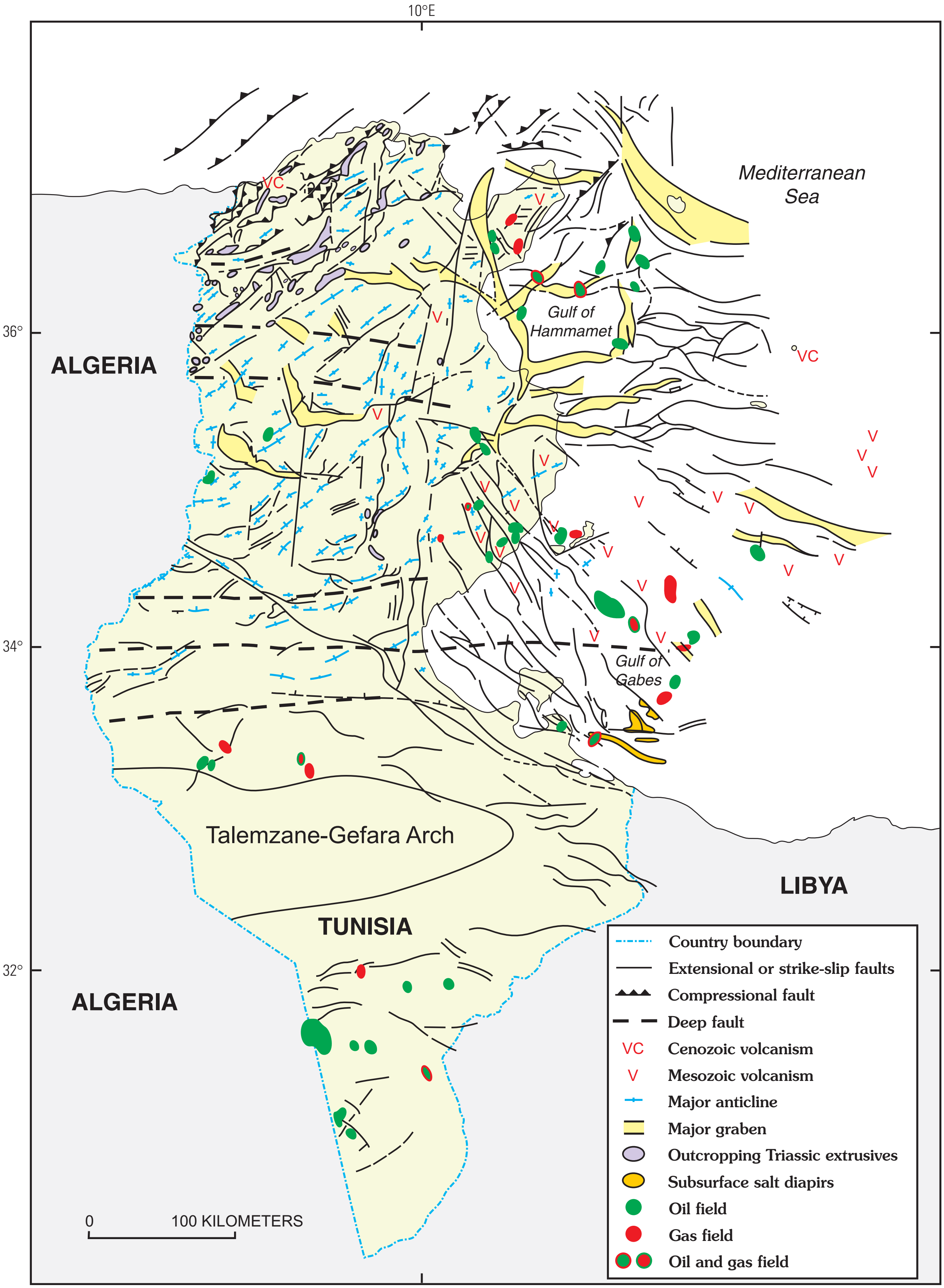


Figure 10. Major faults and anticlines in Tunisia, as well as locations of oil and gas fields (modified from Entreprise Tunisienne d'Activités Pétrolières, 2000). Dashed lines, approximate location; hachured lines, faults showing direction of down-thrown blocks.

fields, 14 are gas fields, and 5 fields are not classified because they contained less than 1 MMBOE. Combined, these fields contained 2,114 MMBO, 15,509 BCFG, and 44 MMBNGL, as known volumes (table 1) (Petroconsultants, 1996a). Minimum field sizes of 4 MMBO and 24 BCFG were chosen for this assessment unit based on the field-size distribution of discov ered fields.

At the end of 1995, the exploration density was approxi mately 15 new-field wildcat wells per 10,000 km^2. Exploration activity was not consistent through time, peaking from the 1970's to the early 1980's, and experiencing a resurgence start ing in the early 1990's. Exploration appears to be in a moder ately mature stage across much of the area. The overall success rate has been approximately 26 discoveries per 100 new-field wildcat wells (or about one discovery per four new-field wildcat wells). As of 1996, offshore fields existed in water depths that range from about 4 to 350 m, averaging about 135 m. The sizes of oil and gas fields discovered have generally decreased through time and with respect to exploration activity. Trends in field sizes or number of discoveries with respect to exploration activ ity (number of new-field wildcat wells drilled) are not apparent. Plots showing exploration activity and discovery history are pre sented in Appendix 1.

Exploration of structural and combination traps is expected to continue, and many more fields, both oil and gas, could be discovered. Discoveries in structural and stratigraphic traps involving the Metlaoui Group reservoirs are likely to be smaller than existing accumulations, whereas discoveries in the Birsa sandstone may contribute larger volumes to reserves than in the past. Stratigraphic traps involving the Fortuna sandstone and lateral equivalents may also contain important accumulations.

This study estimates that about one-half of the total number of fields (discovered and undiscovered) of at least the minimum size has been discovered. The estimated median size and num ber of undiscovered oil fields are 12 MMBO and 30 fields; the same values for undiscovered gas fields are 60 BCFG and 15 fields. The ranges of number, size, and coproduct-ratio esti mates for undiscovered fields are given in table 3.

The estimated means of the undiscovered conventional petroleum volumes are 667 MMBO, 2,746 BCFG, and 64 MMBNGL (table 4). The mean size of the largest anticipated undiscovered oil and gas fields is 110 MMBO and 283 BCFG, respectively.

The Jurassic-Cretaceous Composite Total Petroleum System (204802)

The Jurassic-Cretaceous Composite Total Petroleum Sys tem extends across most of the Pelagian Province. This sys tem and corresponding assessment unit (Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit, 20480201) generally coincide with the potential extent of petroleum migration from Jurassic and Cretaceous source rocks. As mentioned previ ously, the Upper Cretaceous to Paleocene El Haria mudstone separates this total petroleum system from the overlying Tertiary total petroleum system. Where the El Haria mudstone is absent in the southern part of the Pelagian Prov ince, the total petroleum system boundary is approximated by the Cretaceous-Paleocene boundary. Triassic evaporites and Lower Jurassic carbonate rocks separate this total petroleum system from any underlying systems. An events chart (fig. 11) summarizes the ages of source, reservoir, and seal rocks; the timing of trap development; and generation and migration of petroleum.

During the Jurassic and Early Cretaceous, faulting and strong local subsidence defined deep-water basins separated by uplifted fault blocks, which consisted of slope and carbonate platform deposits (Morgan and others, 1998). The deep-water basins allowed deposition of organic-rich sediments and turbidite fan deposits (Bédir and others, 1992; Morgan and others, 1998).

Transpression and inversion during the Late Cretaceous and Paleogene caused uplift and erosion of carbonate plat-forms that formed previously along fault zones. These struc tural events, as well as more recent deformation, provided traps for petroleum accumulations (Bédir and others, 1992; Morgan and others, 1998). Petroleum generation occurred throughout the Tertiary.

Source Rocks

The primary source rocks are mudstone of the Jurassic Nara Formation, Lower Cretaceous M'Cherga Formation, Albian Lower Fahdene Formation, and Cenomanian to Turonian Bahloul Formation. According to Entreprise Tunisienne d'Activités Pétrolières (c. 1999), the Jurassic Nara Formation source rock exists in an elongated northwest to southeast trend from central Tunisia through the Gulf of Gabes and extending along the coast into Libya. Cretaceous source rocks are present throughout much of the Pelagian Province, although the distri bution of the Bahloul Formation is limited to an arcuate and elongate, northwest to southeast trend (fig. 4). Combined, one or more of the Jurassic and Cretaceous source rocks are present across most of the province.

Source rock properties are described by Entreprise Tunisi enne d'Activités Pétrolières (c. 1999) as follows:

1. The Nara Formation source rocks are thin black mud-stone with alternating limestone; approximately 80 m thick; contain as much as 2 percent TOC; maturation described as mature to late mature.
2. The M'Cherga Formation source rocks are light- to dark-gray calcareous and dolomitic mudstone containing type II kerogen; as much as 100 m thick; contain 0.2–3 percent TOC; maturation described as mature to late mature.
3. The Lower Fahdene Formation source rocks are dark pelagic marl with interbedded limestone containing type II and III kerogen; as much as 150 m thick; contain 0.5–3 percent TOC; maturation described as early mature to mature.
4. The Bahloul Formation source rocks are laminated black argillaceous limestone containing type II kerogen; approximately 20 m thick; contain as much as 14 percent TOC; maturation described as early mature to mature.

Table 3. Estimated sizes, number, and coproduct ratios of undiscovered oil and gas fields for each assessment unit in the Pelagian Province (2048).

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; CFG/BO, cubic feet of gas per barrel oil, not calculated for gas fields; BNGL/MMCFG, or BL/MMCFG, barrels of natural gas liquids or barrels of total liquids per million cubic feet of gas. BNGL/MMCFG was calculated for USGS-defined oil fields whereas BL/MMCFG was calculated for USGS-defined gas fields. Shifted mean, mean size of accumulation within a lognormal distribution of field sizes for which origin is selected minimum field size]

USGS Code	Size of accumulations (MMBO or BCFG)					Number of accumulations					Gas-to-oil ratio (CFG/BO)					NGL-to-gas ratio (BNGL/MMCFG)				
	Minimum	Median	Maximum	Mean	Shifted mean	Minimum	Median	Maximum	Mean	Mode	Minimum	Median	Maximum	Mean	Mode	Minimum	Median	Maximum	Mean	Mode
204801	**Bou Dabbous-Tertiary Total Petroleum System**																			
20480101	Bou Dabbous-Tertiary Structural/Stratigraphic Assessment Unit																			
Oil fields	4	12	350	16	20	4	30	80	33	14	1,000	2,000	3,000	2,000	2,000	16	32	48	32	32
Gas fields	24	60	1,000	63	87	2	15	40	16	7						10	15	20	15	15
204802	**Jurassic-Cretaceous Composite Total Petroleum System**																			
20480201	Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit																			
Oil fields	1	5	200	9	10	5	38	105	42	15	1,000	2,000	3,000	2,000	2,000	10	15	20	15	15
Gas fields	6	25	1,000	43	49	3	28	80	31	10						5	10	15	10	10

Table 4. Estimated undiscovered conventional oil, gas, and natural gas liquids volumes for oil and gas fields for each assessment unit in the Pelagian Province (2048).

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; NGL, natural gas liquids; MMBNGL, million barrels of NGL. Volumes of undiscovered NGL were calculated for oil fields whereas volumes of total liquids (oil plus NGL) were calculated for USGS-defined gas fields. Largest anticipated undiscovered field is in units of MMBO for oil fields and BCFG for gas fields. Results shown are estimates that are fully risked with respect to geology and acccessibility. Undiscovered volumes in fields smaller than the selected minimum field size are excluded from the assessment. Means can be summed, but fractiles (F95, F50, and F5) can be summed only if a correlation coefficient of +1.0 is assumed]

USGS Code		MFS	Prob. (0-1)	Undiscovered conventional volumes												Largest anticipated undiscovered field (MMBO or BCFG)			
				Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)							
				F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
204801	**Bou Dabbous-Tertiary Total Petroleum System**																		
20480101	Bou Dabbous-Tertiary Structural/Stratigraphic Assessment Unit																		
	Oil fields	4	1.00	171	602	1,369	667	319	1,169	2,898	1,335	9	37	98	43	35	94	246	110
	Gas fields	24	1.00					363	1,274	2,904	1,411	5	19	45	21	97	240	626	283
	All fields			171	602	1,369	667	682	2,443	5,802	2,746	15	55	142	64				
204802	**Jurassic-Cretaceous Composite Total Petroleum System**																		
20480201	Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit																		
	Oil fields	1	1.00	96	363	841	403	180	703	1,786	807	3	10	27	12	20	56	149	66
	Gas fields	6	1.00					294	1,312	3,181	1,473	3	13	34	15	74	235	684	285
	All fields			96	363	841	403	473	2,015	4,967	2,280	5	23	61	27				
2048	***Total***																		
	Oil fields			267	965	2,210	1,070	499	1,872	4,684	2,142	12	47	125	55				
	Gas fields							657	2,586	6,085	2,884	8	32	79	36				
	All fields			267	965	2,210	1,070	1,156	4,458	10,769	5,026	20	79	204	91				

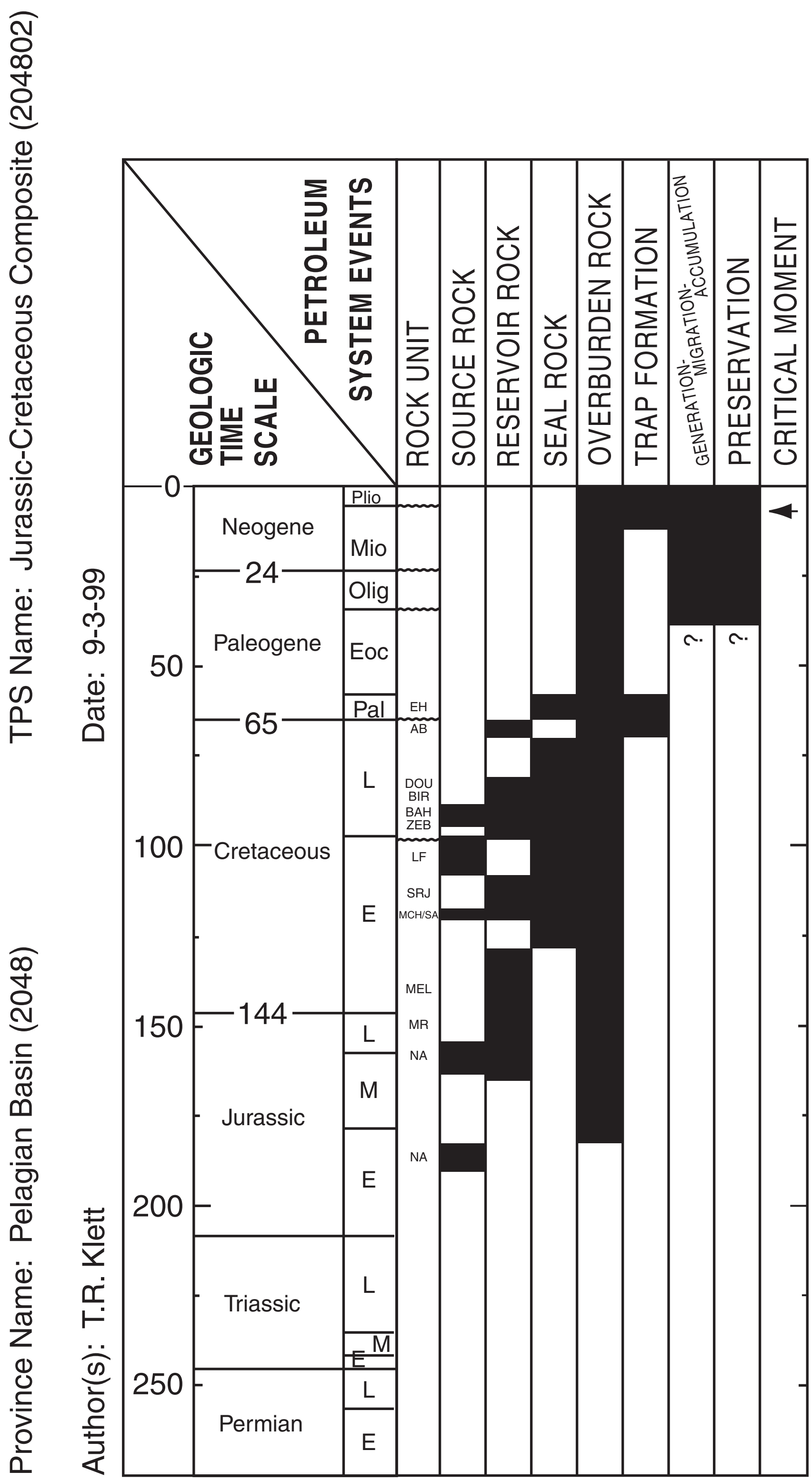


Figure 11. Events chart for Jurassic-Cretaceous Composite Total Petroleum System (204802). Query means extent uncertain. EH, El Haria; AB, Abiod; DOU, Douleb; BIR, Bireno; BAH, Bahloul; ZEB, Zebbag; LF, Lower Fahdene; SRJ, Serdj; MCH, M'Cherga; SA, Sidi Aïch; MEL, Meloussi; MR, M'Rabtine; NA, Nara.

Oil generation from the Nara Formation probably began in the early Tertiary (fig. 11), although generation may have begun as early as the Late Cretaceous in deeper basins (Bédir and others, 1992). Peak petroleum generation of the other source rocks generally occurred during the Miocene to Pliocene (Entreprise Tunisienne d'Activités Pétrolières, c. 1999). Petro leum migrated vertically along faults and fractures, and laterally into adjacent reservoirs.

The API gravity of oil generated from the Jurassic and Cretaceous source rock ranges from 28º to 37º; the mean is 33º (Petroconsultants, 1996a; GeoMark, 1998). The sulfur content ranges from 0.2 to 0.4 percent, with a mean of 0.3 percent (GeoMark, 1998).

Overburden Rocks

Cretaceous and Cenozoic rocks make up most of the overburden. As with the overlying Bou Dabbous–Tertiary Total Petroleum System, overburden rocks are variable across the area (fig. 5). In addition to strata removed by erosion during the Cenozoic (previously described in the Bou Dabbous–Tertiary Total Petroleum System section), minor amounts of Lower Cretaceous and Upper Cretaceous to Paleocene rocks are also absent (figs. 5*B* and 6).

Reservoir Rocks

Known reservoir rocks include: (1) Middle to Upper Jurassic Nara Formation dolomite or dolomitic limestone and M'Rabtine sandstone; (2) Lower Cretaceous Meloussi and Sidi Aïch sandstone and Orbata and Serdj carbonates; and (3) Upper Cretaceous Zebbag, Isis, and Bireno, Douleb, and Miskar carbonates and Abiod fractured chalk (table 2, fig. 6). Figure 12 shows the distribution of Zebbag Formation reservoirs, as well as locations of fields having reported oil and gas volumes from reservoirs within the Jurassic-Cretaceous Composite Total Petroleum System.

Most of the discovered oil volumes in this total petroleum system, as of 1996, appears to be in Lower Cretaceous Bireno (approximately 38 MMBO) and Jurassic (approximately 34 MMBO) reservoirs, whereas most of the discovered gas appears to be in Upper Cretaceous Abiod fractured reservoirs (approximately 1,000 BCFG).

Seal Rocks

Seals include Upper Jurassic to Lower Cretaceous mudstone of the M'Cherga Formation; various Lower to Upper Cretaceous mudstone and carbonate rocks, including Aleg mudstone; and Upper Cretaceous to Paleocene El Haria mudstone (Macgregor and Moody, 1998; Entreprise Tunisienne d'Activités Pétrolières, c. 1999).

Trap Types in Oil and Gas Fields

As with the Bou Dabbous–Tertiary Total Petroleum System, trap types of known accumulations include fault blocks, low-amplitude anticlines, high-amplitude anticlines associated with reverse faults (inversion anticlines), wrench fault structures, and stratigraphic traps (fig. 9*A* and *B*). Volumetrically, most of the discovered oil in the Jurassic-Cretaceous Total Petroleum System appears to be in anticlinal traps, whereas most of the discovered gas appears to be in fault-related traps.

Assessment of Undiscovered Petroleum

One assessment unit was identified for the Jurassic-Cretaceous Composite Total Petroleum System, Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit (20480201) (fig. 3). As of 1996, twenty-six fields reported petroleum volumes in reservoirs of the corresponding total petroleum system, and these fields are allocated to this assessment unit. Of these discovered fields, 11 are oil fields, 6 are gas fields, and 9 fields are not classified because they contain less than 1 MMBOE. Combined, these fields contain 103 MMBO, 1,301 BCFG, and 23 MMBNGL, as known volumes (table 1) (Petroconsultants, 1996a). Minimum field sizes of 1 MMBO and 6 BCFG were chosen for this assessment unit based on the field-size distribution of discovered fields.

At the end of 1995, the exploration density was approximately eight new-field wildcat wells per 10,000 km^2. Exploration activity has been variable through time and appears to be in an immature stage. The overall success rate is approximately 14 discoveries per 100 new-field wildcat wells (or about one discovery per seven new-field wildcat wells). As of 1996, offshore fields existed in water depths that range from about 5 to 82 m, averaging about 46 m. The size and number of oil fields appear to have increased with respect to exploration activity, whereas trends for gas fields were not apparent. Additionally, more recent oil field discoveries have been made at shallower depths. Plots showing exploration activity and discovery history are presented in Appendix 2.

Exploration for structural and combination traps is expected to continue, resulting in the probable discovery of more fields, both oil and gas. Discoveries in structural and stratigraphic traps involving Zebbag (and lateral equivalents), Douleb, and Abiod reservoirs will most likely continue as exploration progresses seaward into deeper water. Some of these discoveries may be substantial. More discoveries may also be made in Jurassic rocks, but these may be few and small due to the limited extent of mature source rocks and reservoirs.

This study estimates that about one-fourth of the total number of fields (discovered and undiscovered) of at least the minimum size has been discovered to date. The estimated median size and number of undiscovered oil fields are 5 MMBO and 38 fields; the same values for undiscovered gas fields are 25 BCFG and 28 fields. The ranges of number, size, and coproduct-ratio estimates for undiscovered fields are given in table 3.

The estimated means of the undiscovered conventional petroleum volumes are 403 MMBO, 2,280 BCFG, and 27 MMBNGL (table 4). In addition, the mean size of the largest anticipated undiscovered oil and gas fields is 66 MMBO and 285 BCFG, respectively.

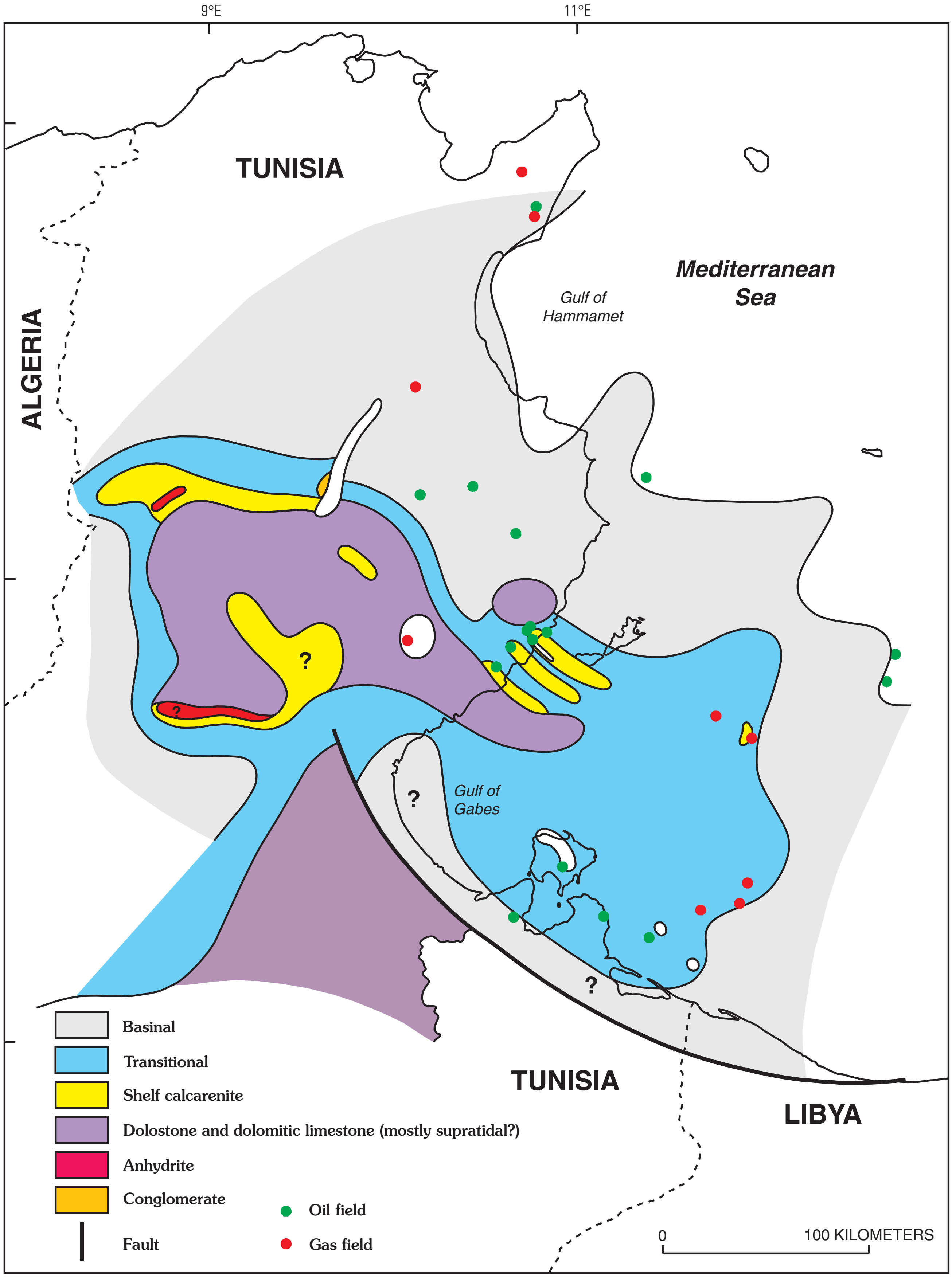


Figure 12. Lithofacies map of the Zebbag Formation and locations of fields with reported oil and gas volumes in Jurassic-Cretaceous Composite Total Petroleum System (204802) (modified from Bishop, 1988; Petroconsultants, 1996b). White areas, rock section is absent. Queries mean extent uncertain.

Summary

Two “composite” total petroleum systems, the Bou Dabbous–Tertiary and Jurassic-Cretaceous Composite, are identified in the Pelagian Province (2048). The Bou Dabbous–Tertiary Total Petroleum System (204801) and corresponding assessment unit coincide with the potential extent of petroleum migration from Eocene source rocks. The Jurassic-Cretaceous Composite Total Petroleum System (204802) and corresponding assessment unit coincide with the potential extent of petroleum migration from Jurassic and Cretaceous source rocks. The Upper Cretaceous to Paleocene El Haria mudstone separates the two total petroleum systems over much of the area.

It is likely that much of the petroleum in the Gulf of Hammamet area was derived from Cretaceous source rocks. If this is the case, then the discovered and undiscovered oil and gas volumes of the Bou Dabbous–Tertiary Total Petroleum System should be included in the Jurassic-Cretaceous Composite Total Petroleum System.

The primary source rock of the Bou Dabbous–Tertiary Total Petroleum System is dark-brown marl and mudstone of the lower Eocene Bou Dabbous Formation, which became mature in the Miocene to Pleistocene. Known reservoir rocks include lateral equivalents of the lower Eocene Bou Dabbous Formation, such as the El Garia fractured limestone; Eocene Jirani dolostone, Jdeir limestone, and Reineche limestone; Oligocene to Miocene Ketatna limestone; and the middle Miocene Aïn Grab limestone and Birsa sandstone. Seals include Eocene and Miocene mudstone and carbonate rocks. Known accumulations are in fault blocks, low-amplitude anticlines, high-amplitude anticlines associated with reverse faults, wrench fault structures, and stratigraphic traps.

The primary source rocks of the Jurassic-Cretaceous Composite Total Petroleum System include mudstone of the Jurassic Nara Formation, Lower Cretaceous M’Cherga and Lower Fahdene Formations, and Upper Cretaceous Bahloul Formation. Oil generation probably began in the early Tertiary, and peak petroleum generation likely took place in the Miocene and Pliocene. Known reservoir rocks include the Nara Formation dolomite or dolomitic limestone; Upper Jurassic M’Rabtine sandstone; Lower Cretaceous Meloussi and Sidi Aïch sandstone and Orbata and Serdj carbonates; and Upper Cretaceous Zebbag, Isis, Bireno, Douleb, and Miskar carbonates and Abiod chalk. Seals include Upper Jurassic to Lower Cretaceous mudstone of the M’Cherga Formation, various Lower to Upper Cretaceous mudstone and carbonate rocks, and the Upper Cretaceous to Paleocene El Haria mudstone. Trap types of known accumulations include fault blocks, low-amplitude anticlines, high-amplitude anticlines associated with reverse faults, wrench fault structures, and stratigraphic traps.

The estimated mean undiscovered conventional petroleum resources in the Bou Dabbous–Tertiary Total Petroleum System are 667 MMBO, 2,746 BCFG, and 64 MMBNGL. The estimated mean undiscovered conventional petroleum resources in the Jurassic-Cretaceous Composite Total Petroleum System are 403 MMBO, 2,280 BCFG, and 27 MMBNGL. The combined estimated mean undiscovered conventional petroleum resources of both total petroleum systems of the Pelagian Province are 1,070 MMBO, 5,026 BCFG, and 91 MMBNGL.

References Cited

Aliev, M., Aït Laoussine, N., Avrov, V., Aleksine, G., Barouline, G., Lakovlev, B., Korj, M., Kouvykine, J., Makarov, V., Mazanov, V., Medvedev, E., Mkrtchiane, O., Moustafinov, R., Oriev, L., Oroudjeva, D., Oulmi, M., and Saïd, A., 1971, Geological structures and estimation of oil and gas in the Sahara in Algeria: Spain, Altamira-Rotopress, S.A., 265 p.

Arab Petroleum Research Center, 1998, Arab Oil and Gas Directory: Paris, Arab Petroleum Research Center, 640 p.

Bédir, M., Zargouni, F., Tlig, S., and Bobier, C., 1992, Subsurface geodynamics and petroleum geology of transform margin basins in the Sahel of Mahdia and El Jem (eastern Tunisia): American Association of Petroleum Geologists Bulletin, v. 76, no. 9, p. 1417–1442.

Bishop, W.F., 1975, Geology of Tunisia and adjacent parts of Algeria and Libya: American Association of Petroleum Geologists Bulletin, v. 59, no. 3, p. 413–450.

Bishop, W.F., 1988, Petroleum geology of east-central Tunisia: American Association of Petroleum Geologists Bulletin, v. 72, no. 9, p. 1033–1058.

Bobier, C., Viguier, C., Chaari, A., and Chine, A., 1991, The post-Triassic sedimentary cover of Tunisia: Seismic sequences and structure: Tectonophysics, v. 195, p. 371–410.

Boote, D.R.D., Clark-Lowes, D.D., and Traut, M.W., 1998, Palaeozoic petroleum systems of North Africa, *in* Macgregor, D.S., Moody, R.T.J., and Clark-Lowes, D.D., eds., Petroleum geology of North Africa: Geological Society, London, Special Publication 132, p. 7–68.

Burollet, P.F., 1967a, General geology of Tunisia, *in* Guidebook to the geology and history of Tunisia: Petroleum Exploration Society of Libya, Ninth Annual Field Conference, p. 51–58.

Burollet, P.F., 1967b, Tertiary geology of Tunisia, *in* Guidebook to the geology and history of Tunisia: Petroleum Exploration Society of Libya, Ninth Annual Field Conference, p. 215–225.

Burollet, P.F., 1990, Evolution of Atlassic basins in Tunisia [abs.]: American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 622.

Burollet, P.F., 1991, Structures and tectonics of Tunisia: Tectonophysics, v. 195, p. 359–369.

Burollet, P.F., Mugniot, J.M., and Sweeney, P., 1978, The geology of the Pelagian block—The margins and basins off southern Tunisia and Tripolitania, *in* Nairn, A.E.M., Kanes, W.H., and Stehli, F.G., eds., The ocean basins and margins: New York, Plenum Press, v. 4B, p. 331–359.

Busson, G., 1967, Mesozoic of southern Tunisia, *in* Guidebook to the geology and history of Tunisia: Petroleum Exploration Society of Libya, Ninth Annual Field Conference, p. 131–151.

Davies, W.C., and Bel Haiza, A., 1990, Sweeter E and P terms, Cretaceous Abiod chalk oil play lead to busier exploration in Tunisia: Oil and Gas Journal, December 10, p. 50–53.

Entreprise Tunisienne d’Activités Pétrolières, 1997, Tunisian Stratigraphic Chart: Tunis, Tunisia, Entreprise Tunisienne d’Activités Pétrolières.

Entreprise Tunisienne d’Activités Pétrolières, c. 1999, Information packet: Tunis, Tunisia, Entreprise Tunisienne d’Activités Pétrolières.

Entreprise Tunisienne d'Activités Pétrolières, 2000, Tunisia open acreage: Tunis, Tunisia, Imprimeries Réunies Groupe Cérès Conseil DDB, 77 p.

Environmental Systems Research Institute, 1996, ArcWorld 1:3M World cartographic layers: Redlands, Calif., Environmental Systems Research Institute, Inc.; available from Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373-8100 U.S.A.

Finetti, I., 1982, Structure, stratigraphy and evolution of central Mediterranean: Bollettino di Geofisica Teorica ed Applicata, v. 24, no. 96, p. 247–312.

GeoMark Research, 1998, OILS; Oil information library system, version 1.0: Houston, Texas, GeoMark Research, Inc.; database available from GeoMark Research, Inc., 9748 Whithorn Drive, Houston, TX 77095 U.S.A.

Guiraud, R., 1998, Mesozoic rifting and basin inversion along the northern African Tethyan margin: an overview, *in* Macgregor, D.S., Moody, R.T.J., and Clark-Lowes, D.D., eds., Petroleum geology of North Africa: Geological Society, London, Special Publication 132, p. 217–229.

Hammuda, O.S., van Hinte, J.E., and Nederbragt, S., 1991, Geohistory analysis mapping in central and southern Tarabulus Basin, northwestern offshore Libya, *in* Salem, M.J., Hammuda, O.S., and Eliagoubi, B.A., eds., The geology of Libya, Volume IV: Amsterdam, The Netherlands, Elsevier Science Publishers B.V., p. 1657–1680.

Jongsma, D., van Hinte, J.E., and Woodside, J.M., 1985, Geologic structure and neotectonics of the North African Continental Margin south of Sicily: Marine and Petroleum Geology, v. 2, p. 156–179.

Klett, T.R., Ahlbrandt, T.S., Schmoker, J.W., and Dolton, G. L., 1997, Ranking of the world's oil and gas provinces by known petroleum volumes: U.S. Geological Survey Open-File Report 97-463, 1 CD-ROM.

Knott, I., Moody, R., and Sandman, R., 1995, Coniacian-Turonian carbonates of the Miskar Field, offshore Tunisia [abs]: American Association of Petroleum Geologists Bulletin, v. 79, no. 8, p. 1227.

Long, M., 1978, Tertiary oil discoveries whet explorer interest off Tunisia: Oil and Gas Journal, v. 76, no. 2 (January 9), p. 64–69.

Lore, G.L., Brooke, J.P., Cooke, D.W., Klazynski, R.J., Olson, D.L., and Ross, K.M., 1996, Summary of the 1995 assessment of conventionally recoverable hydrocarbon resources of the Gulf of Mexico and Atlantic Outer Continental Shelf: Minerals Management Service OCS Report MMS 96-0047, 67 p.

Loucks, R.G., Moody, R.T.J., Bellis, J.K., and Brown, A.A., 1998, Regional depositional setting and pore network systems of the El Garia Formation (Metlaoui Group, Lower Eocene), offshore Tunisia, *in* Macgregor, D.S., Moody, R.T.J., and Clark-Lowes, D.D., eds., Petroleum geology of North Africa: Geological Society, London, Special Publication 132, p. 355–374.

Lucazeau, F., and Ben Dhia, H., 1989, Preliminary heat-flow density data from Tunisia and the Pelagian Sea: Canadian Journal of Earth Sciences, v. 26, p. 993–1000.

Macgregor, D.S., and Moody, R.T.J., 1998, Mesozoic and Cenozoic petroleum systems of North Africa, *in* Macgregor, D.S., Moody, R.T.J., and Clark-Lowes, D.D., eds., Petroleum geology of North Africa: Geological Society, London, Special Publication 132, p. 201–216.

Magoon, L.B., and Dow, W.G., 1994, The petroleum system, *in* Magoon, L.B., and Dow, W.G., eds., The petroleum system—From source to trap: American Association of Petroleum Geologists Memoir 60, p. 3–24.

Montgomery, S., 1994, Ghadames Basin and surrounding areas—Structure, tectonics, geochemistry and field summaries: Petroleum Frontiers, v. 10, no. 4, 79 p.

Morgan, M.A., Grocott, J., and Moody, R.T.J., 1998, The structural evolution of the Zaghouan-Ressas Structural Belt, northern Tunisia, *in* Macgregor, D.S., Moody, R.T.J., and Clark-Lowes, D.D., eds., Petroleum geology of North Africa: Geological Society, London, Special Publication 132, p. 405–422.

M'Rabet, A., 1984, Neocomian deltaic complex in central Tunisia: A particular example of ancient sedimentation and basin evolution: Sedimentary Geology, v. 40, p. 191–209.

Nelson, H.D., ed., 1979, Libya, a country study: Washington, D.C., American University, Foreign Area Studies, 350 p.

Ouali, J., 1985, Structure et évolution géodynamique du chaînon Nara-Sidi Khalif (Tunisie Centrale): Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, v. 9, no. 1, p. 155–182.

Persits, F., Ahlbrandt, T., Tuttle, M., Charpentier, R., Brownfield, M., and Takahashi, K., 1997, Maps showing geology, oil and gas fields and geologic provinces of Africa: U.S. Geological Survey Open-File Report 97-470A.

Petroconsultants, 1996a, Petroleum exploration and production database: Houston, Texas, Petroconsultants, Inc., [database available from Petroconsultants, Inc., P.O. Box 740619, Houston, TX 77274-0619].

Petroconsultants, 1996b, PetroWorld 21: Houston, Texas, Petroconsultants, Inc., [database available from Petroconsultants, Inc., P.O. Box 740619, Houston, TX 77274-0619].

Petzet, G.A., 1999, Patience, persistence preceded Elephant discovery in Libya: Oil and Gas Journal, v. 97, no. 20 (May 17), p. 65–66.

Salaj, J., 1978, The geology of the Pelagian block; The eastern Tunisian platform, *in* Nairn, A.E.M., Kanes, W.H., and Stehli, F.G., eds., The ocean basins and margins; The western Mediterranean, v. 4B: New York, Plenum Press, p. 361–416.

Schmoker, J.W., and Crovelli, R.A., 1998, A simplified spreadsheet program for estimating future growth of oil and gas reserves: Nonrenewable Resources, v. 7, no. 2, p. 149–155.

Schwab, A.M., 1995, Oligocene-Miocene shallow marine carbonates in offshore Tunisia: A sequence stratigraphic case study of an integrated data set [abs.]: American Association of Petroleum Geologists Bulletin, v. 79, no. 8, p. 1247.

Vially, R., Letouzey, J., Bénard, F., Haddadi, N., Desforges, G., Askri, H., and Boudjema, A., 1994, Basin inversion along the North African margin—The Saharan Atlas (Algeria), *in* Roure, F., ed., Peri-Tethyan platforms: Paris, Éditions Technip, p. 79–117.

Wilson, M., and Guiraud, R., 1998, Late Permian to Recent magmatic activity on the African-Arabian margin of the Tethys, *in* Macgregor, D.S., Moody, R.T.J., and Clark-Lowes, D.D., eds., Petroleum geology of North Africa: Geological Society, London, Special Publication 132, p. 231–263.

U.S. Geological Survey World Energy Assessment Team, 2000, U.S. Geological Survey World Petroleum Assessment 2000—Description and results: U.S. Geological Survey Digital Data Series DDS-60, 4 CD-ROMs.

Appendices

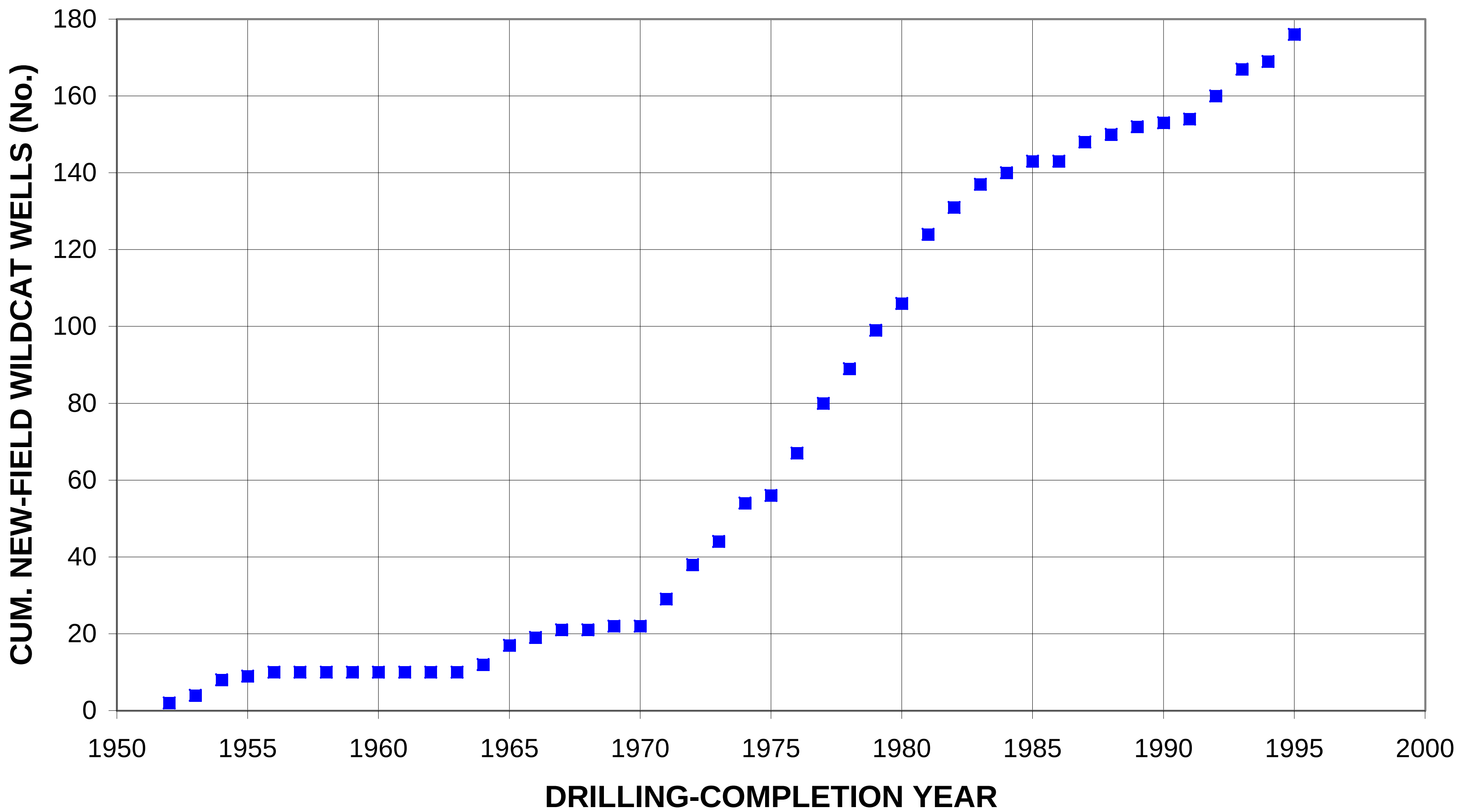
Two sets of exploration-activity and discovery-history plots are provided for each of the assessment units in the Pelagian Province, one set showing known field sizes (cumulative production plus remaining reserves) and another showing field sizes that were adjusted to compensate for potential reserve growth that may occur in the next 30 years (labeled "grown"). Within each set of plots, oil fields and gas fields are treated separately. The plots include:

- Cumulative Number of New-Field Wildcat Wells vs. Drilling-Completion Year
- Number of New-Field Wildcat Wells vs. Drilling-Completion Year
- Oil- or Gas-Field Size (MMBO or BCFG) vs. Oil- or Gas-Field Rank by Size (With Respect to Discovery Halves or Thirds)
- Number of Oil or Gas Fields vs. Oil- or Gas-Field Size Classes (MMBO or BCFG) (With Respect to Discovery Halves or Thirds)
- Volume of Oil or Gas (MMBO or BCFG) vs. Oil- or Gas-Field Size Classes (MMBO or BCFG)
- Oil- or Gas-Field Size (MMBO or BCFG) vs. Field-Discovery Year
- Oil- or Gas-Field Size (MMBO or BCFG) vs. Cumulative Number of New-Field Wildcat Wells
- Cumulative Oil or Gas Volume (MMBO or BCFG) vs. Field-Discovery Year
- Cumulative Oil or Gas Volume (MMBO or BCFG) vs. Cumulative Number of New-Field Wildcat Wells
- Cumulative Number of Oil or Gas Fields vs. Field-Discovery Year

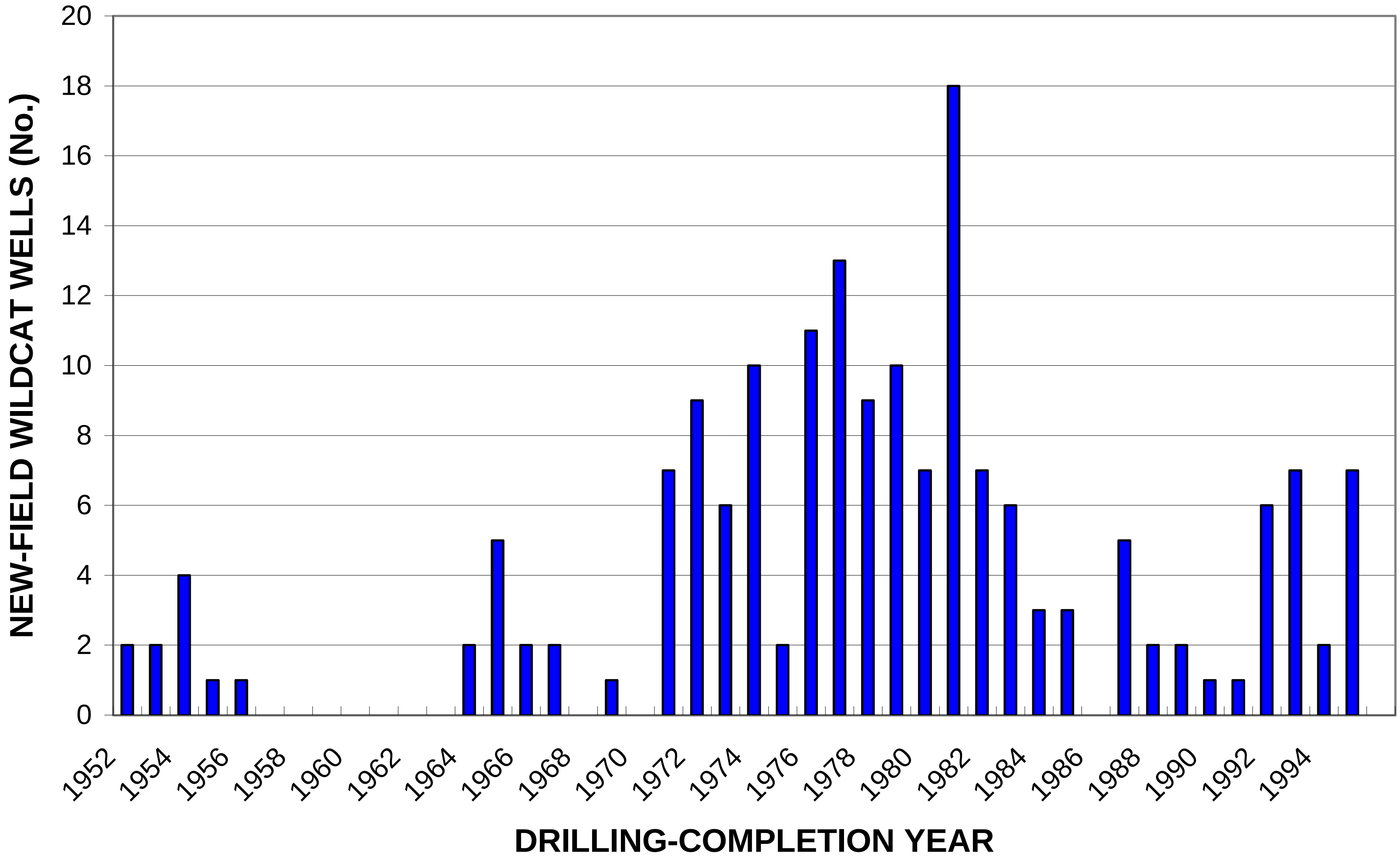
- Cumulative Number of Oil or Gas Fields vs. Cumulative Number of New-Field Wildcat Wells
- Reservoir Depth, Oil or Gas Fields (m) vs. Field-Discovery Year
- Reservoir Depth, Oil or Gas Fields (m) vs. Cumulative Number of New-Field Wildcat Wells
- Gas/Oil, Oil Fields (CFG/BO) vs. Mean Reservoir Depth (m)
- NGL/Gas, Oil Fields (BNGL/MMCFG) vs. Mean Reservoir Depth (m)
- Liquids/Gas, Gas Fields (BL/MMCFG) vs. Mean Reservoir Depth (m)
- Number of Reservoirs in Oil Fields vs. API Gravity (Degrees)

Appendix 1. Exploration-activity and discovery-history plots for the Bou Dabbous-Tertiary Structural/Stratigraphic Assessment Unit (20480101). *A*. Plots of known oil and gas volumes.

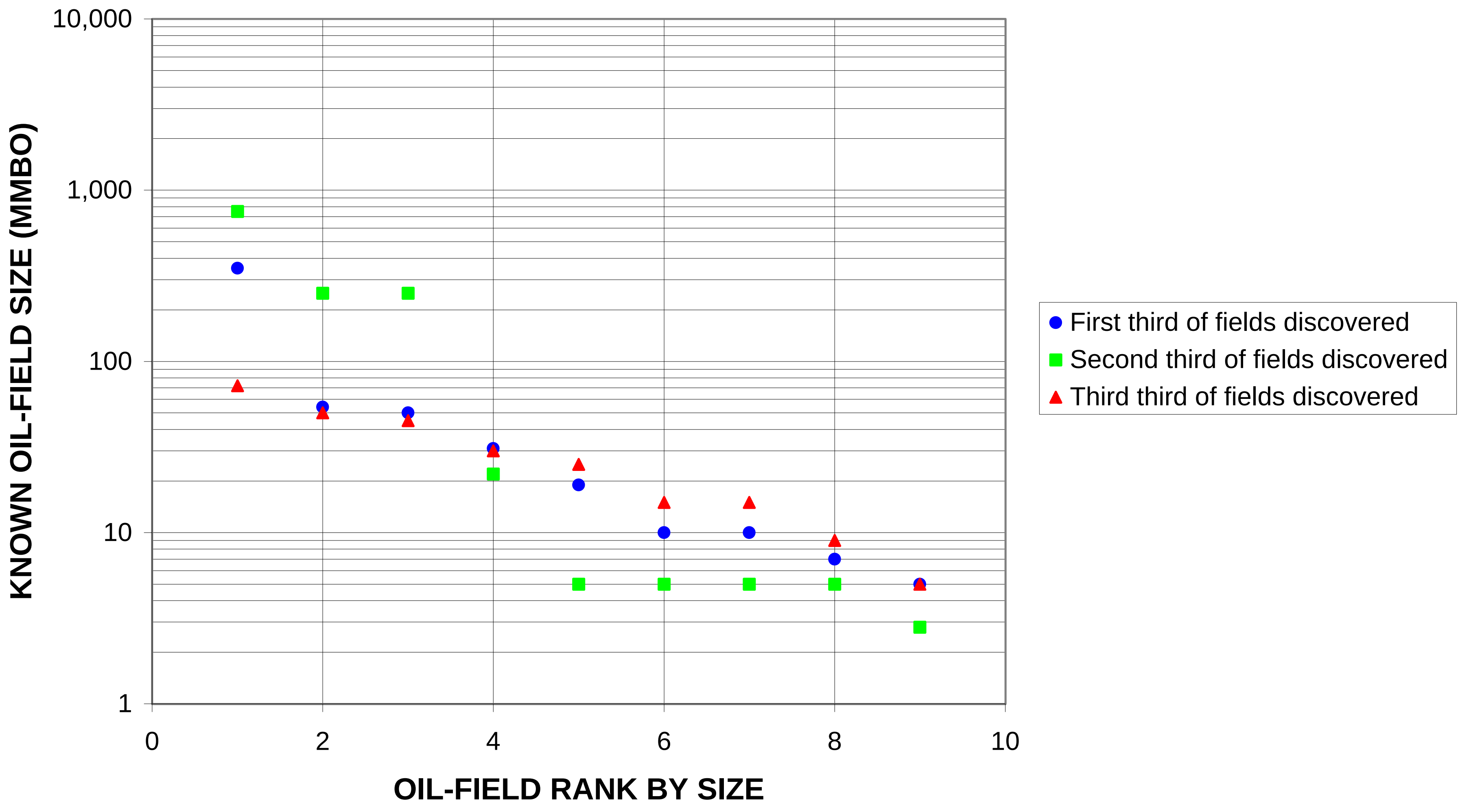
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



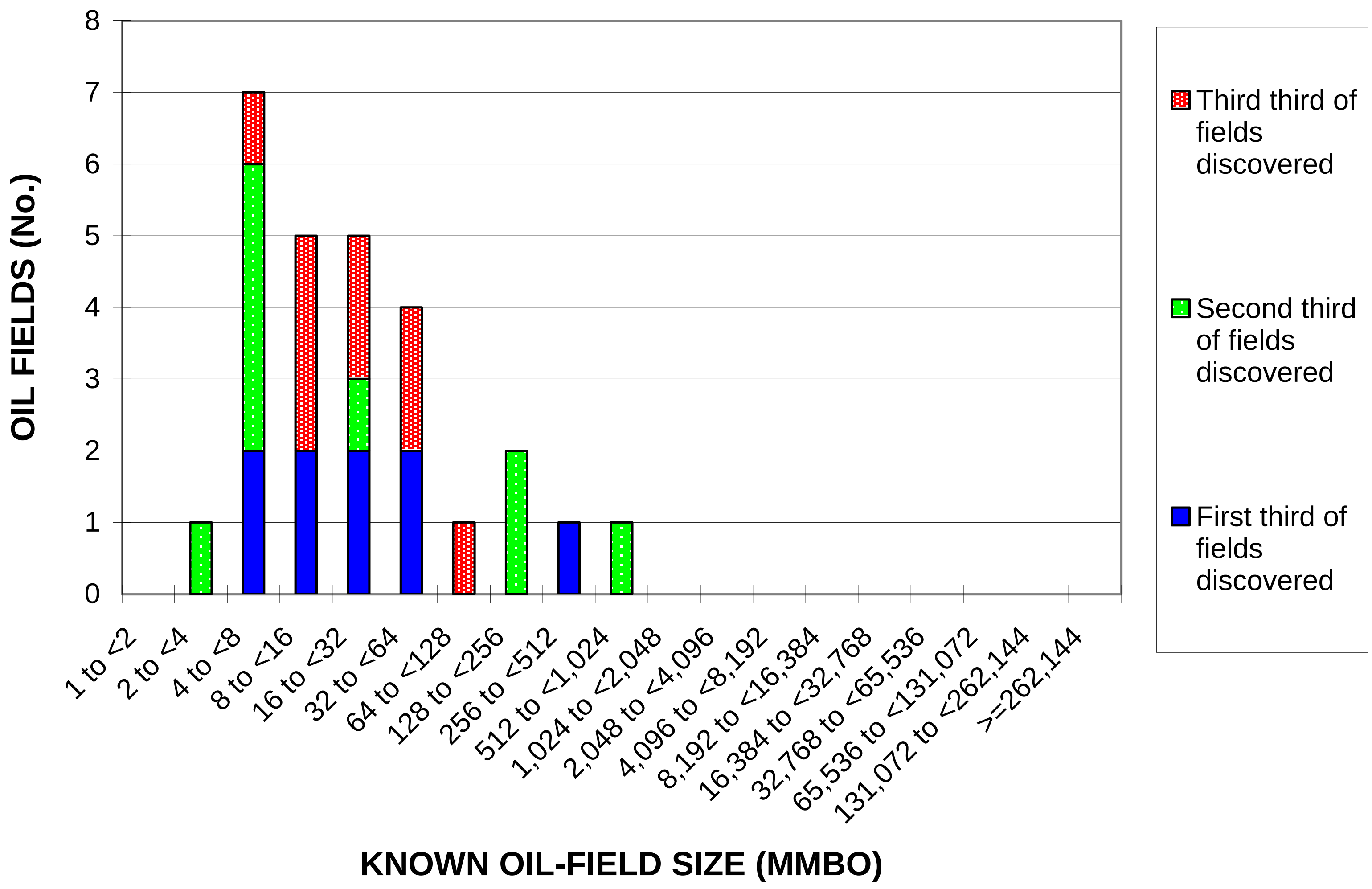
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



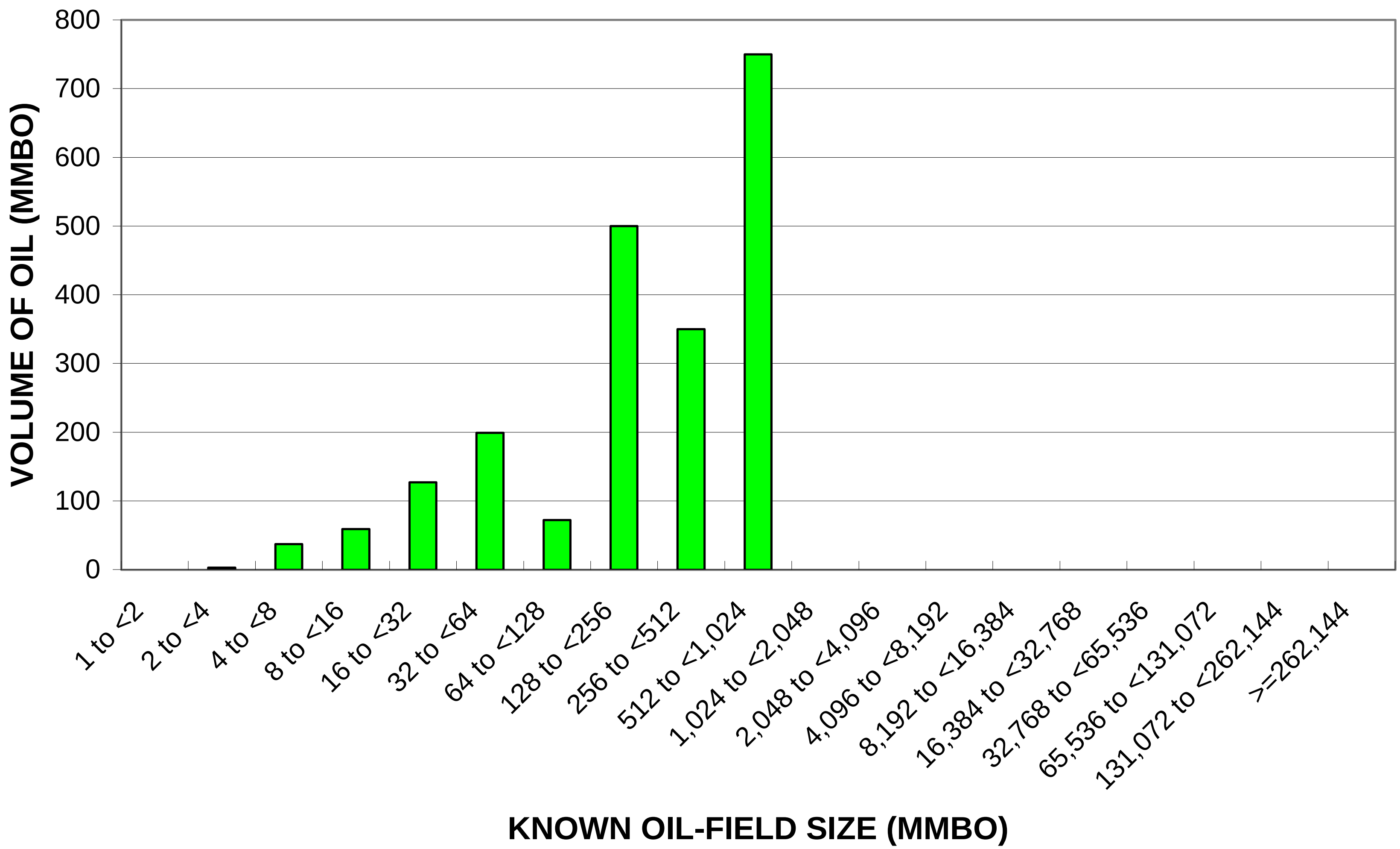
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



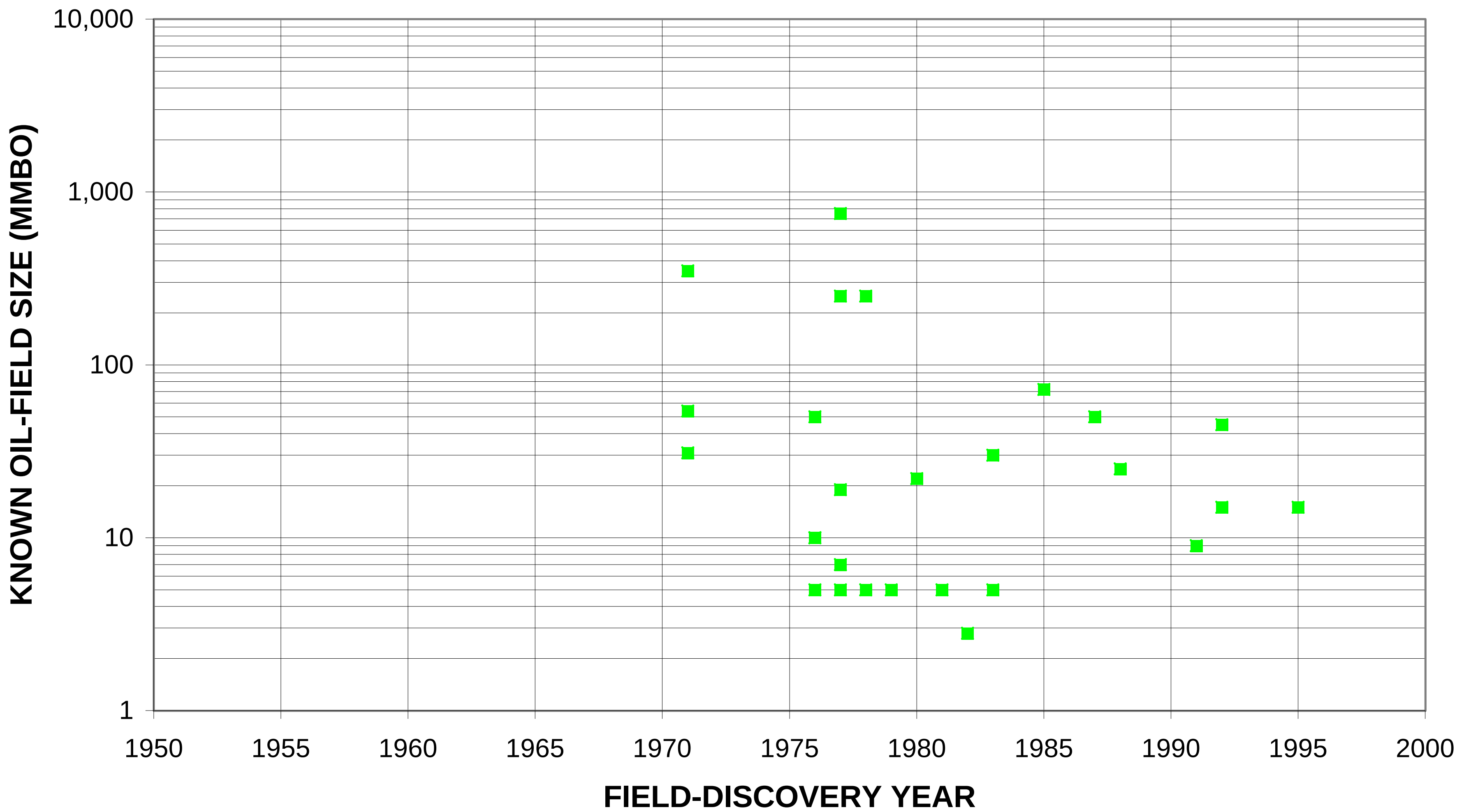
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

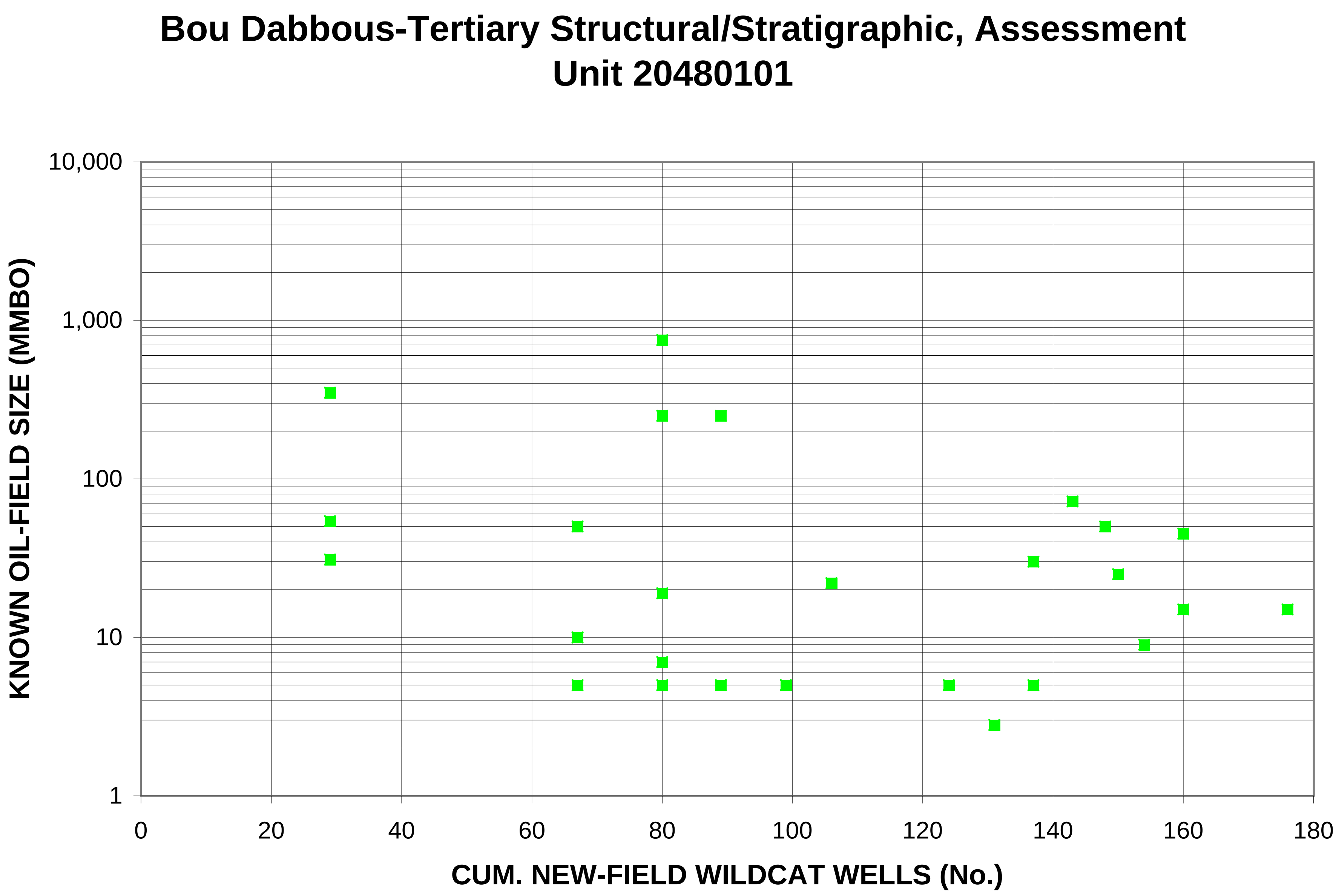


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

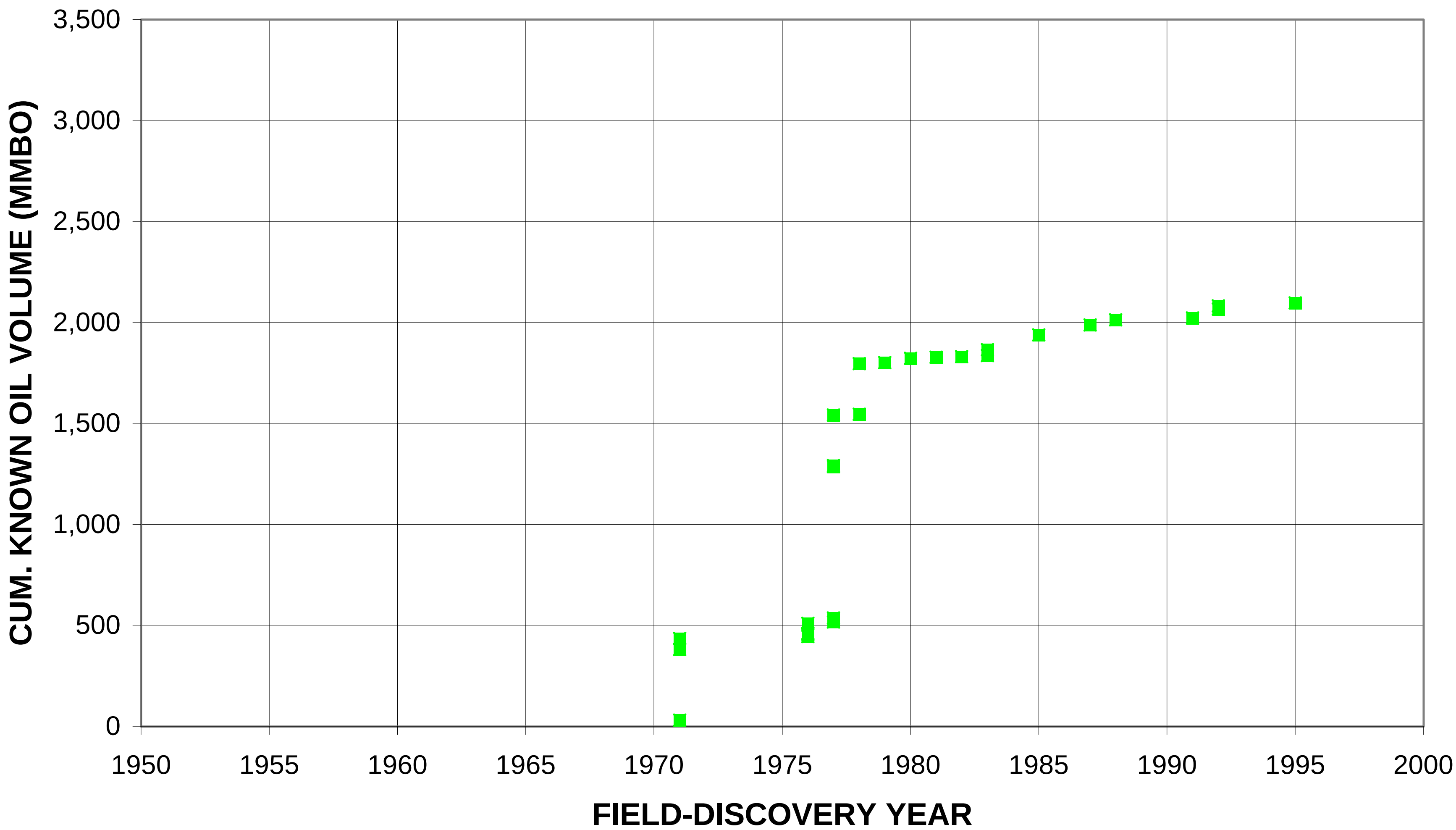


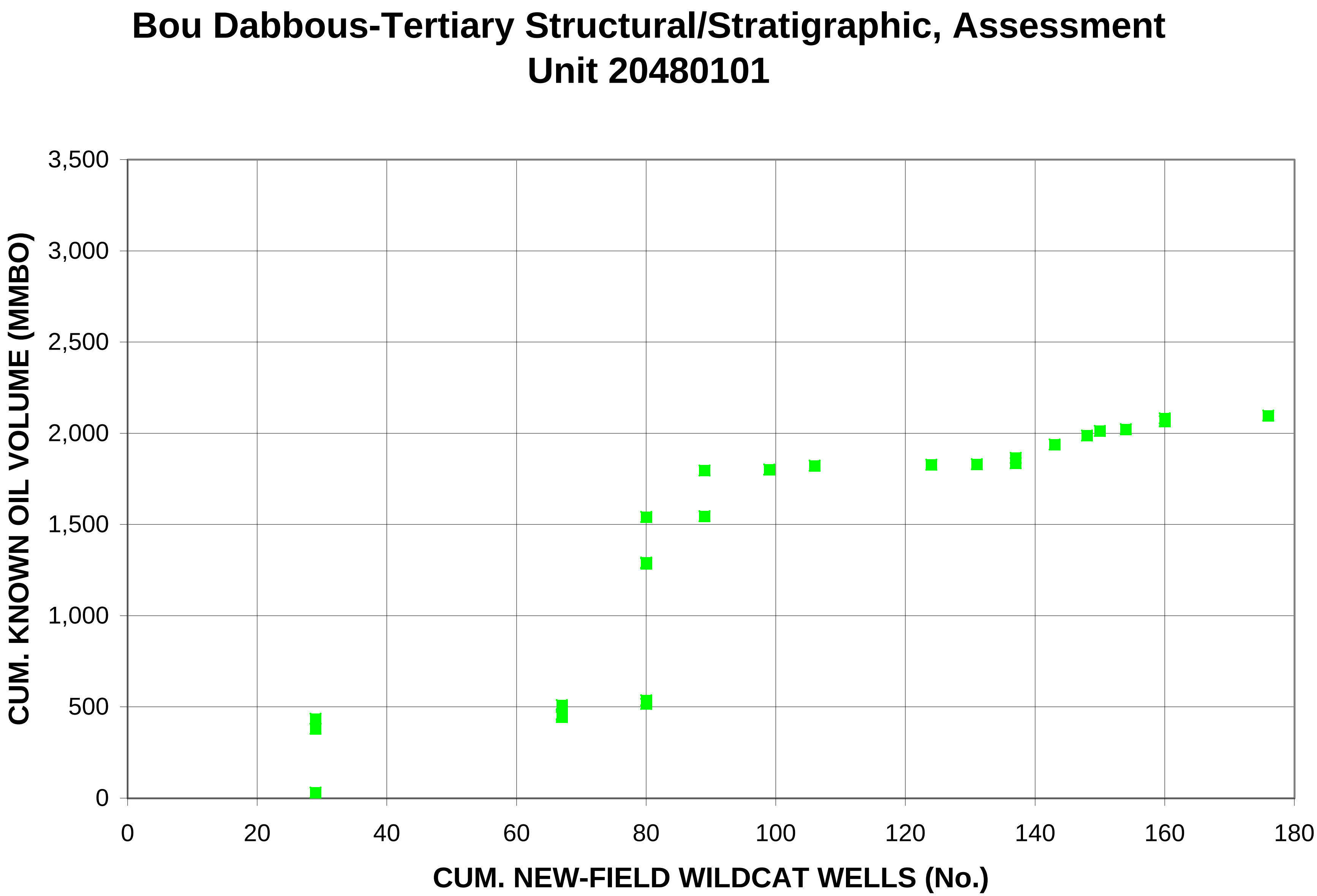
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101




Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
10,000
1,000
100
10
1
0
20
40
60
80
100
120
140
160
180
KNOWN OIL-FIELD SIZE (MMBO)
CUM. NEW-FIELD WILDCAT WELLS (No.)

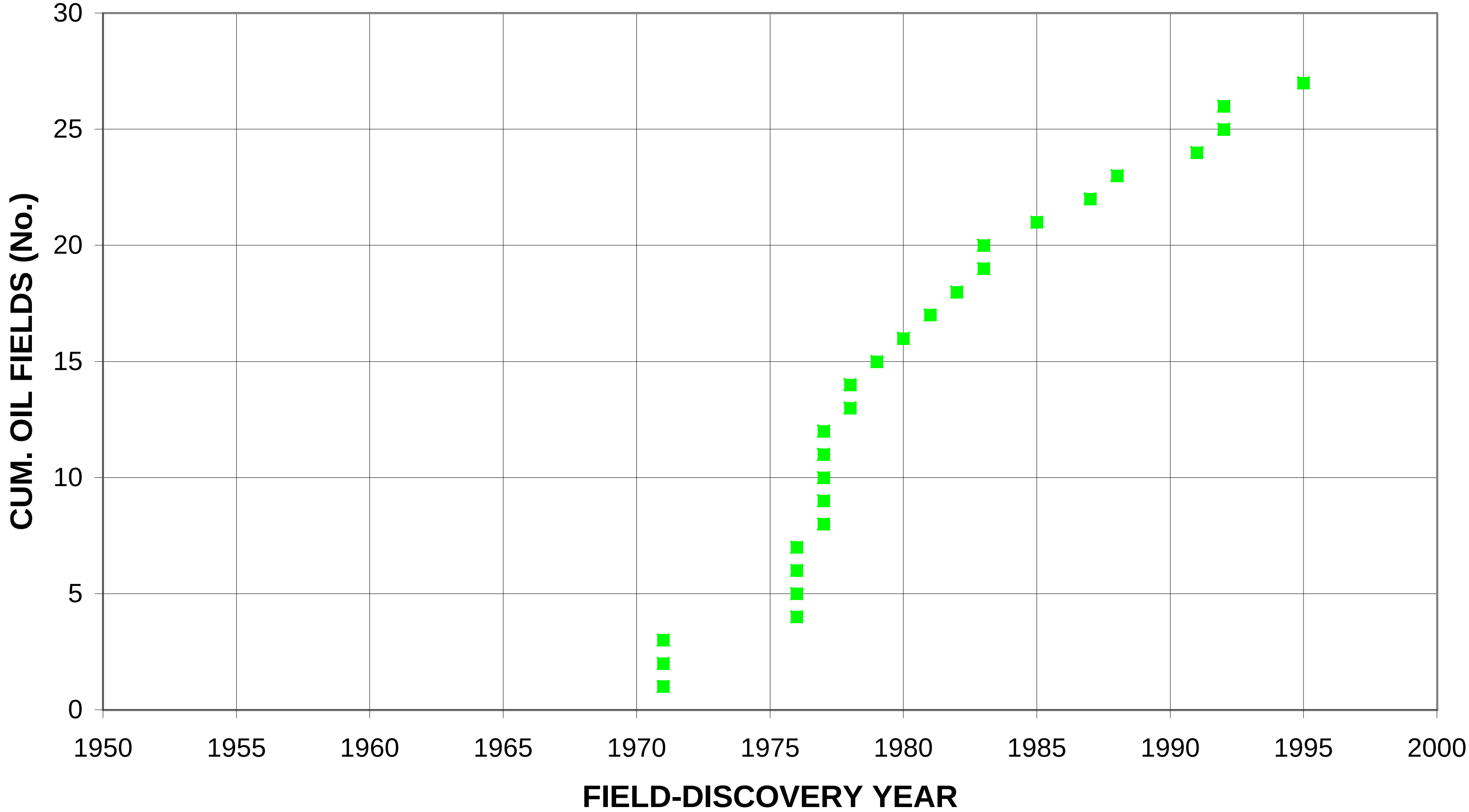
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



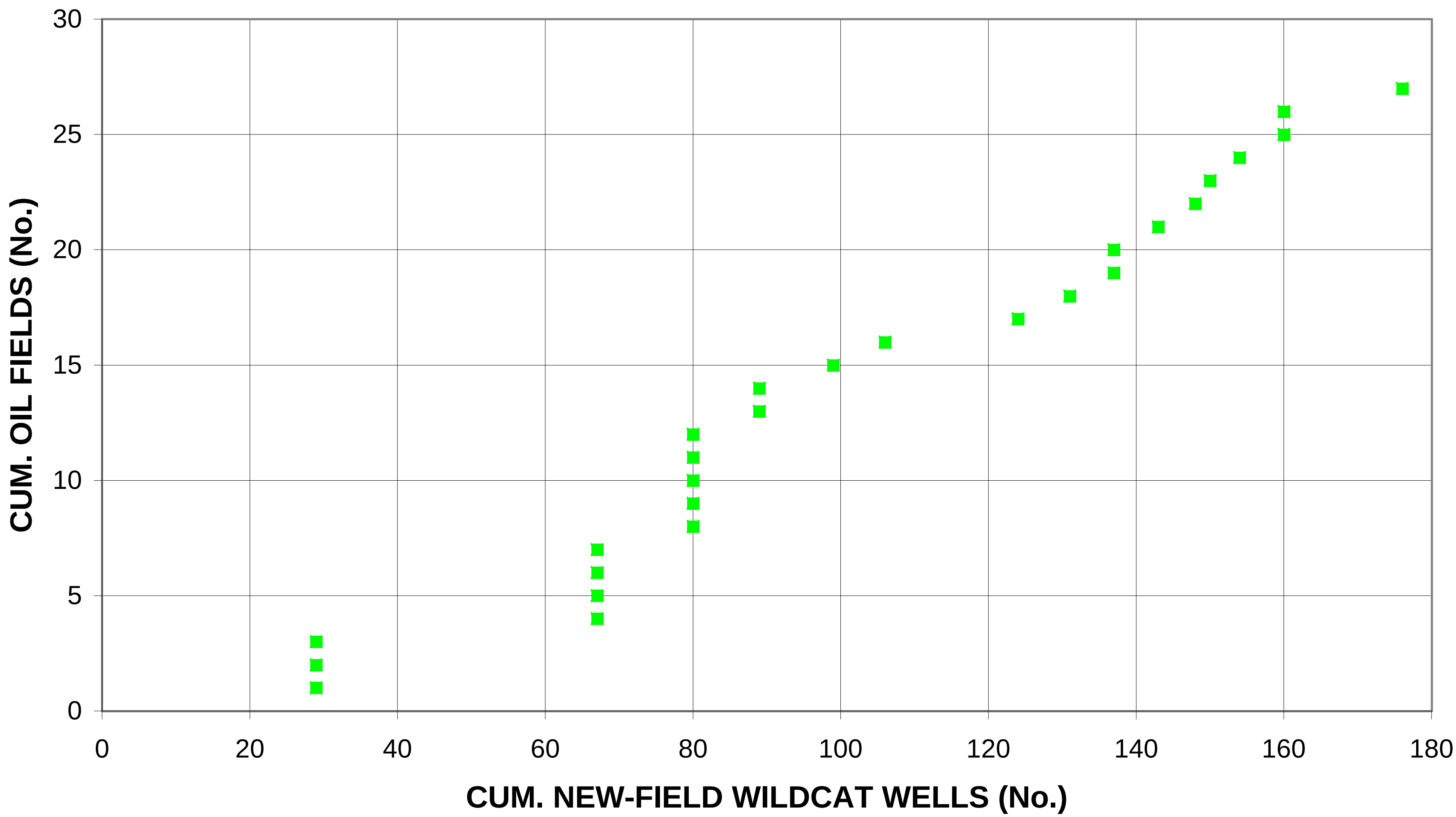


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
CUM. KNOWN OIL VOLUME (MMBO)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
20
40
60
80
100
120
140
160
180
CUM. NEW-FIELD WILDCAT WELLS (No.)

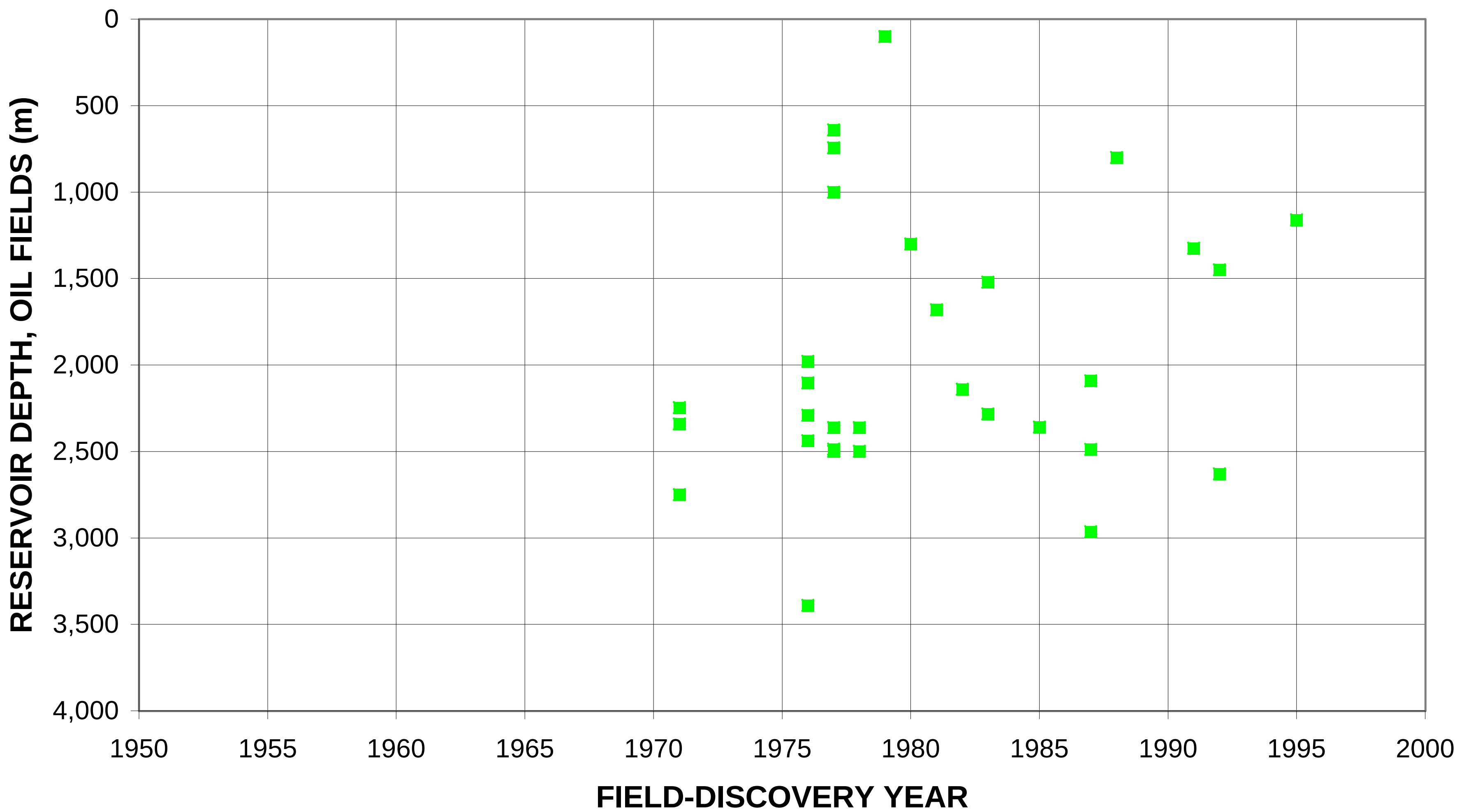
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



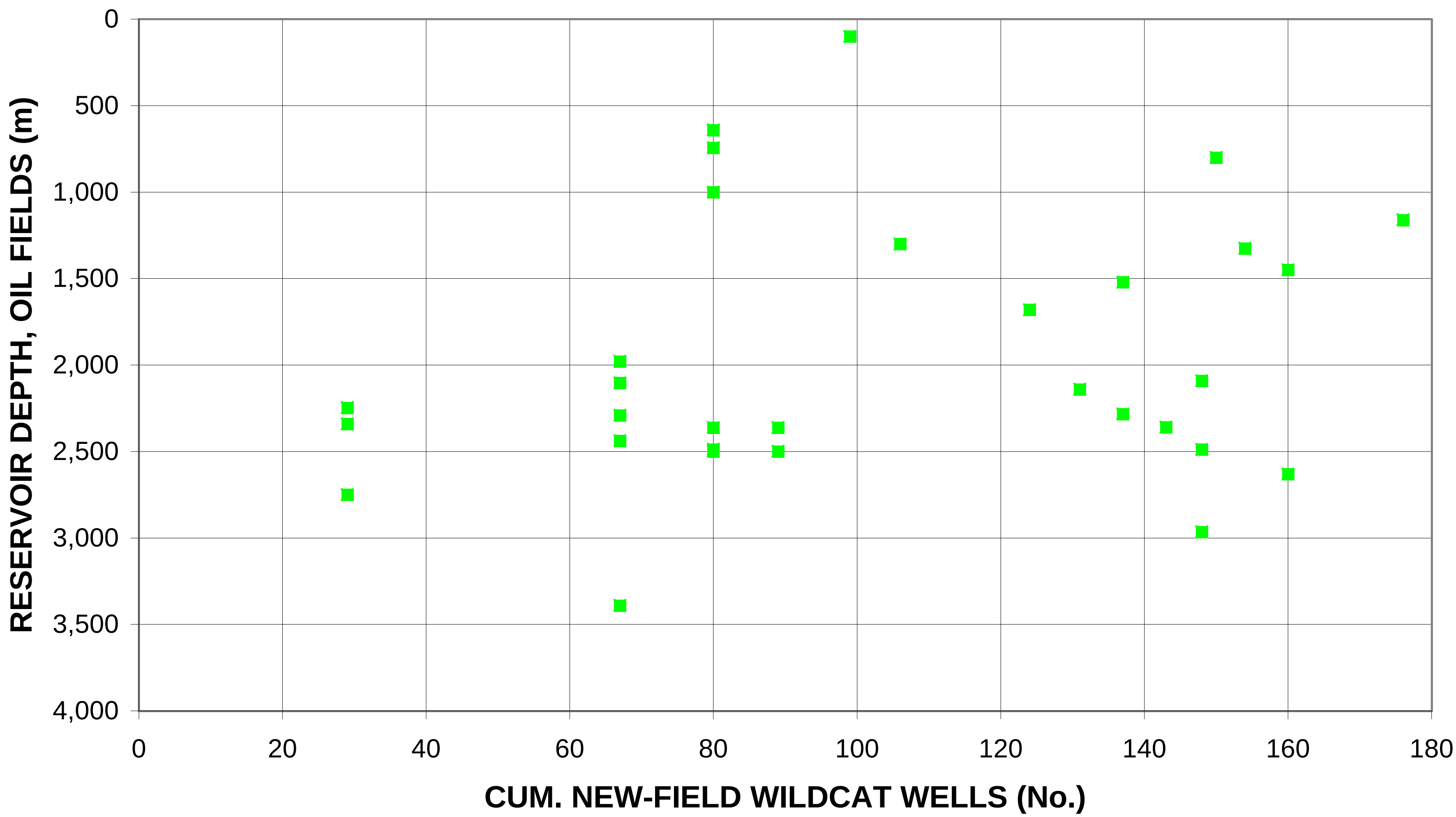
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

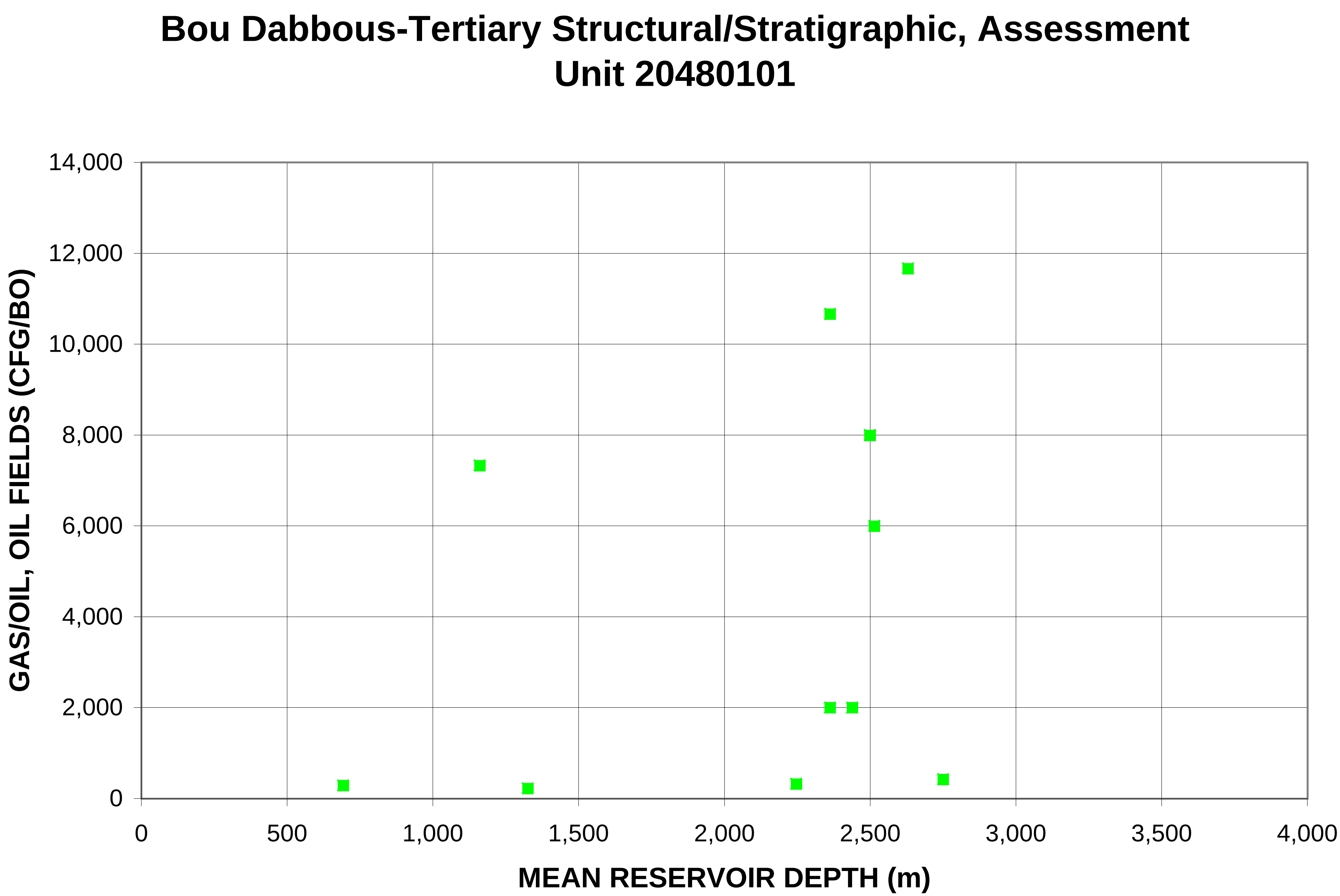


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

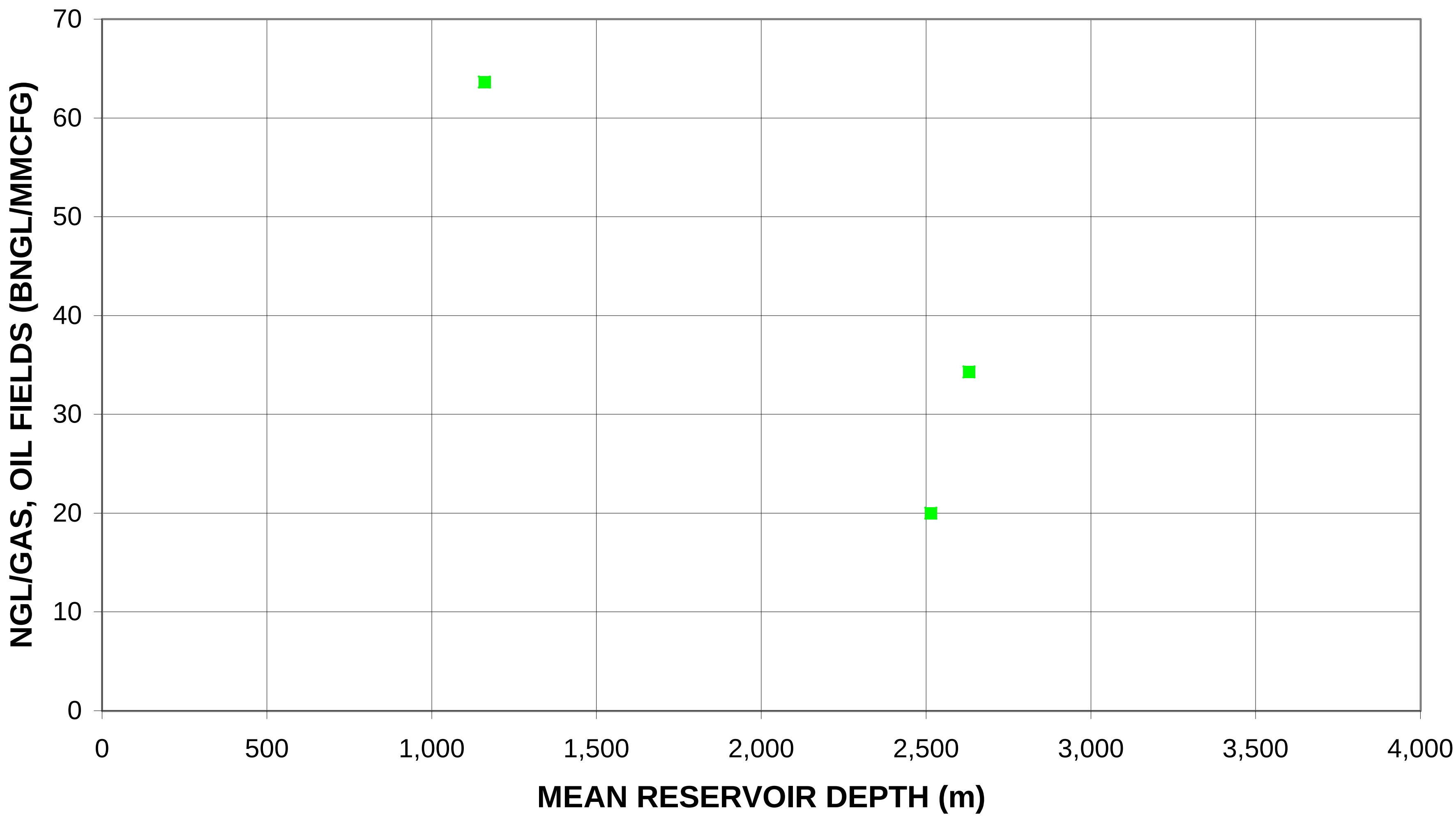


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

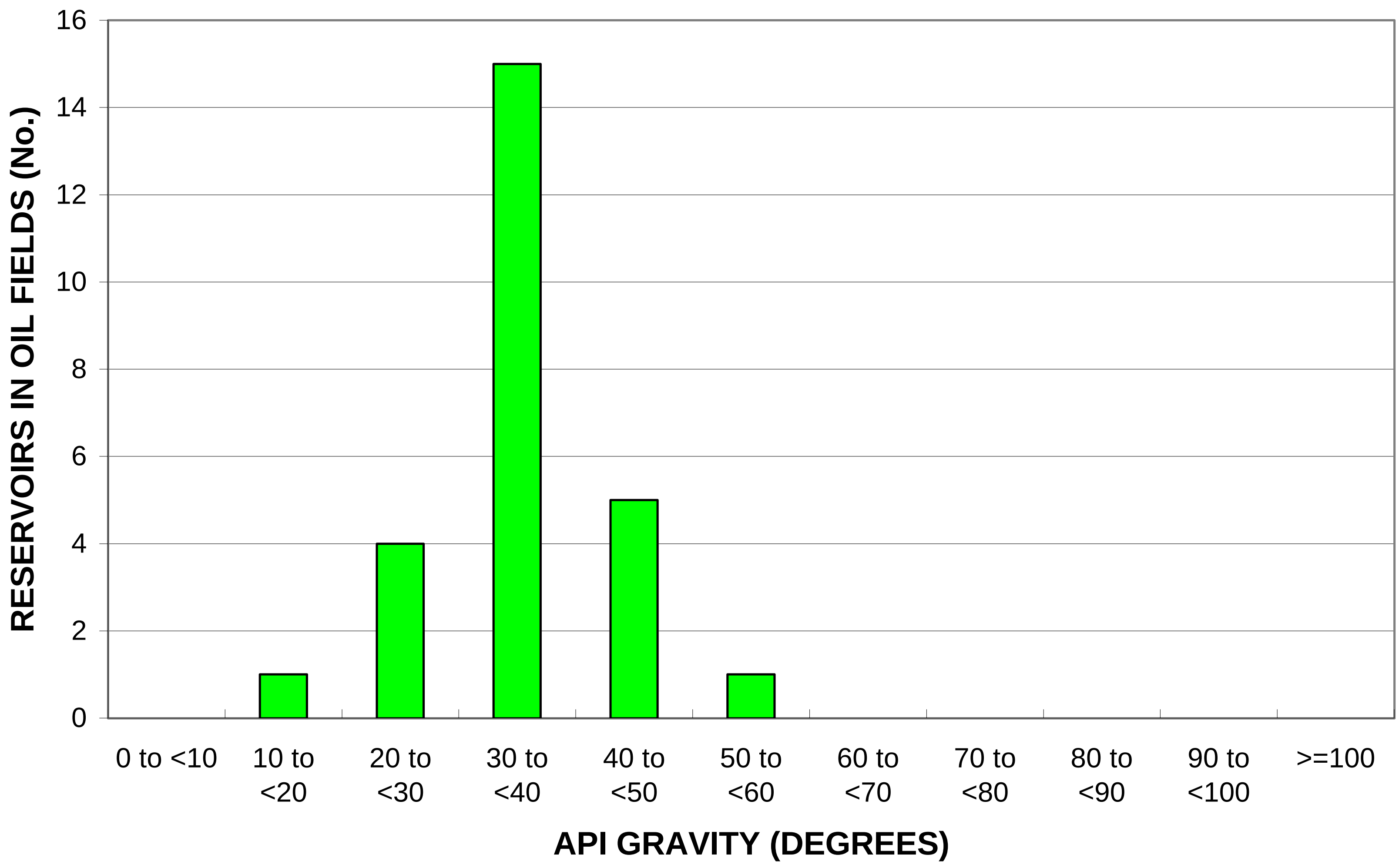



Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
GAS/OIL, OIL FIELDS (CFG/BO)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
MEAN RESERVOIR DEPTH (m)

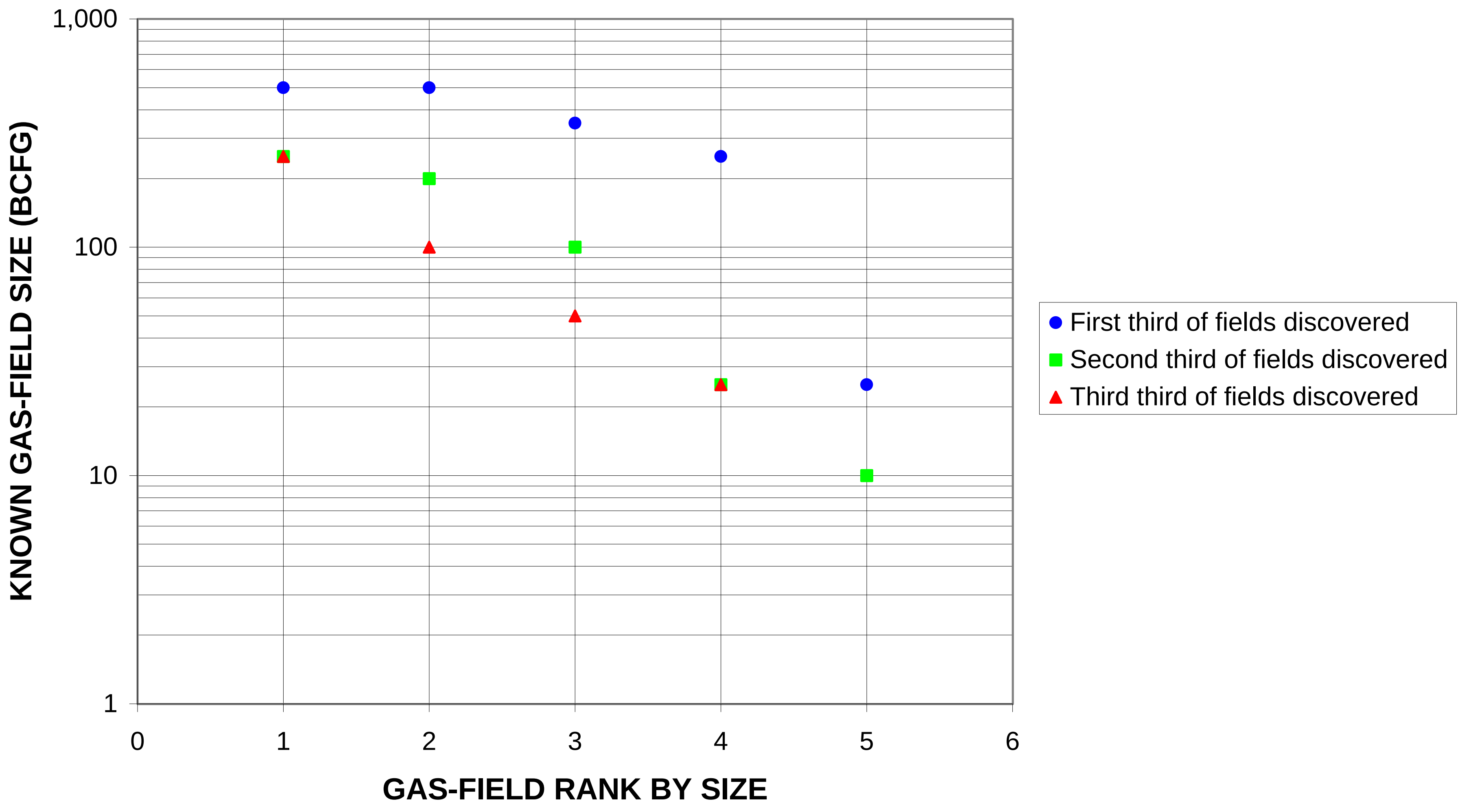
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



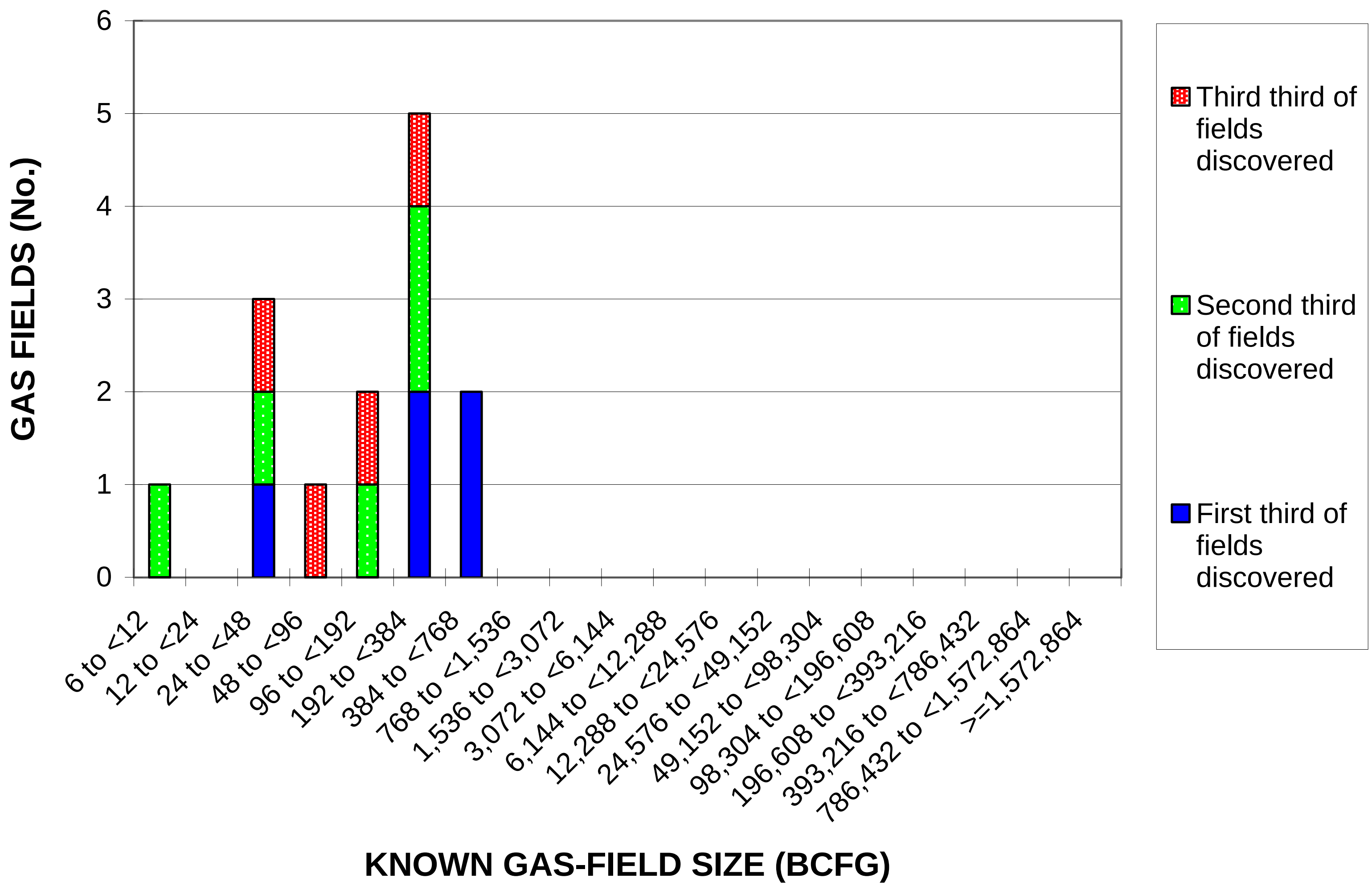
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

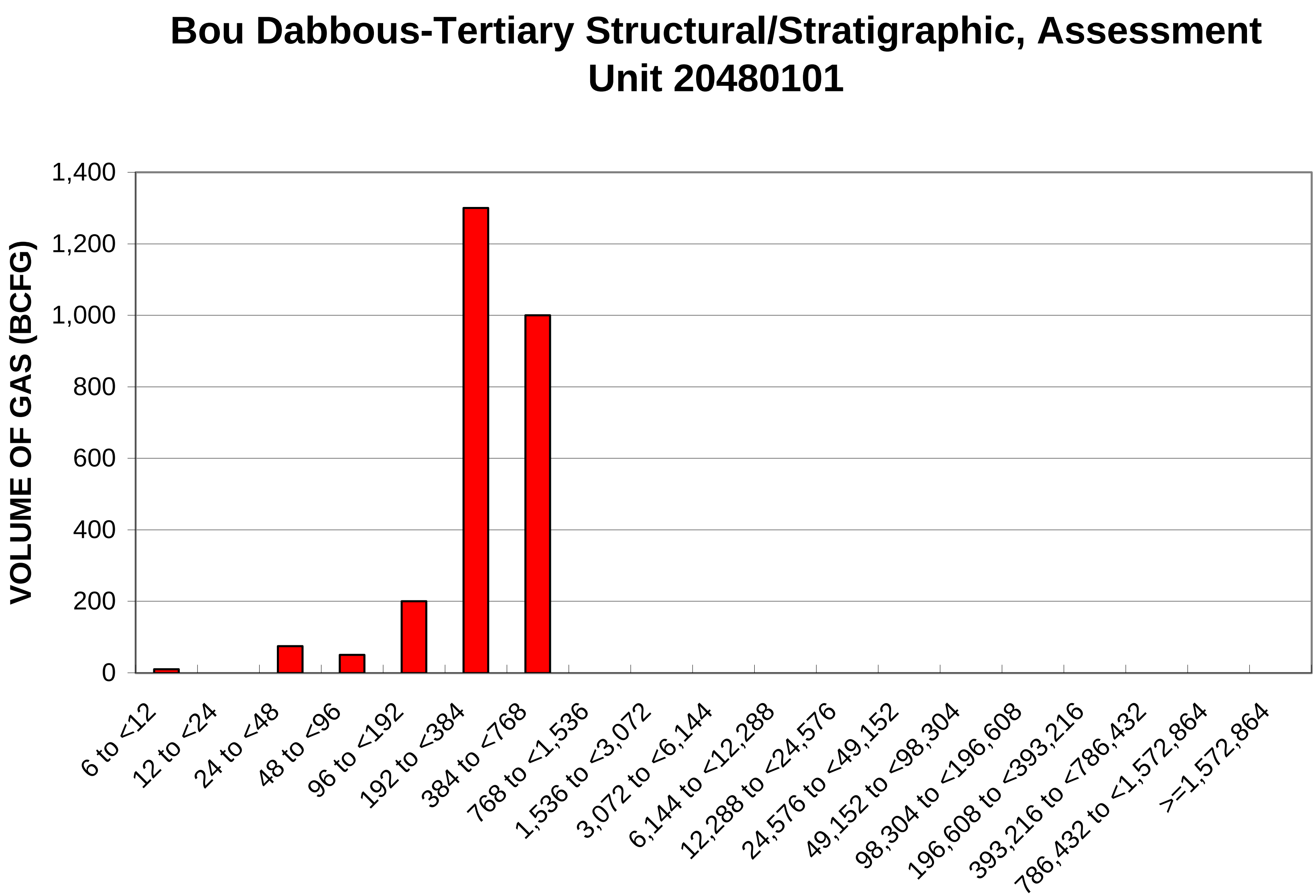


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



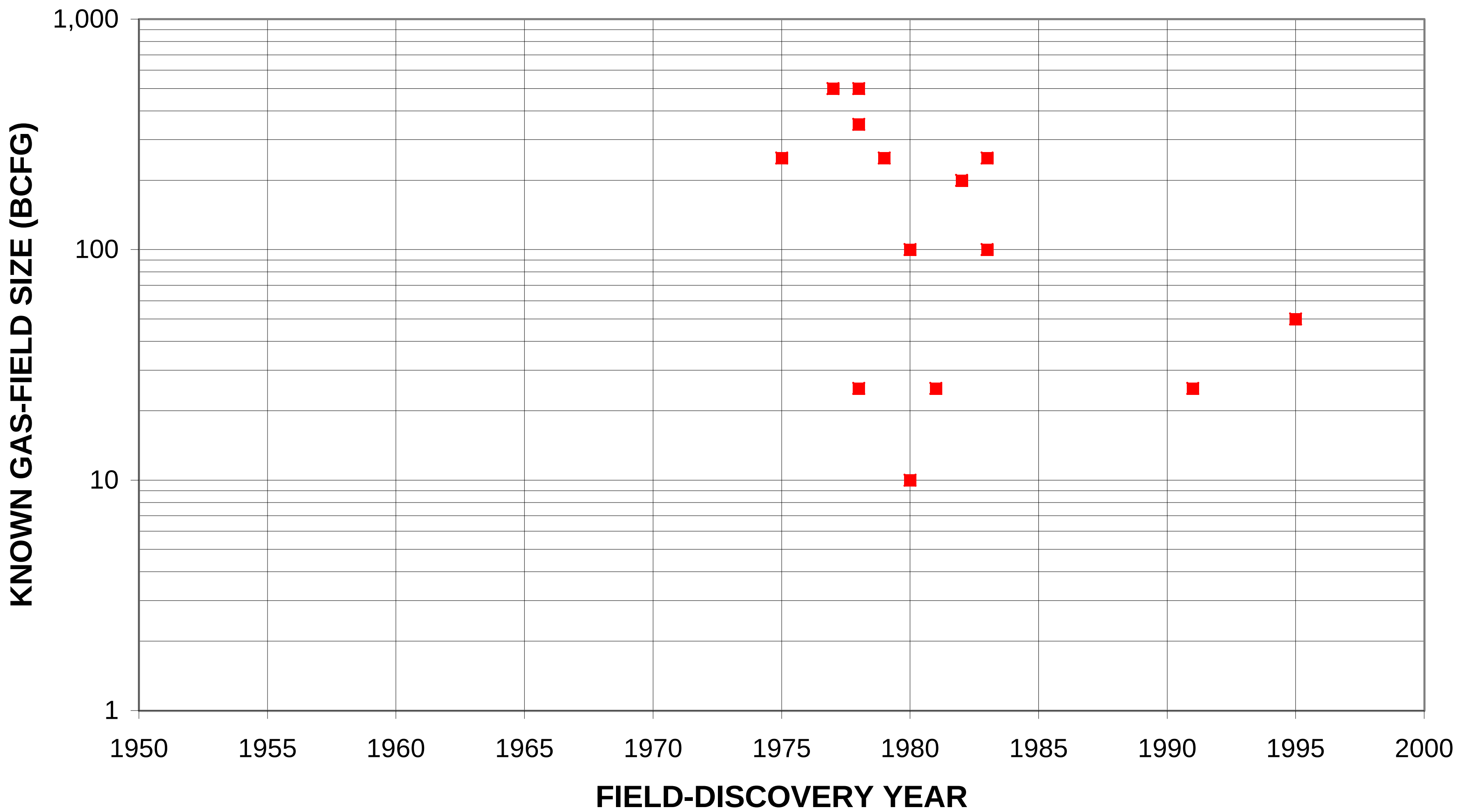
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



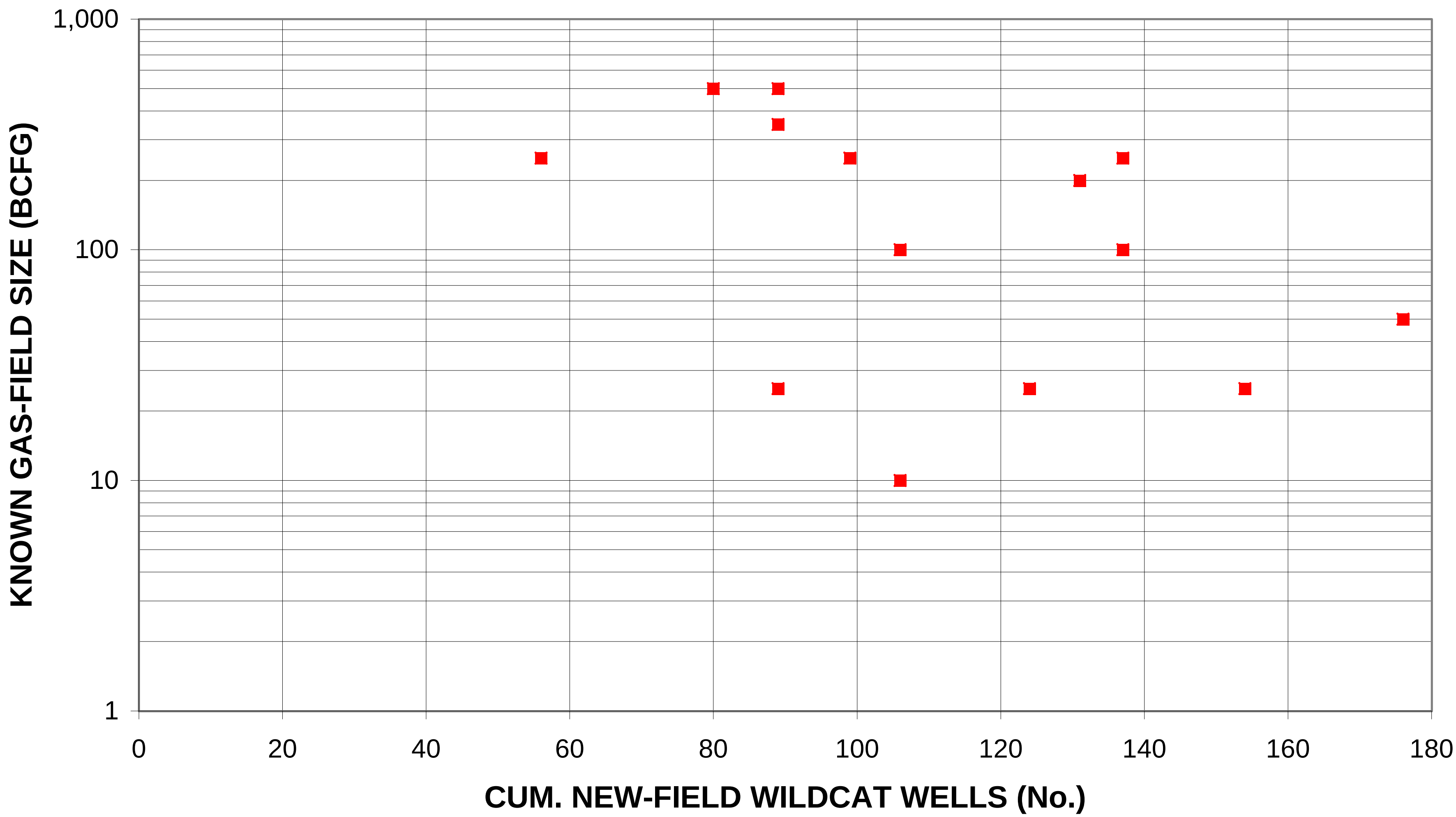


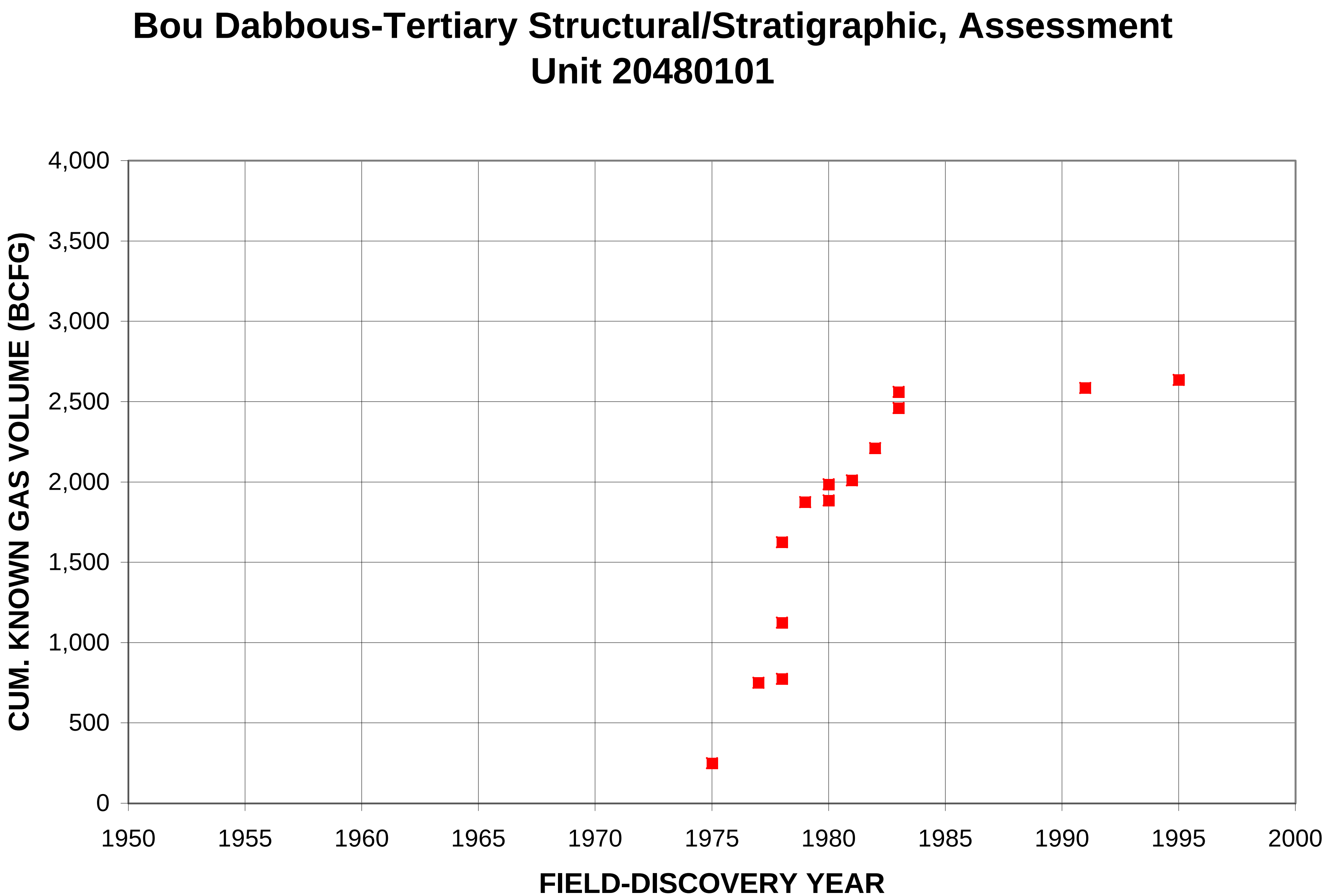
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
VOLUME OF GAS (BCFG)
1,400
1,200
1,000
800
600
400
200
0
6 to <12
12 to <24
24 to <48
48 to <96
96 to <192
192 to <384
384 to <768
768 to <1,536
1,536 to <3,072
3,072 to <6,144
6,144 to <12,288
12,288 to <24,576
24,576 to <49,152
49,152 to <98,304
98,304 to <196,608
196,608 to <393,216
393,216 to <786,432
786,432 to <1,572,864
>=1,572,864
KNOWN GAS-FIELD SIZE (BCFG)

Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

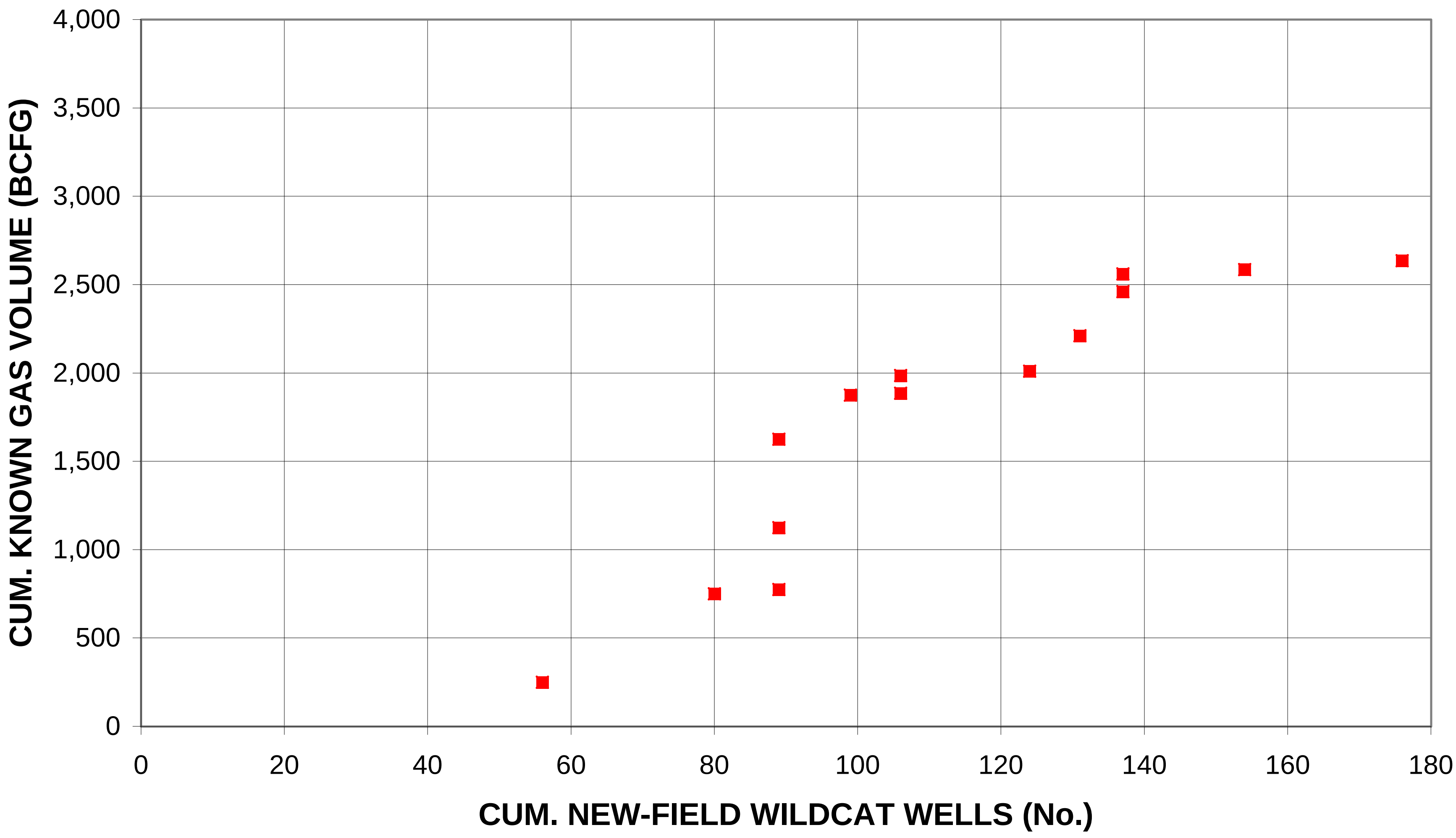


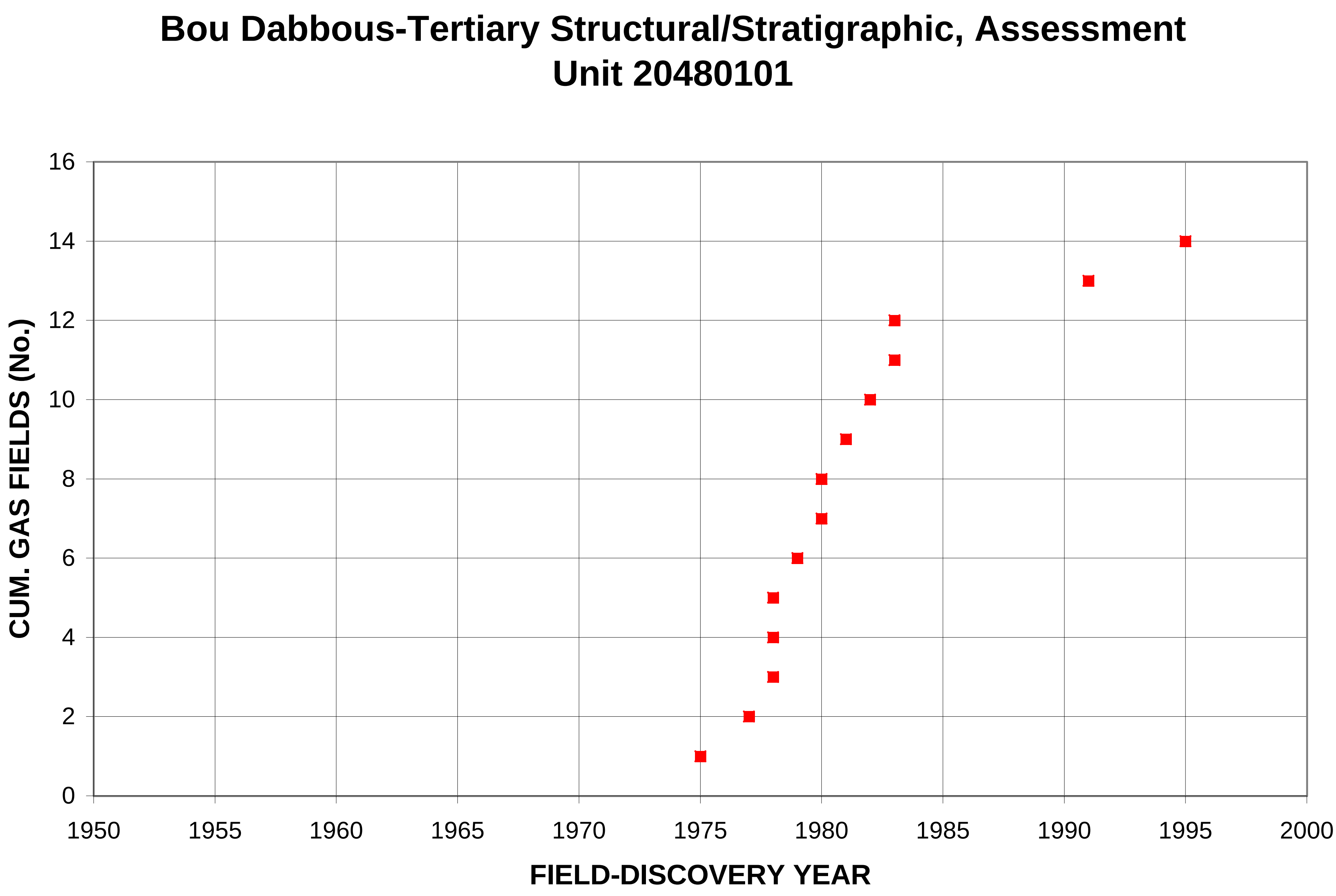
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



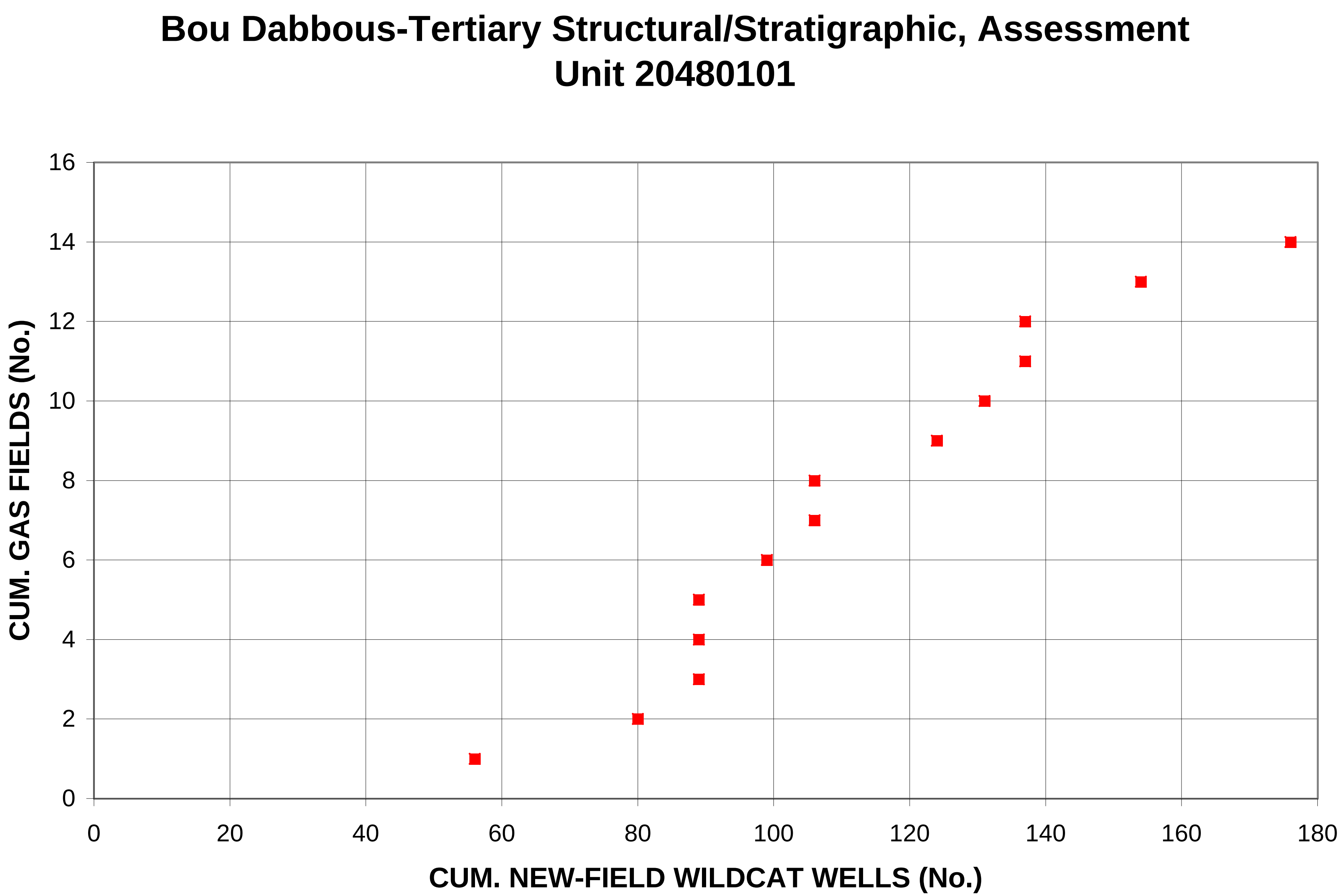

Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
CUM. KNOWN GAS VOLUME (BCFG)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
FIELD-DISCOVERY YEAR

Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



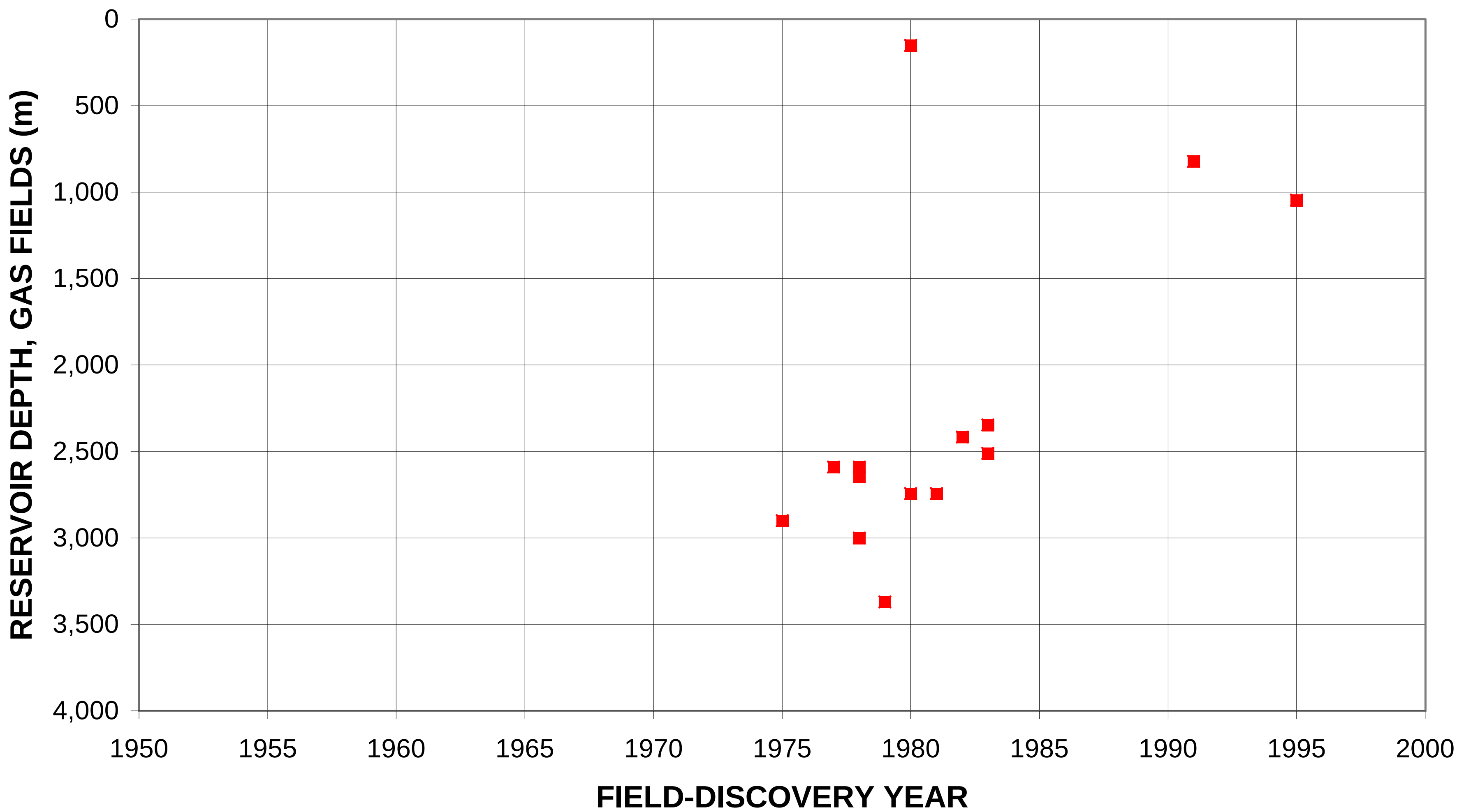


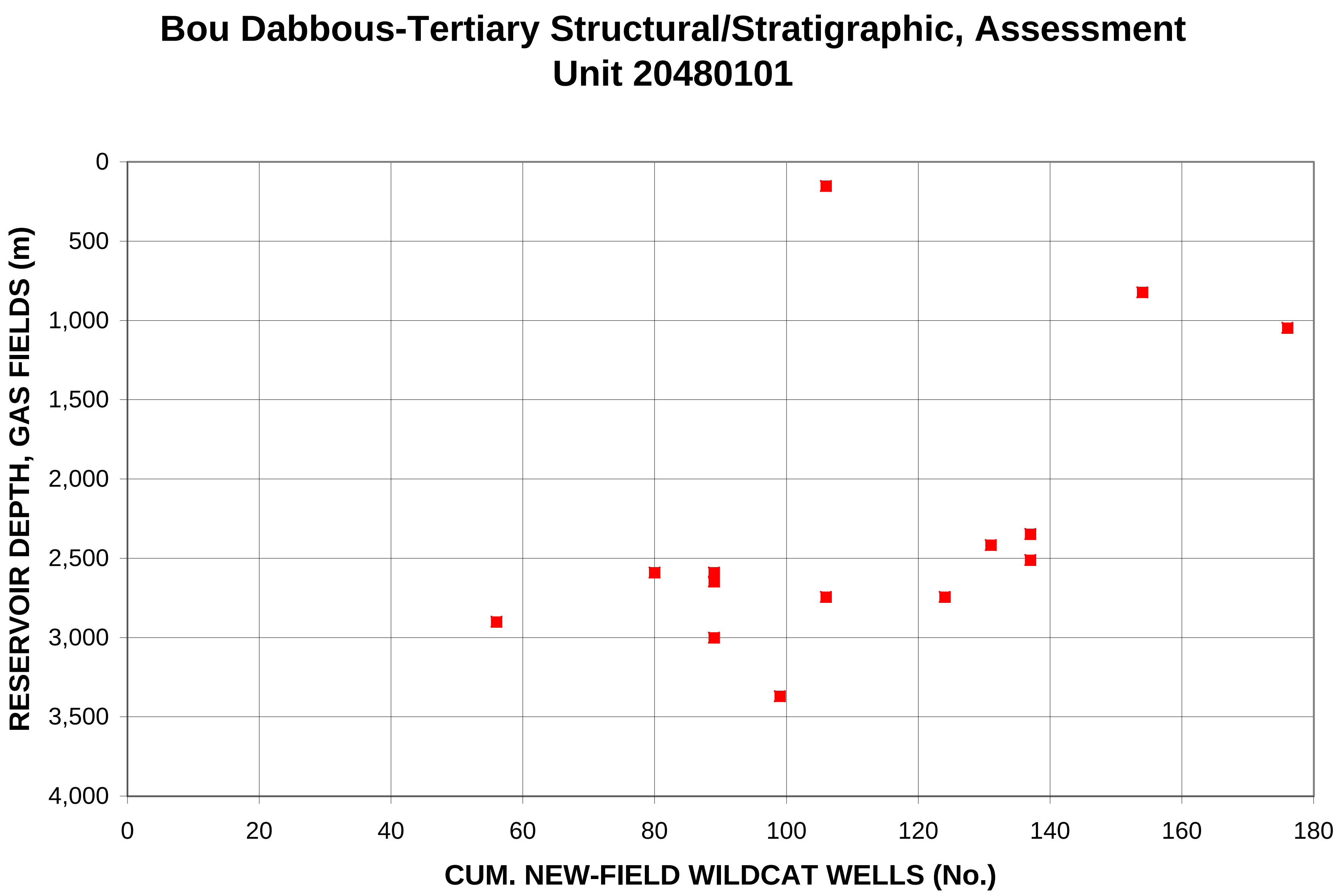
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
CUM. GAS FIELDS (No.)
0
2
4
6
8
10
12
14
16
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
FIELD-DISCOVERY YEAR

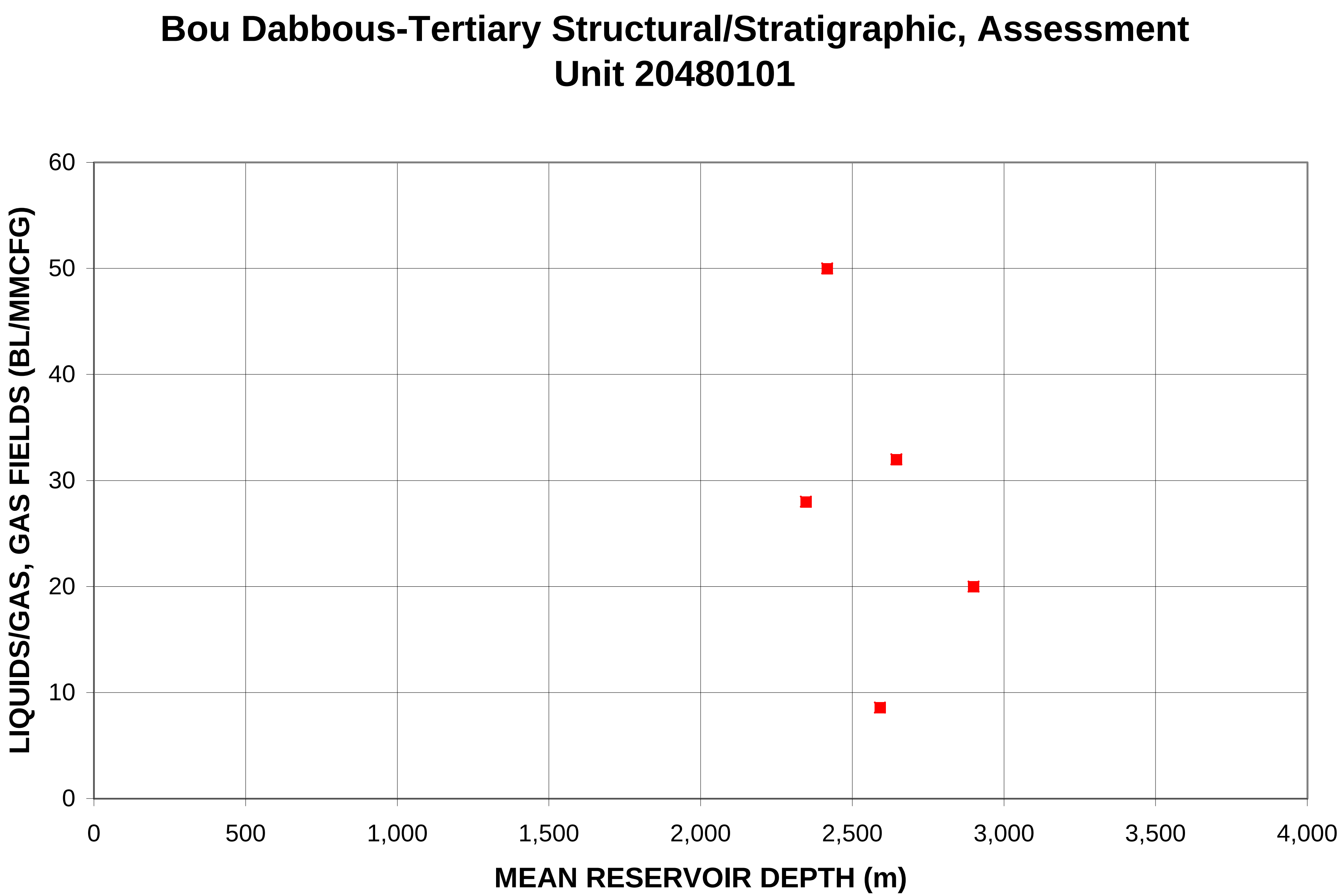


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
CUM. GAS FIELDS (No.)
CUM. NEW-FIELD WILDCAT WELLS (No.)
0
2
4
6
8
10
12
14
16
0
20
40
60
80
100
120
140
160
180

Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

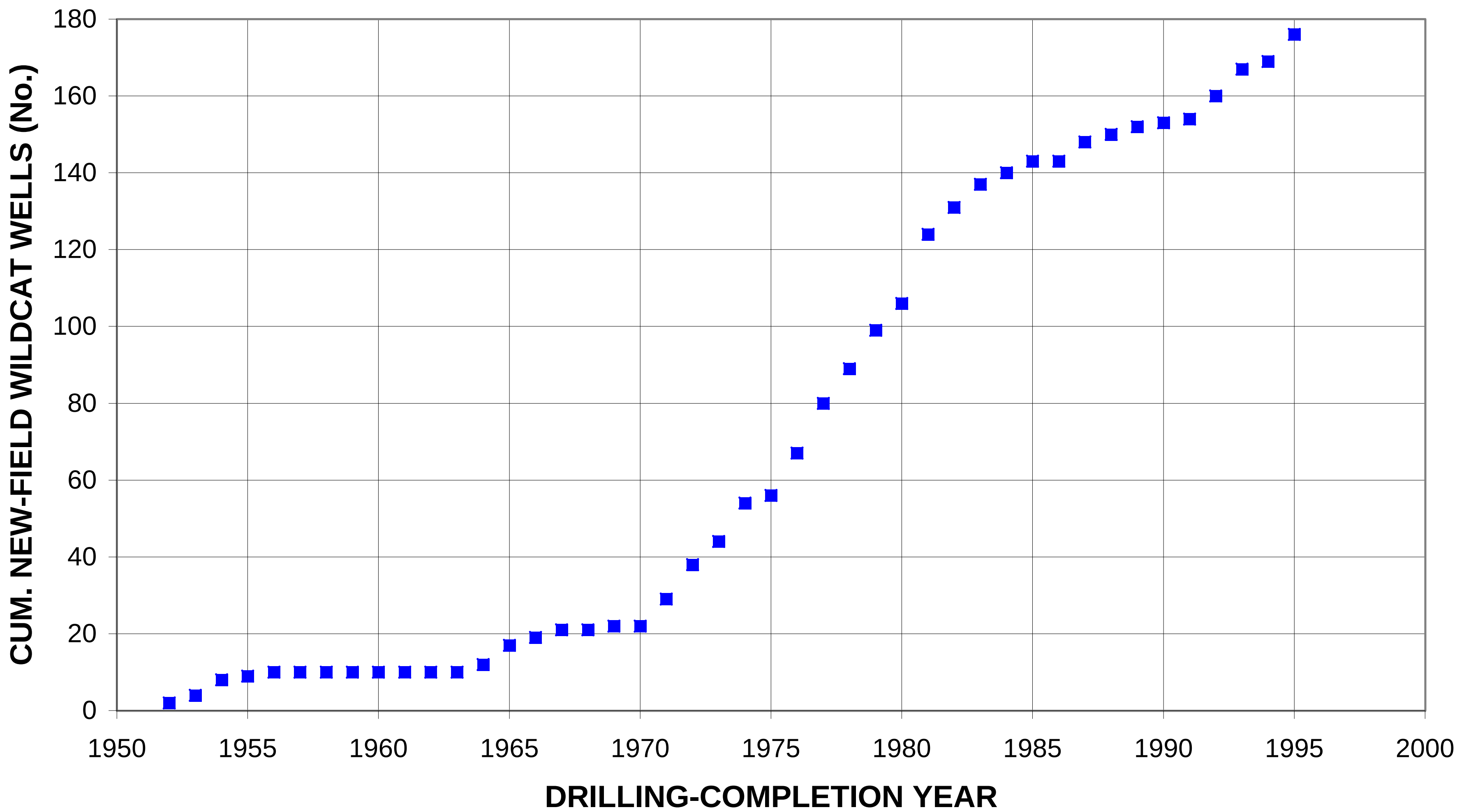



Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
RESERVOIR DEPTH, GAS FIELDS (m)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
0
20
40
60
80
100
120
140
160
180
CUM. NEW-FIELD WILDCAT WELLS (No.)

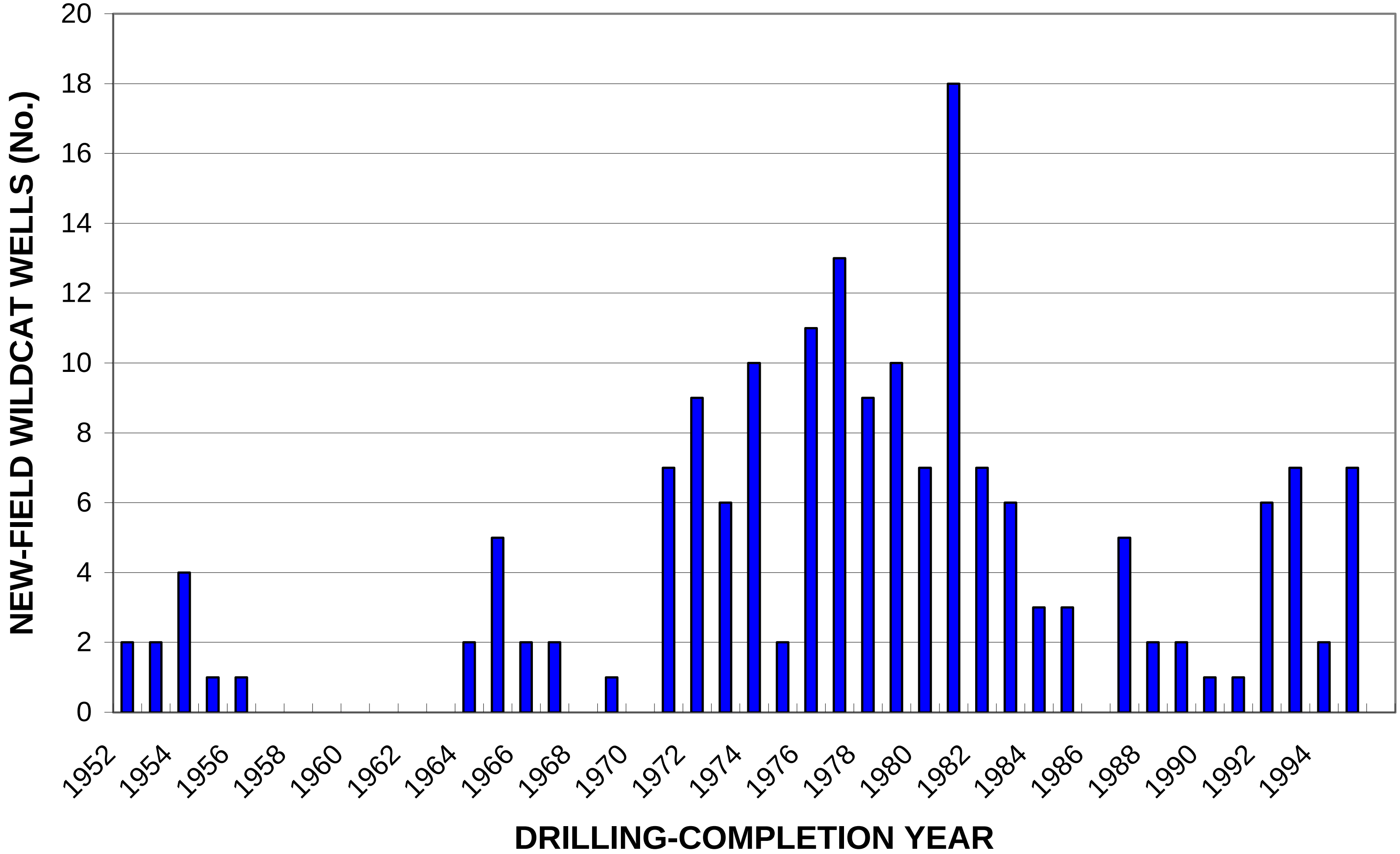

Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
LIQUIDS/GAS, GAS FIELDS (BL/MMCFG)
0
10
20
30
40
50
60
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
MEAN RESERVOIR DEPTH (m)

Appendix 1. Exploration-activity and discovery-history plots for the Bou Dabbous-Tertiary Structural/Stratigraphic Assessment Unit (20480101). *B*. Plots of grown oil and gas volumes.

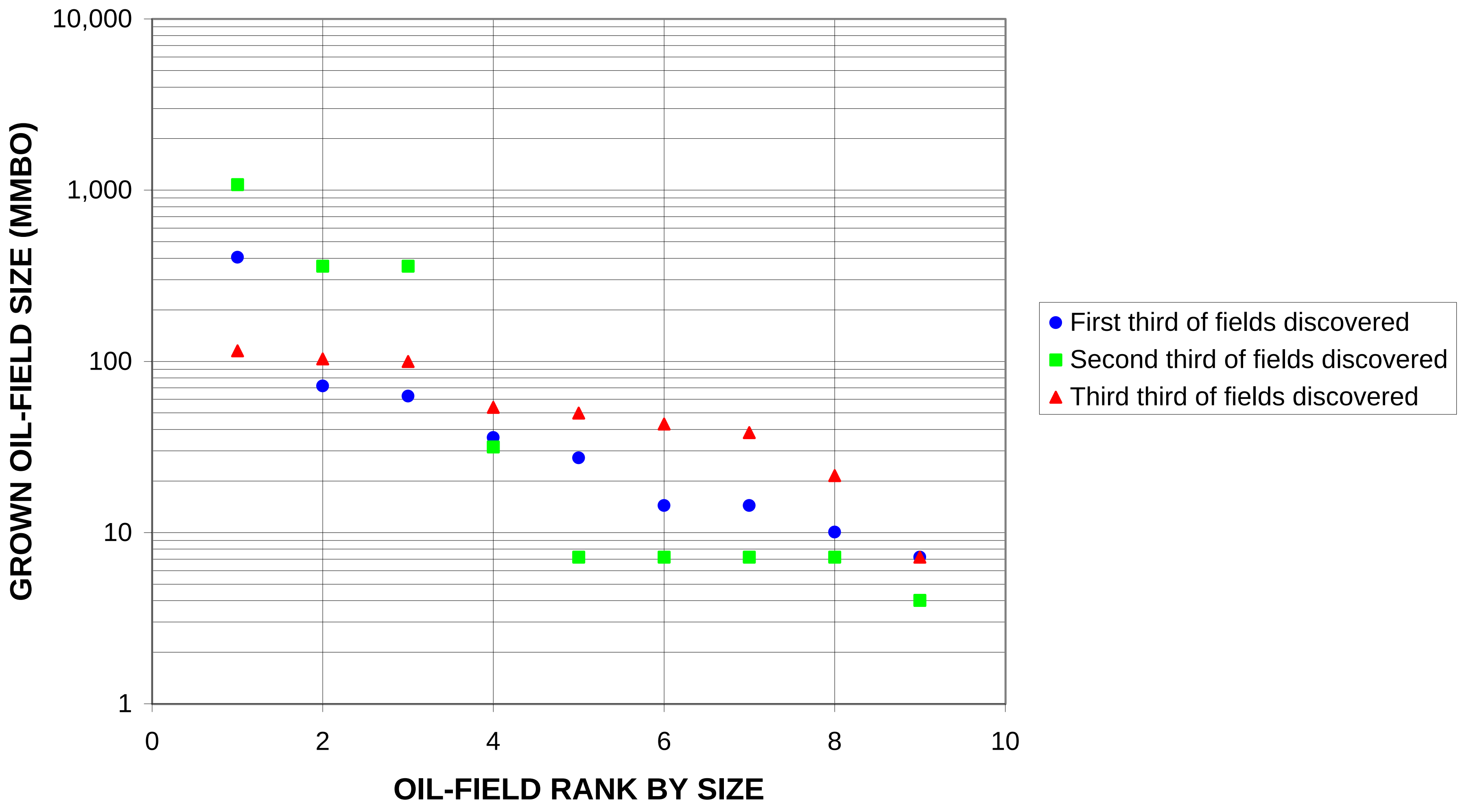
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



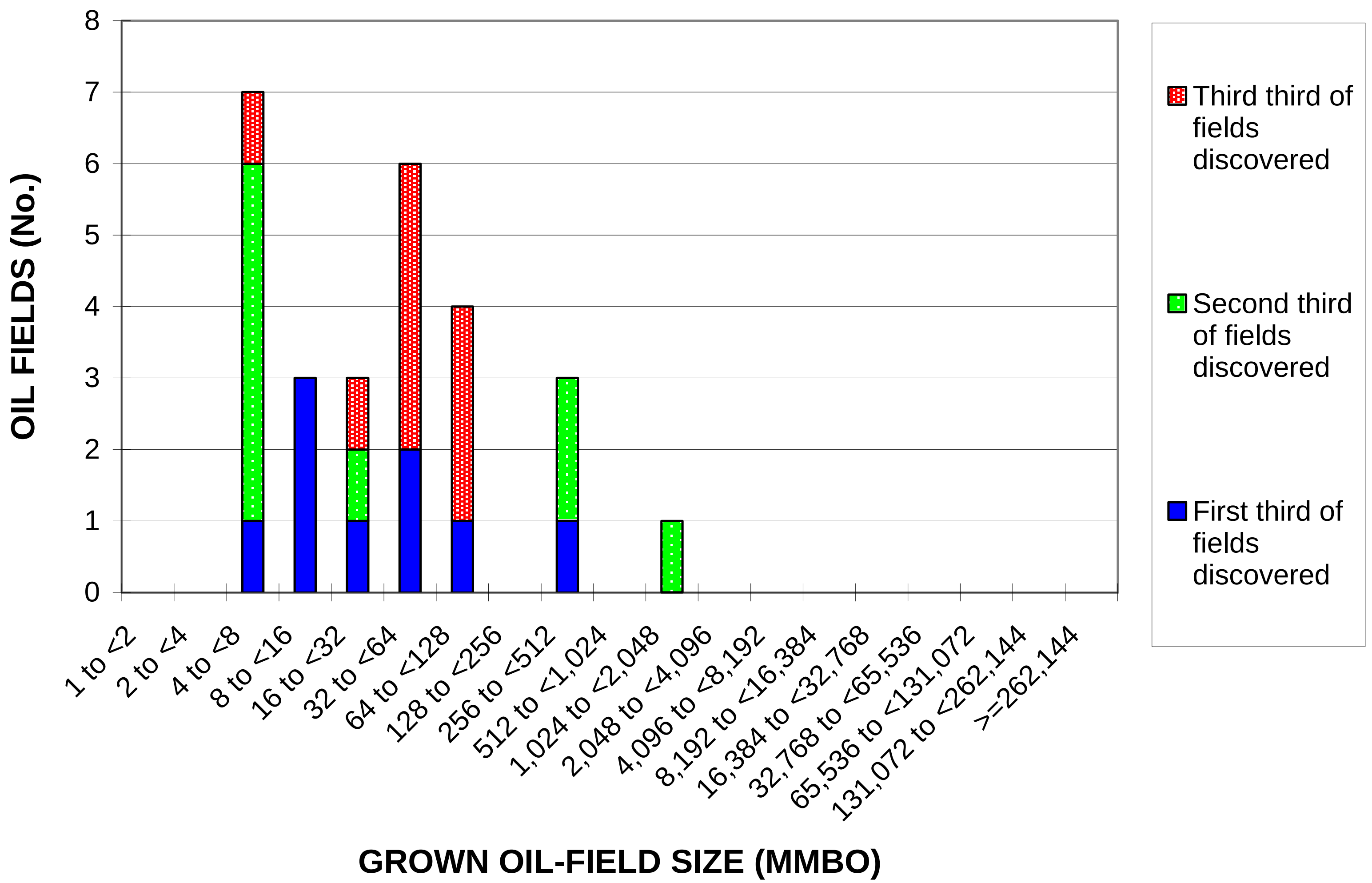
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

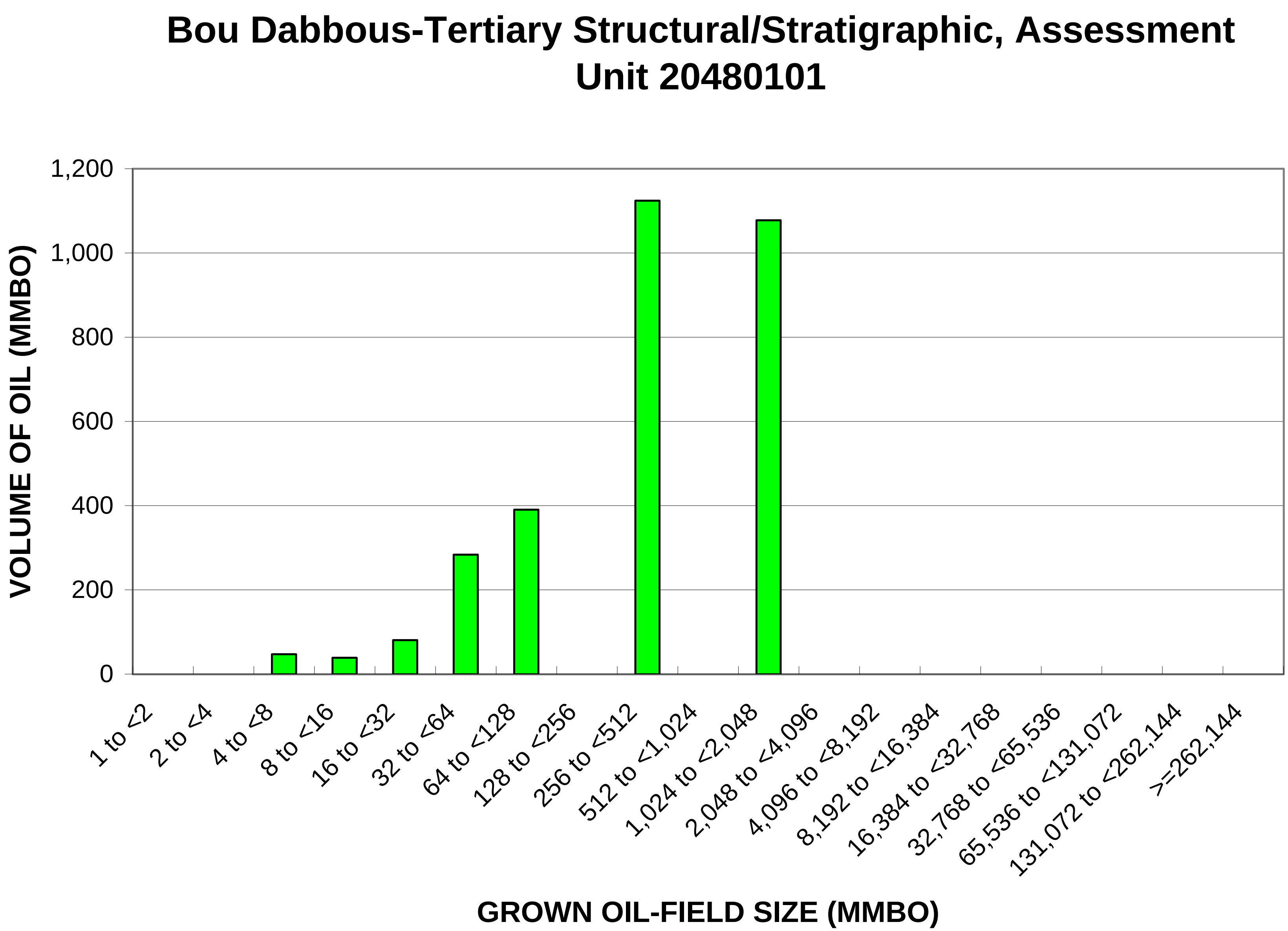


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

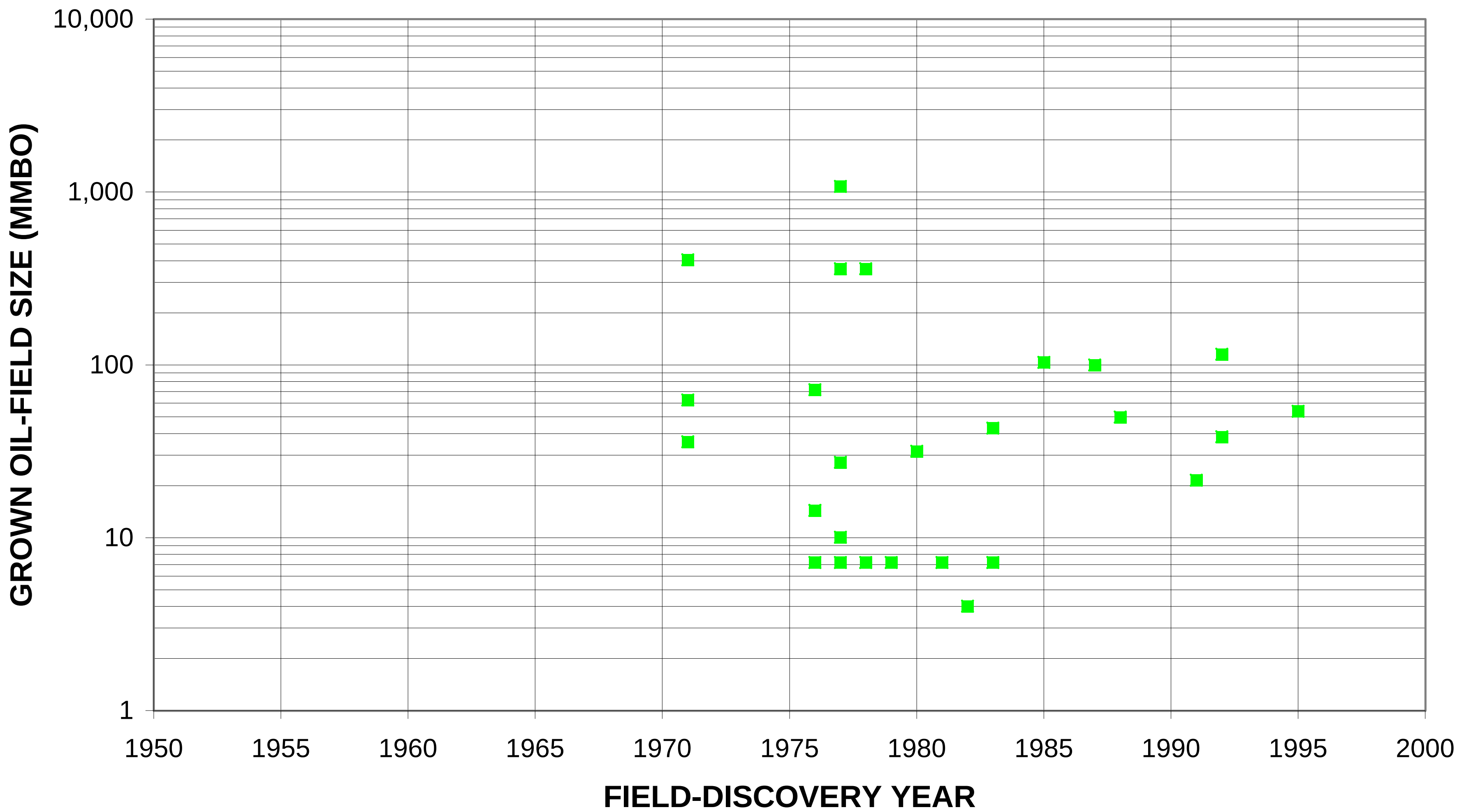


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

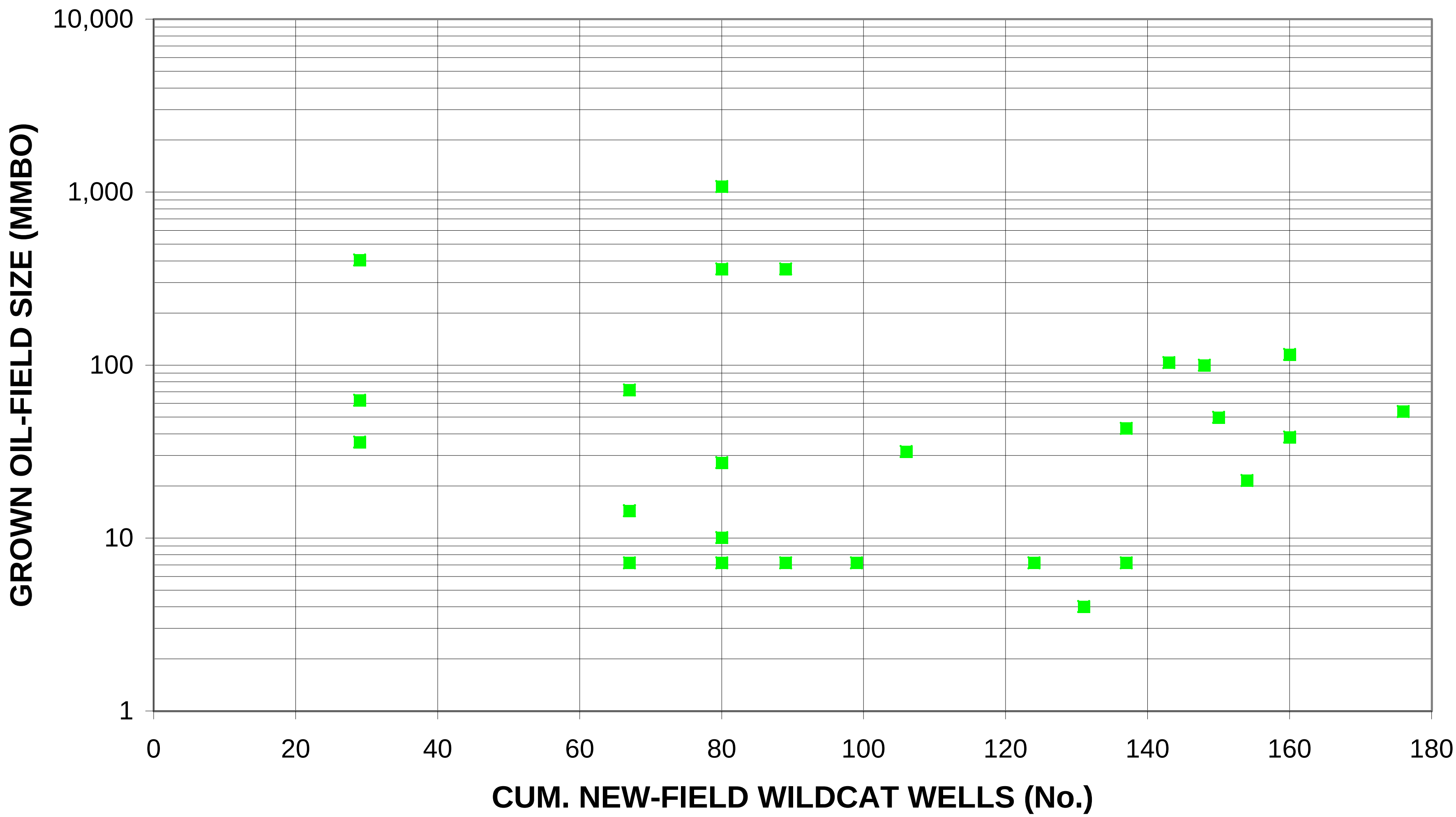



Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
VOLUME OF OIL (MMBO)
1,200
1,000
800
600
400
200
0
1 to <2
2 to <4
4 to <8
8 to <16
16 to <32
32 to <64
64 to <128
128 to <256
256 to <512
512 to <1,024
1,024 to <2,048
2,048 to <4,096
4,096 to <8,192
8,192 to <16,384
16,384 to <32,768
32,768 to <65,536
65,536 to <131,072
131,072 to <262,144
>=262,144
GROWN OIL-FIELD SIZE (MMBO)

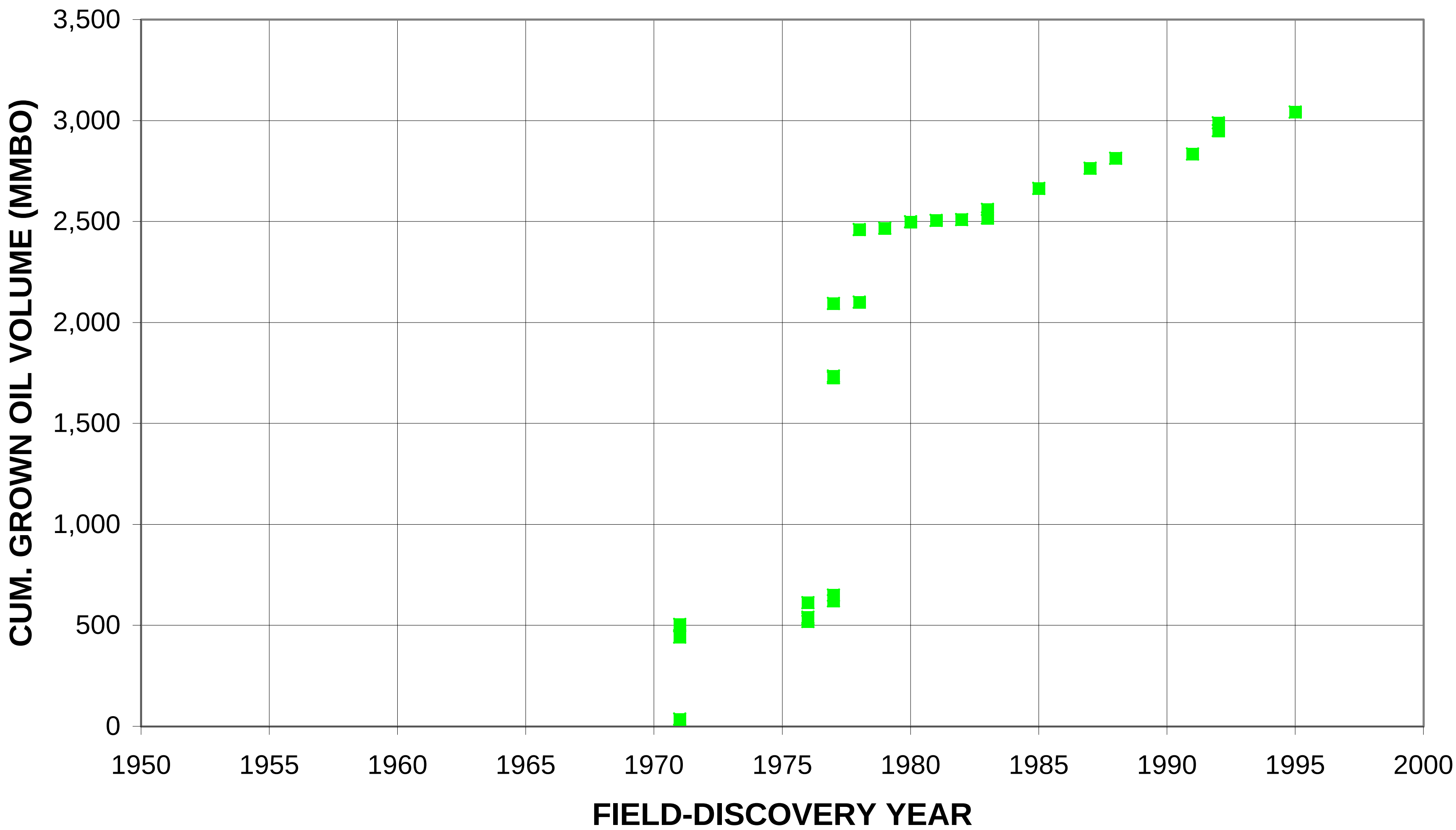
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



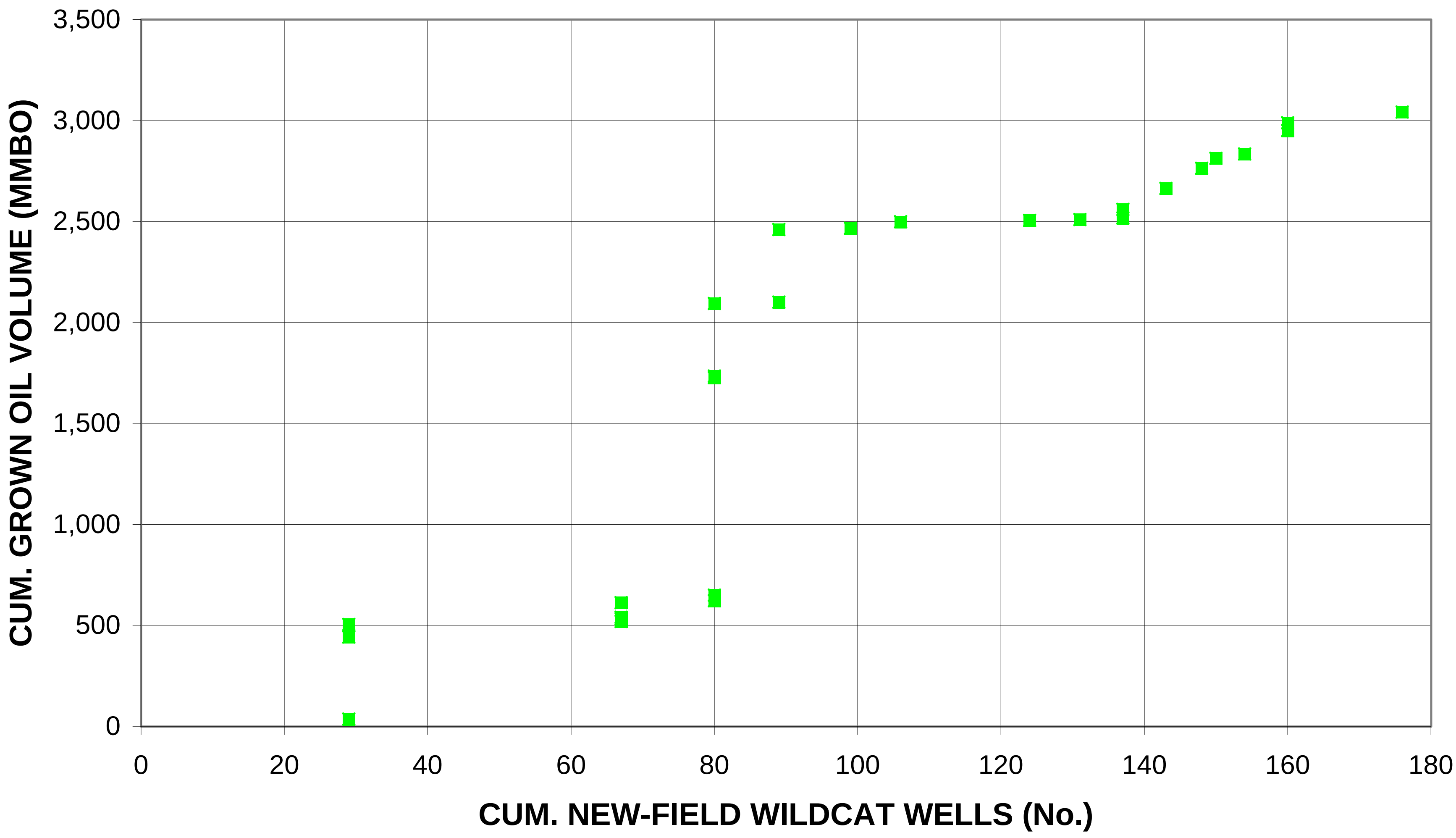
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



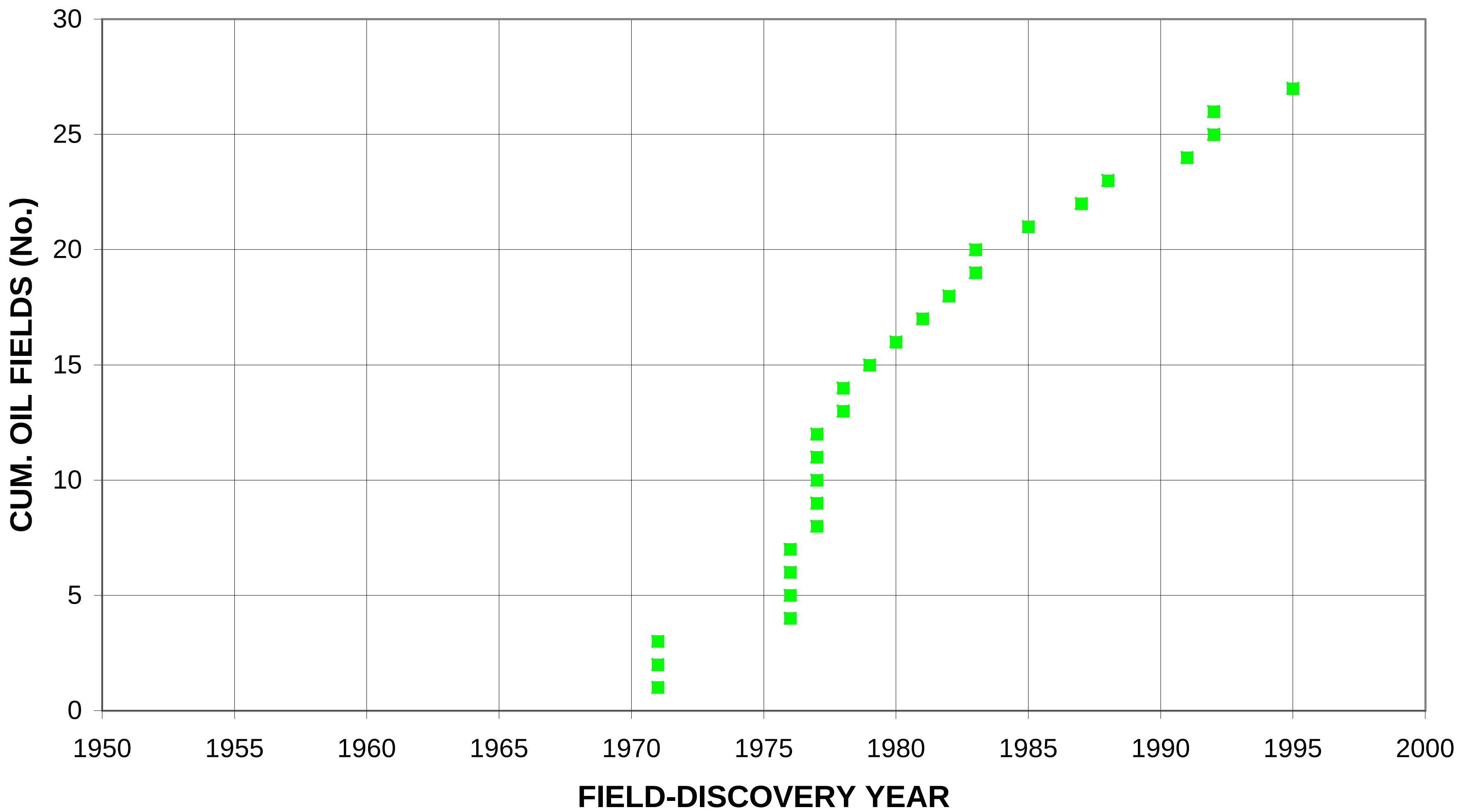
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



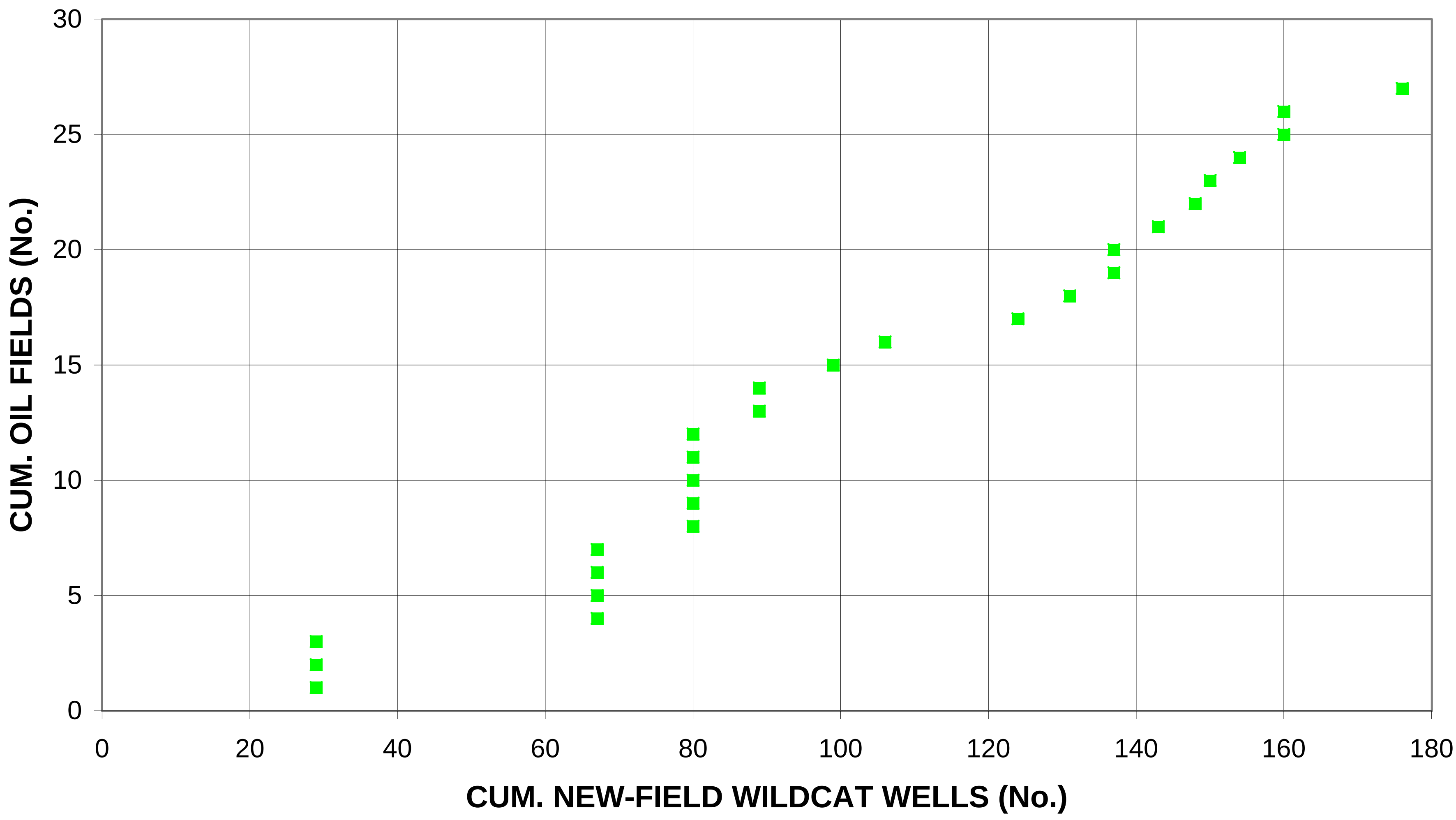
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



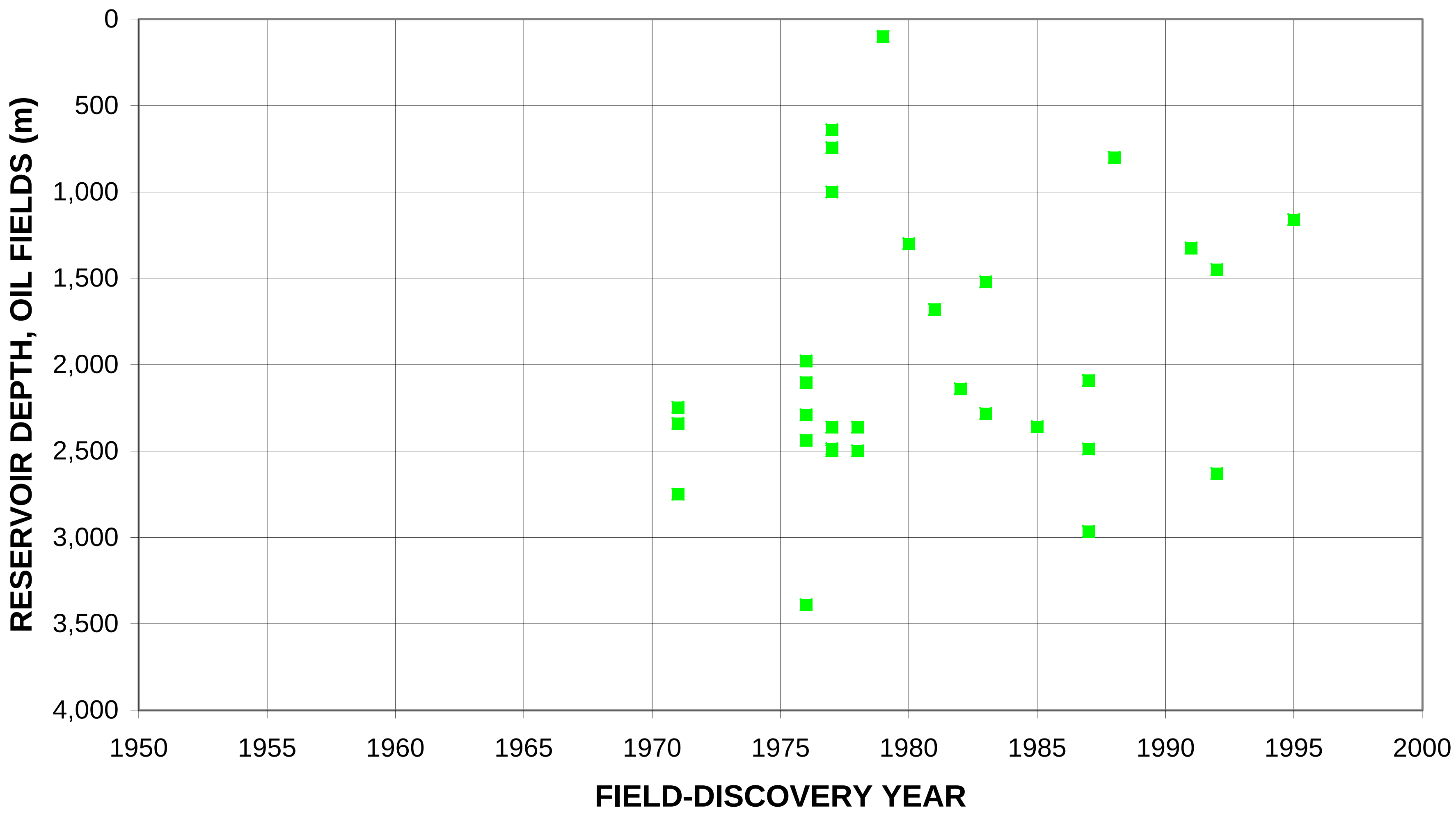
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

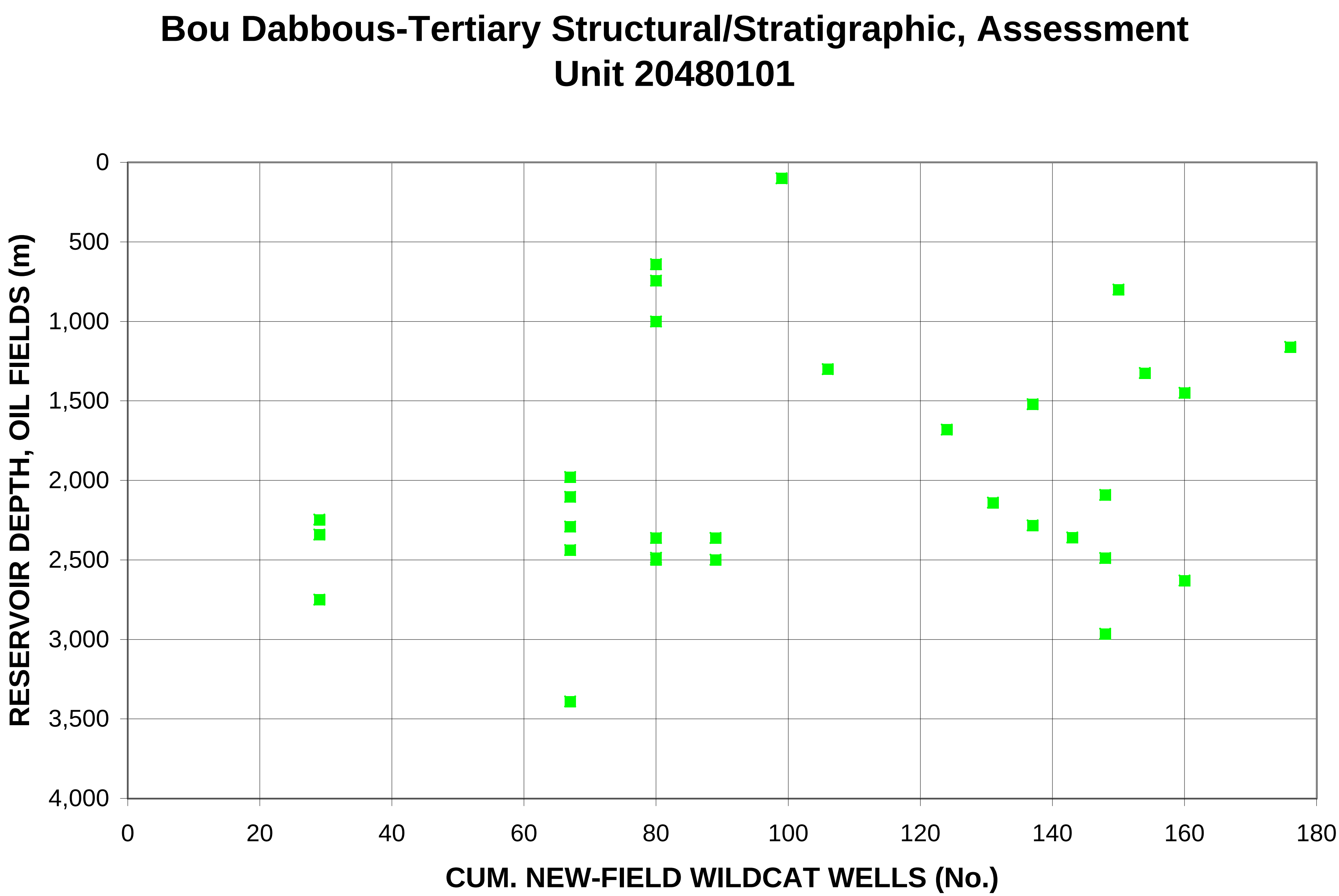


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

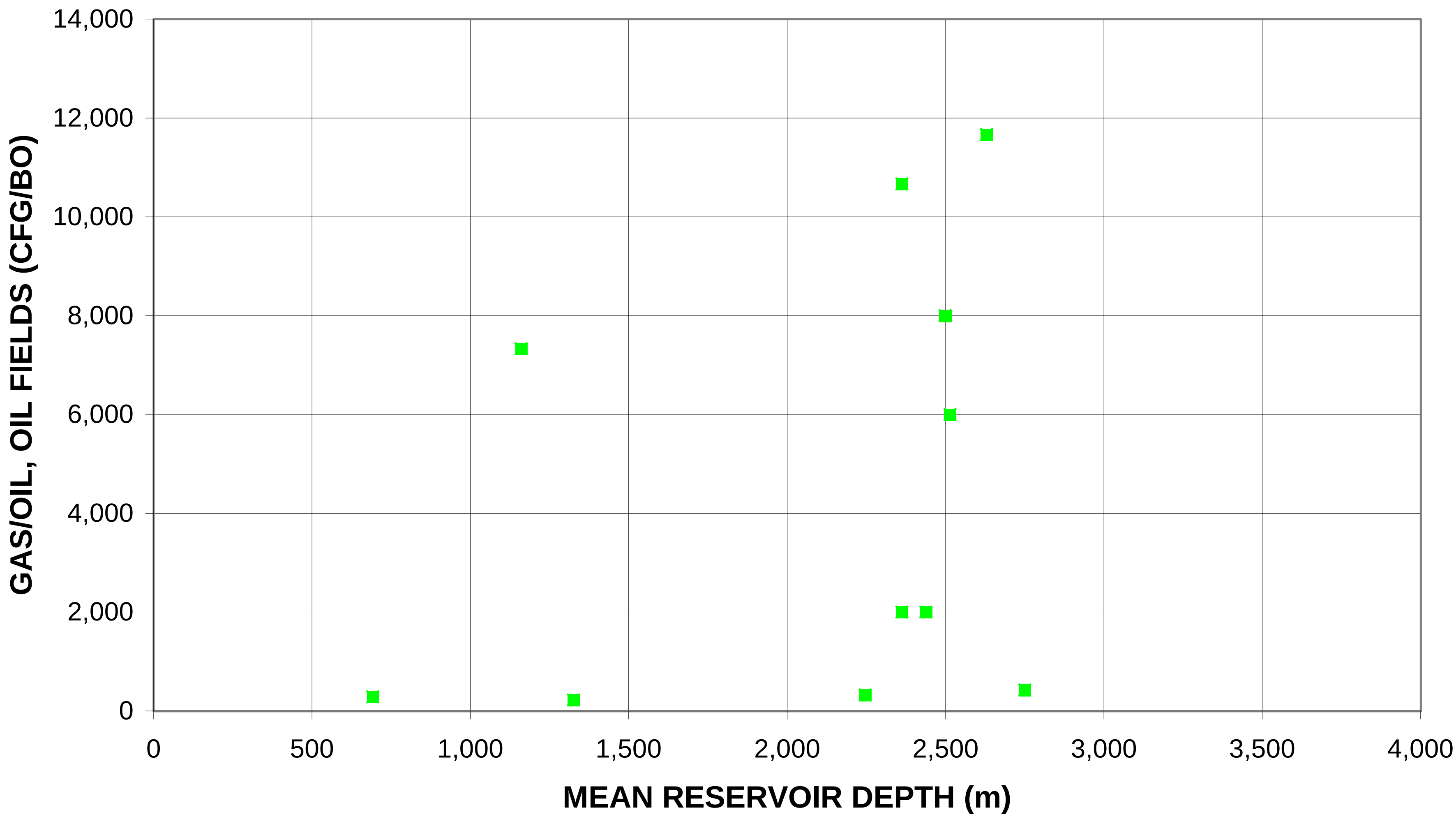


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

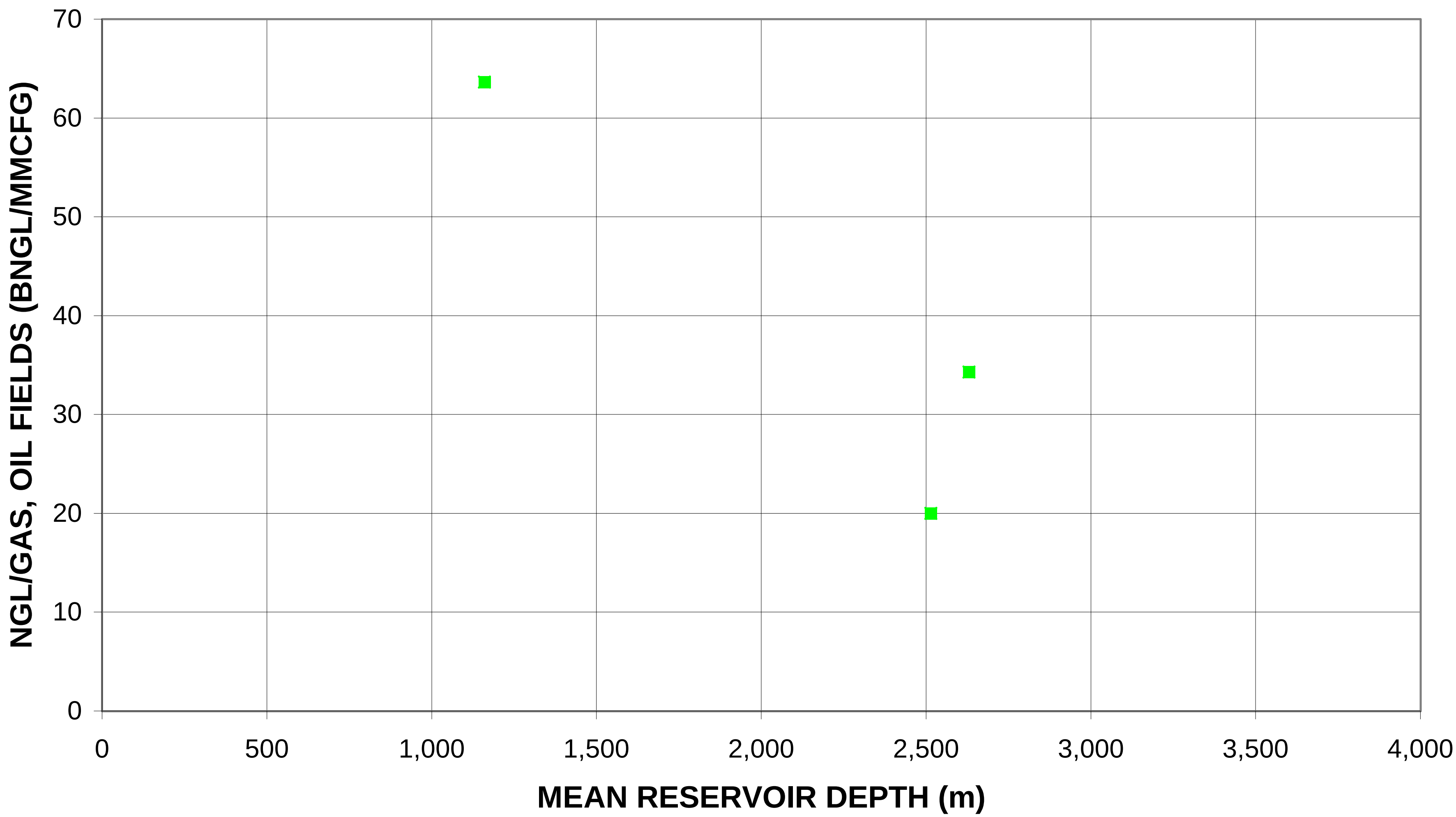



Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
RESERVOIR DEPTH, OIL FIELDS (m)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
0
20
40
60
80
100
120
140
160
180
CUM. NEW-FIELD WILDCAT WELLS (No.)

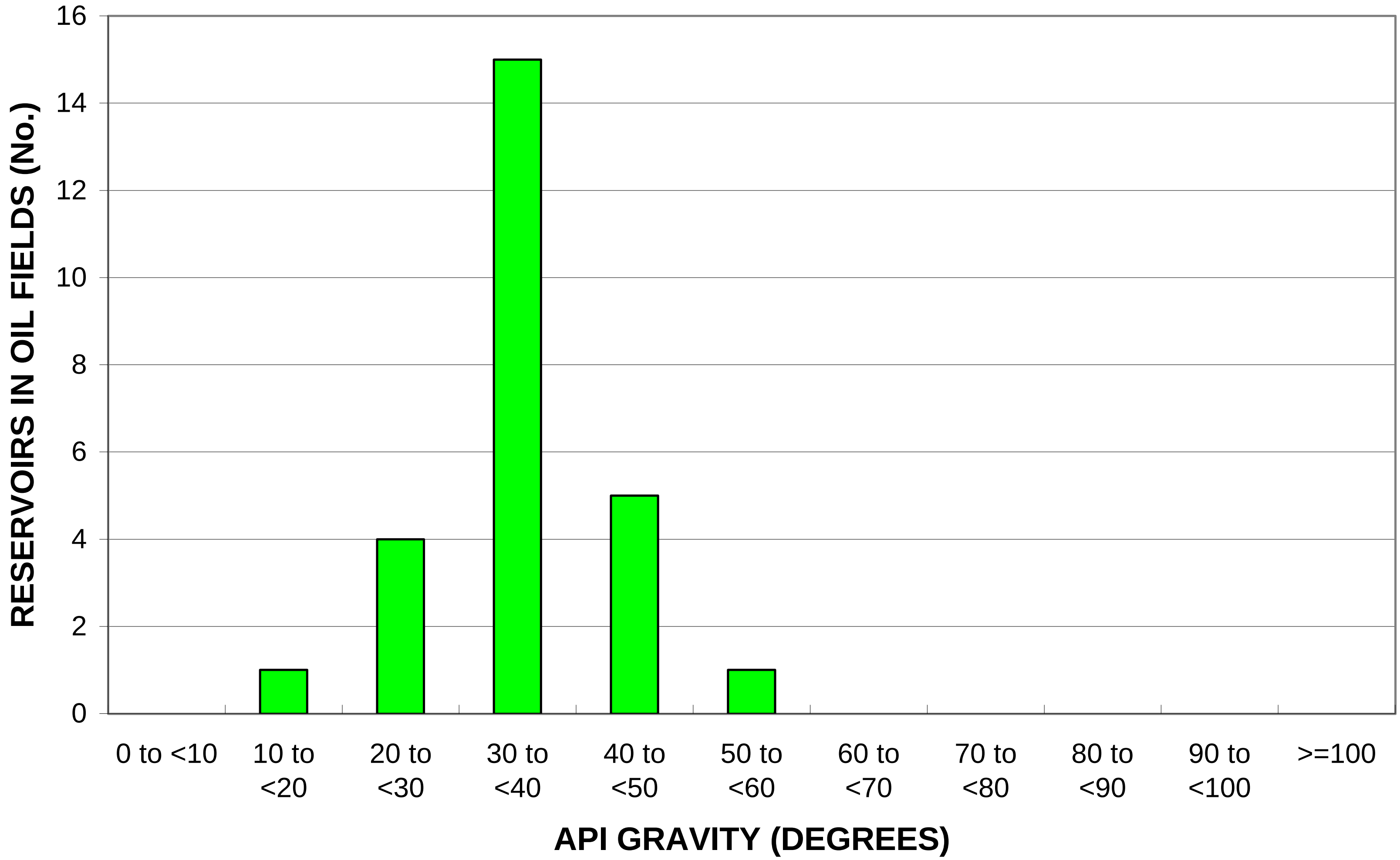
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



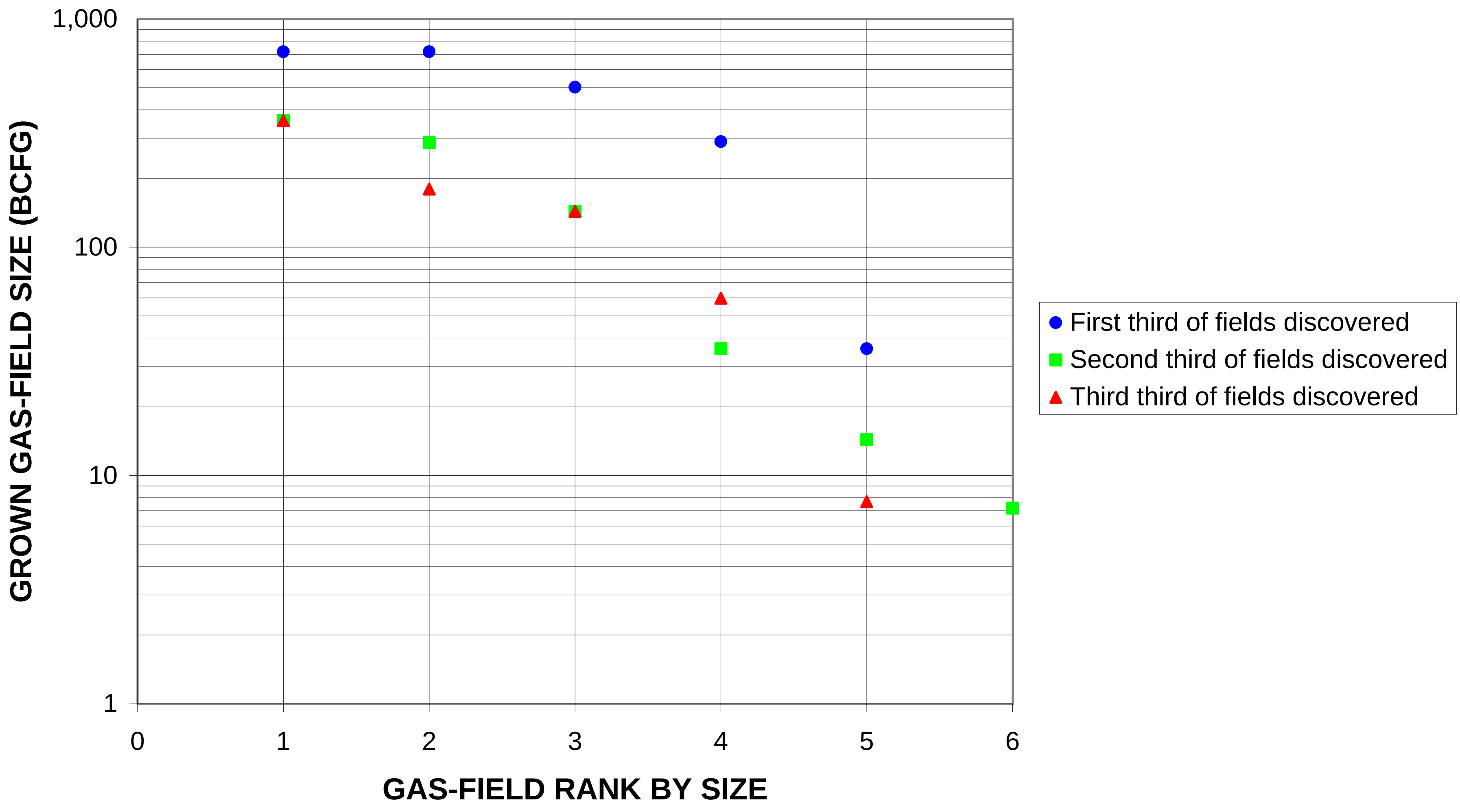
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

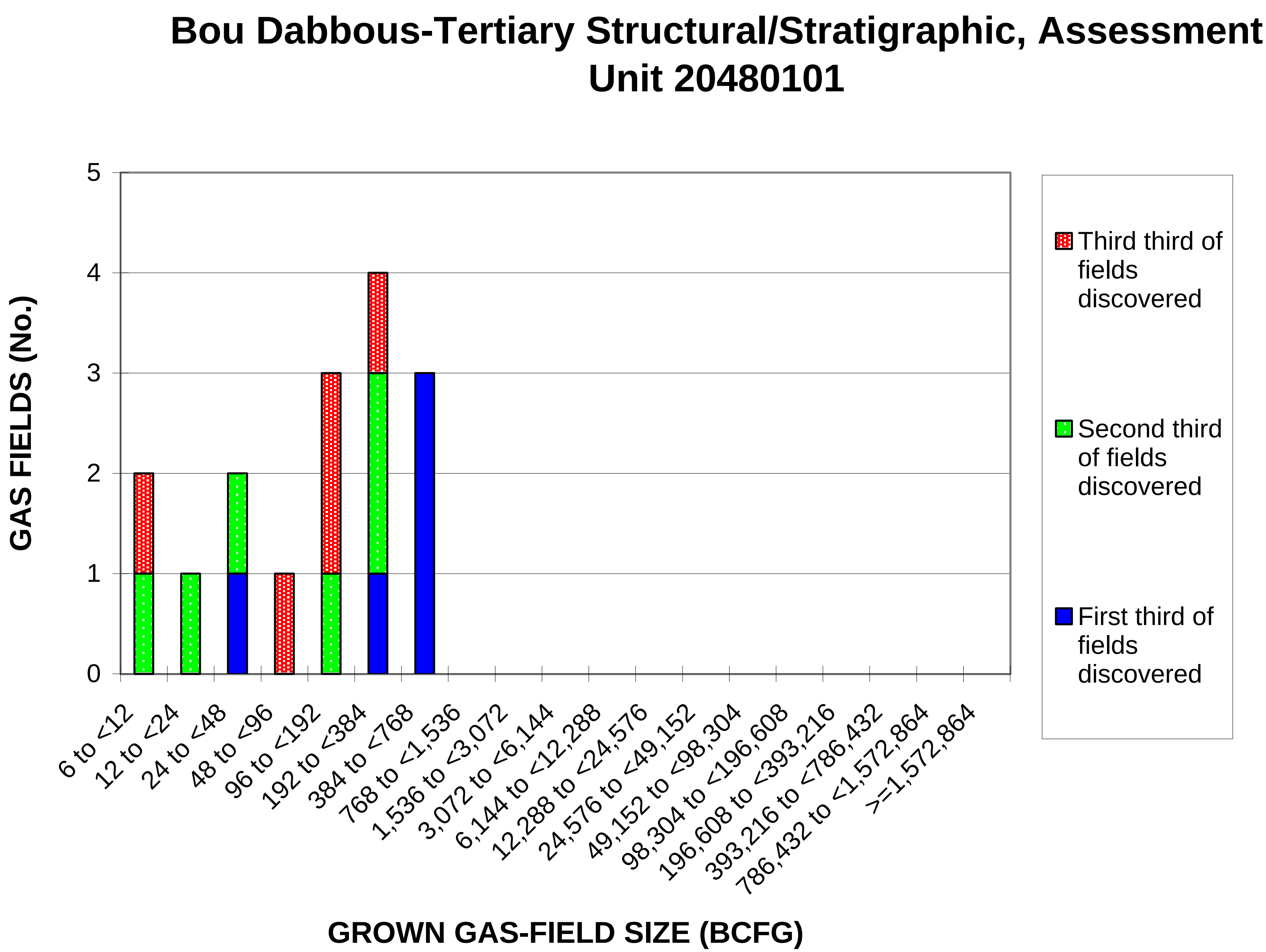


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

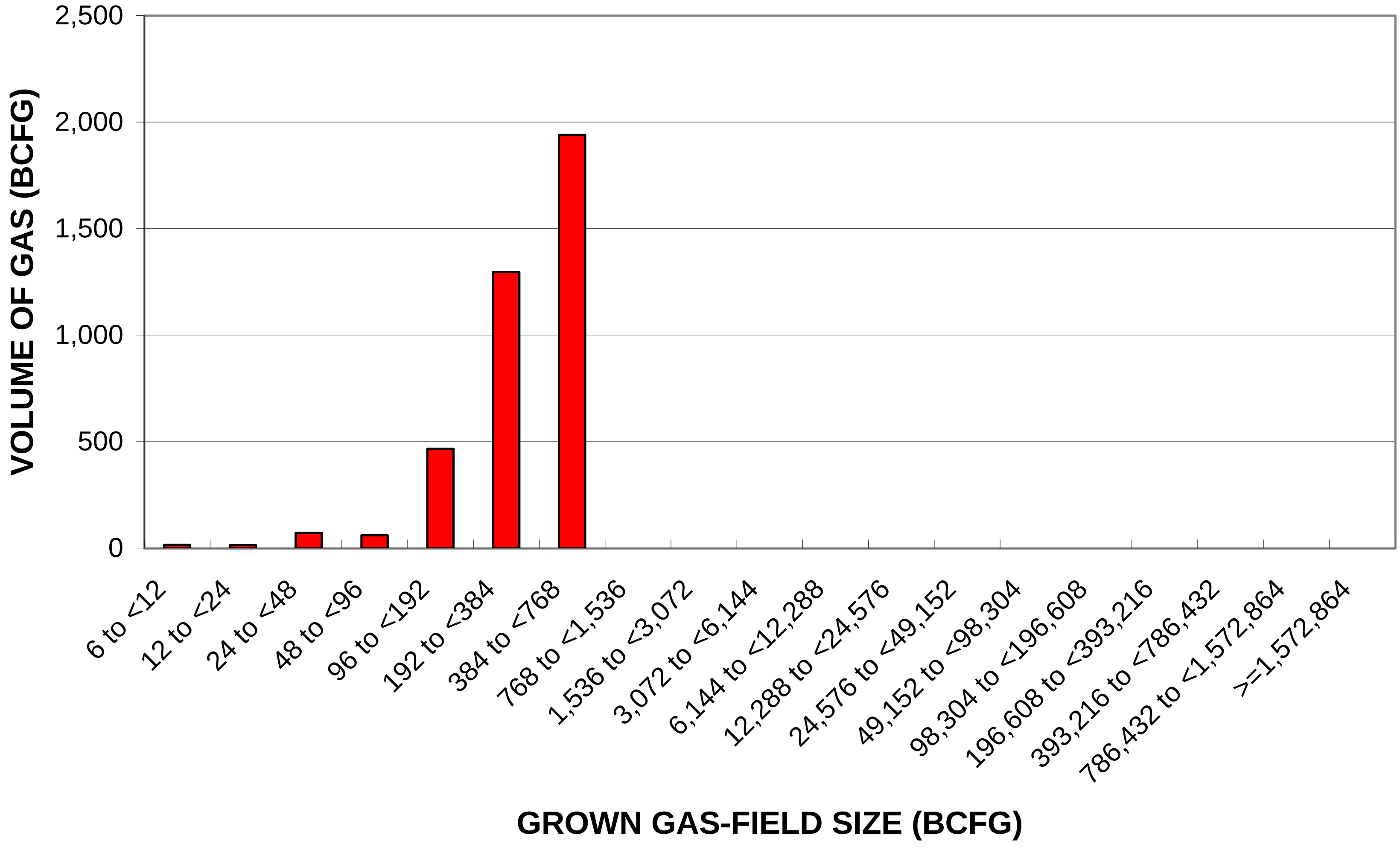


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

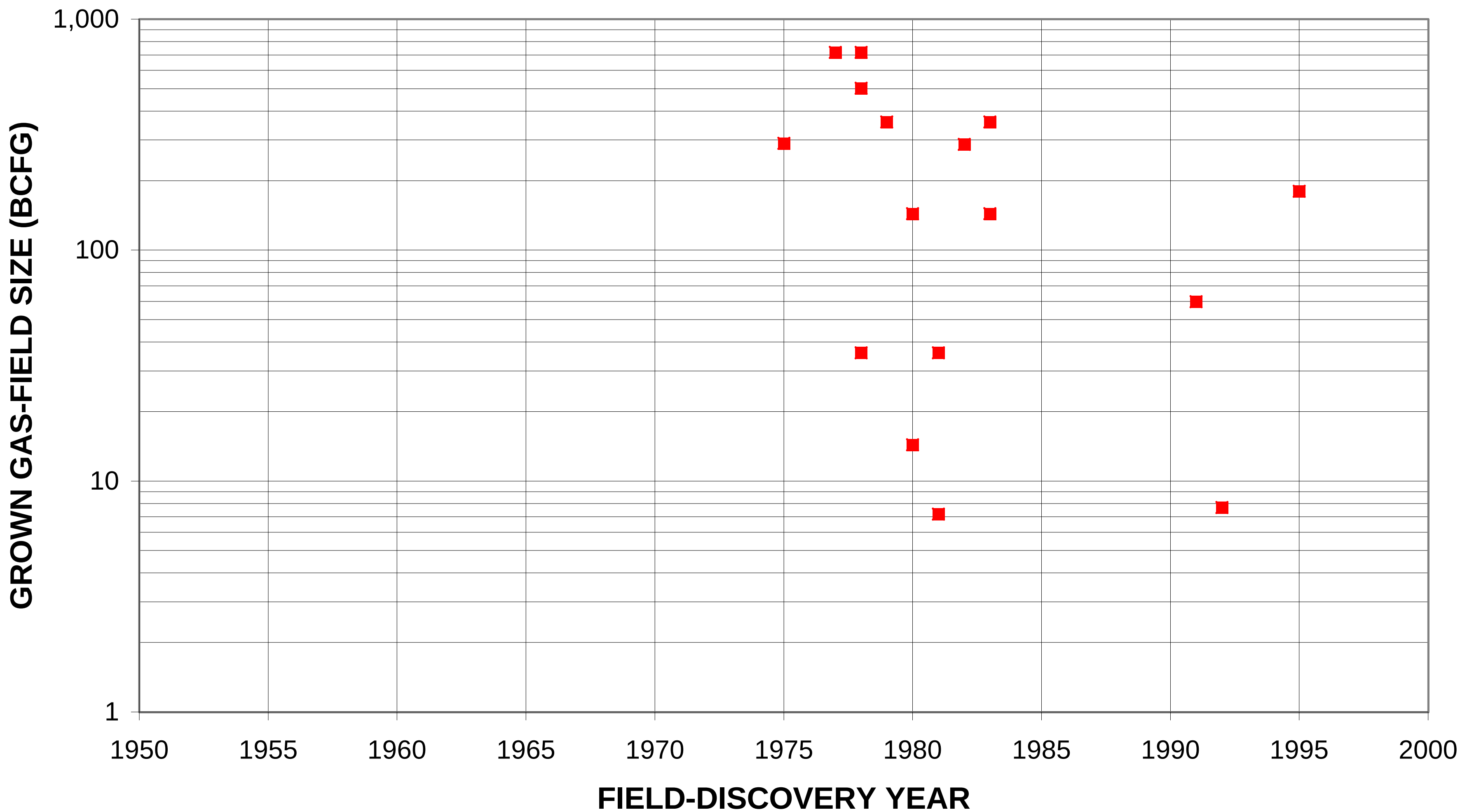



Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
GAS FIELDS (No.)
0
1
2
3
4
5
6 to <12
12 to <24
24 to <48
48 to <96
96 to <192
192 to <384
384 to <768
768 to <1,536
1,536 to <3,072
3,072 to <6,144
6,144 to <12,288
12,288 to <24,576
24,576 to <49,152
49,152 to <98,304
98,304 to <196,608
196,608 to <393,216
393,216 to <786,432
786,432 to <1,572,864
>=1,572,864
GROWN GAS-FIELD SIZE (BCFG)
Third third of fields discovered
Second third of fields discovered
First third of fields discovered

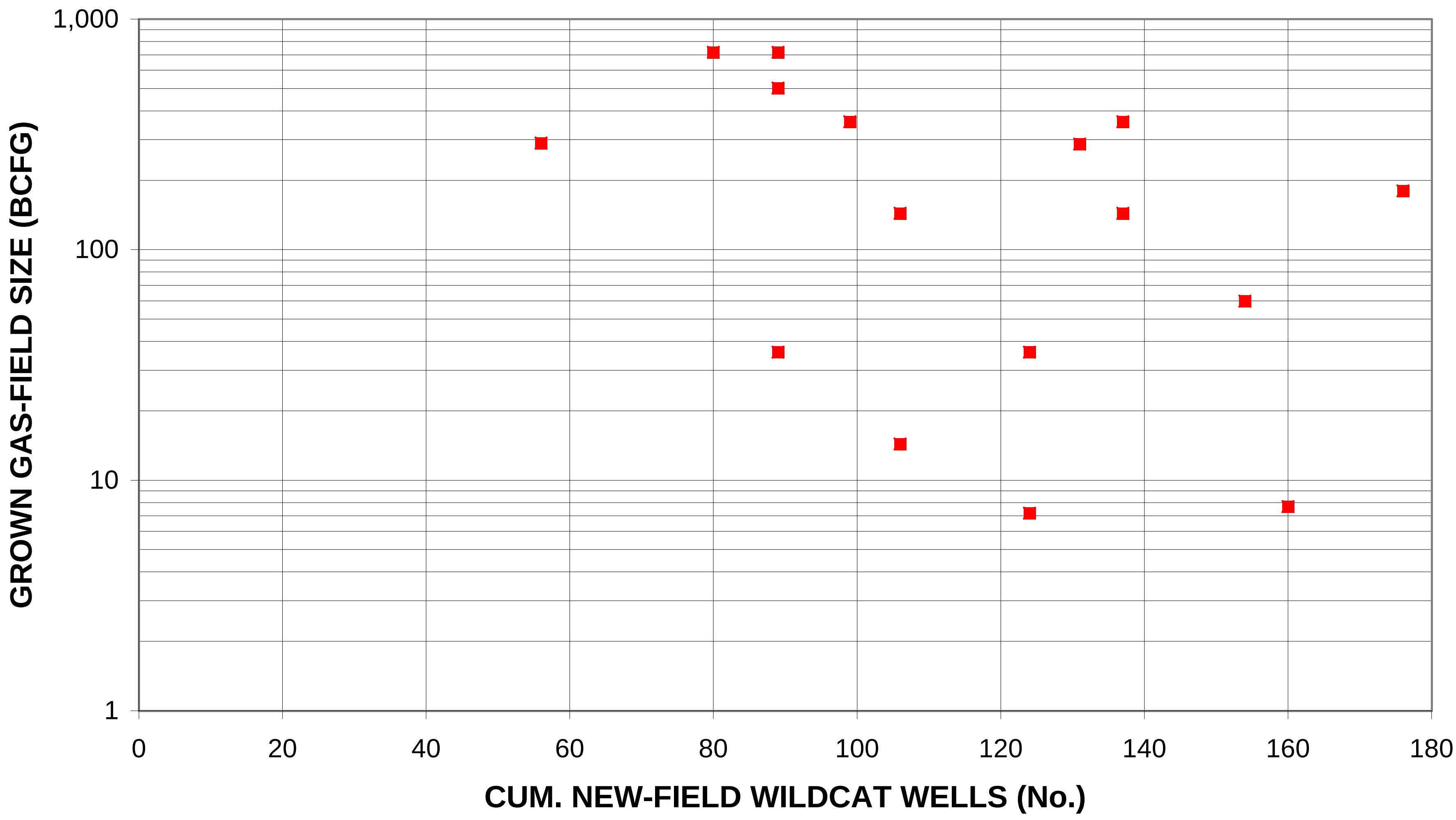
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



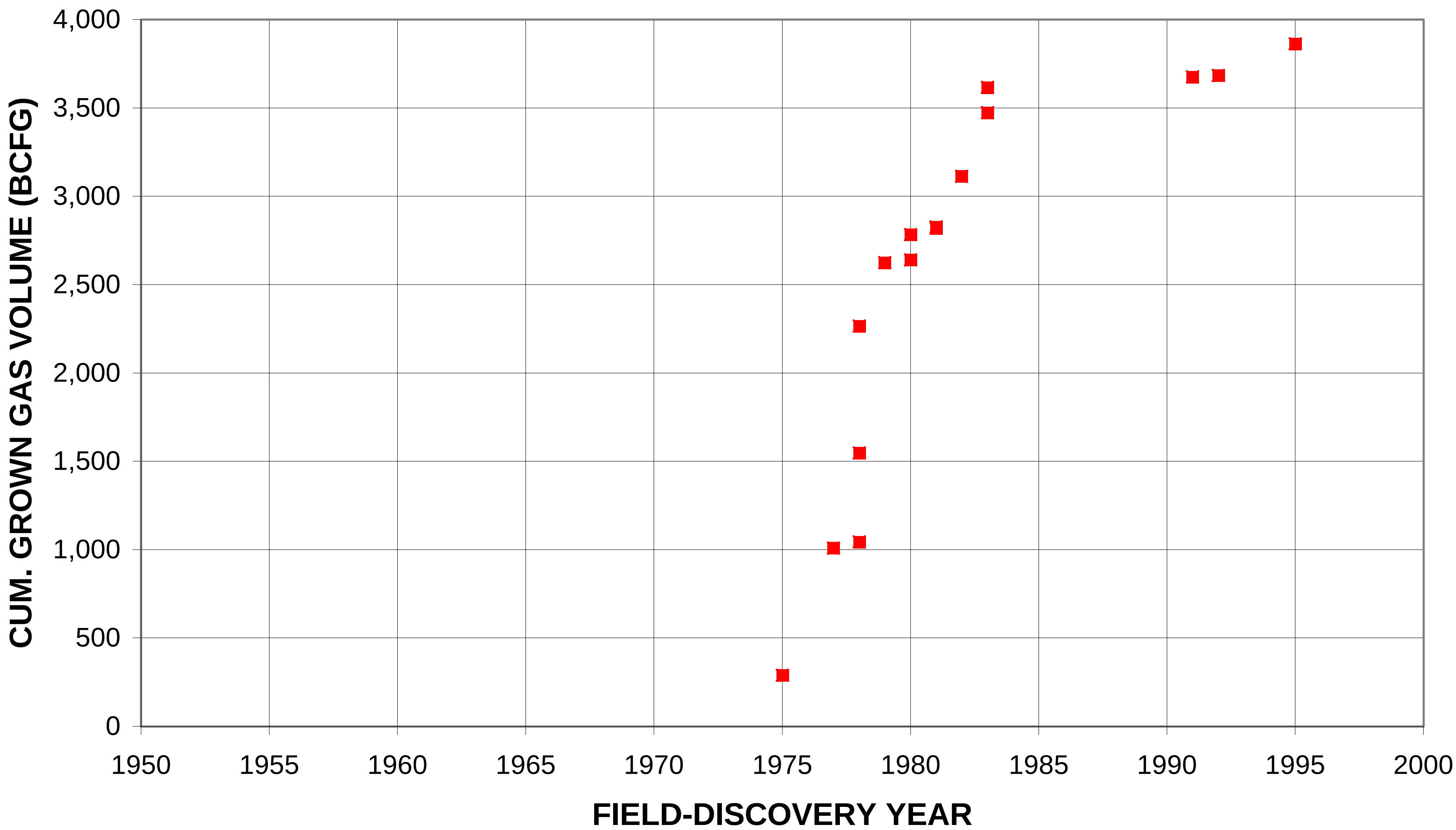
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



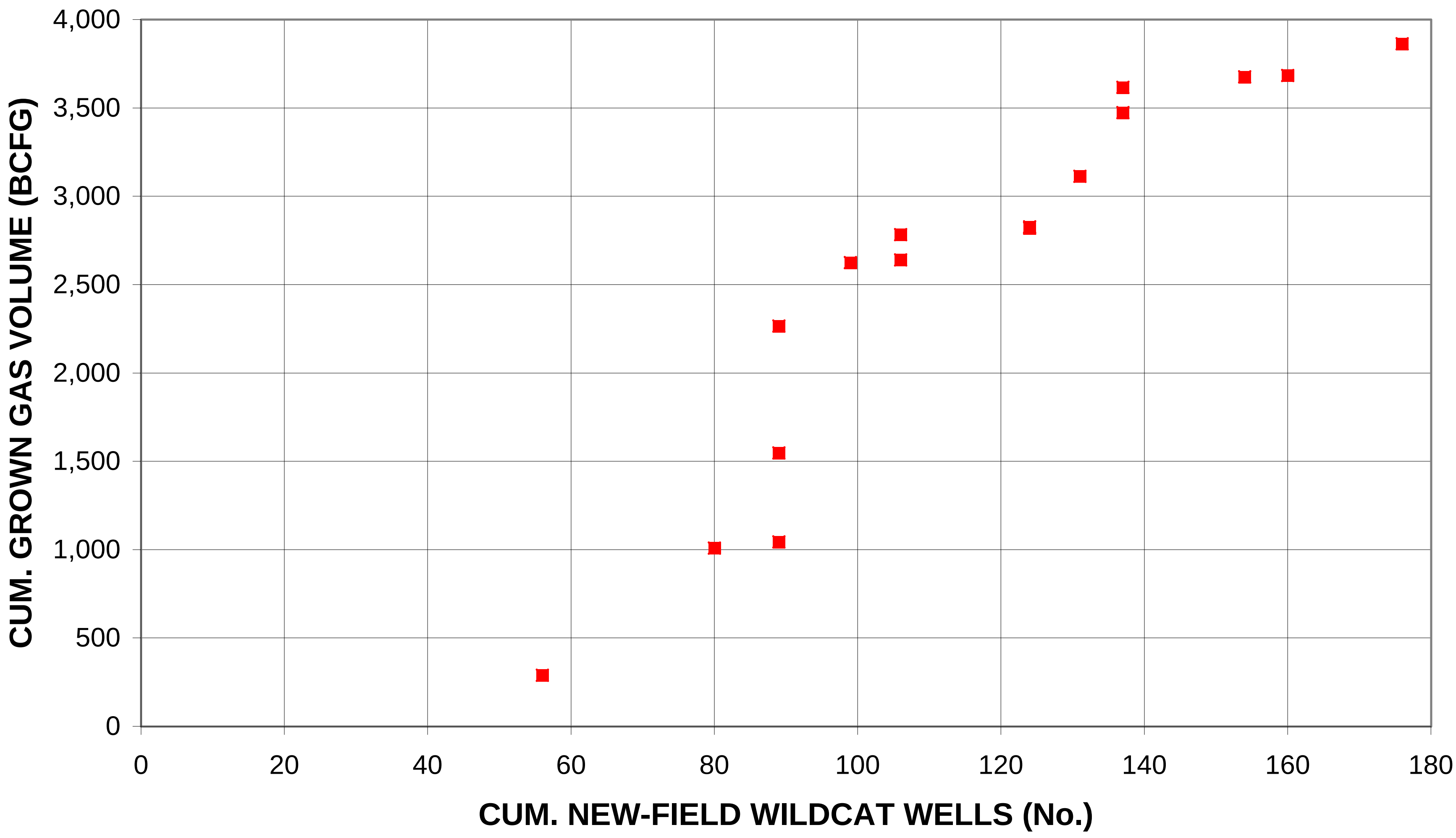
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



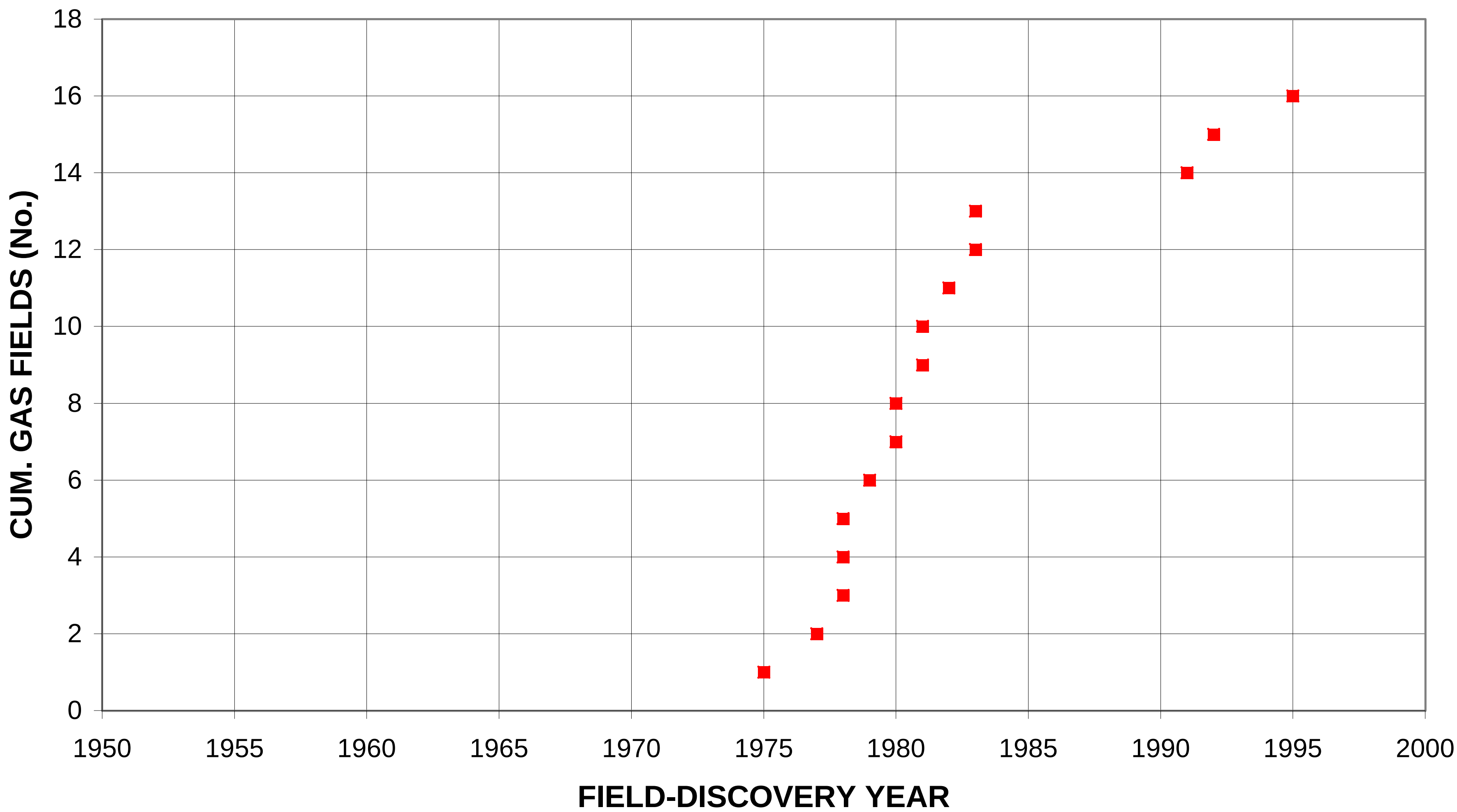
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101



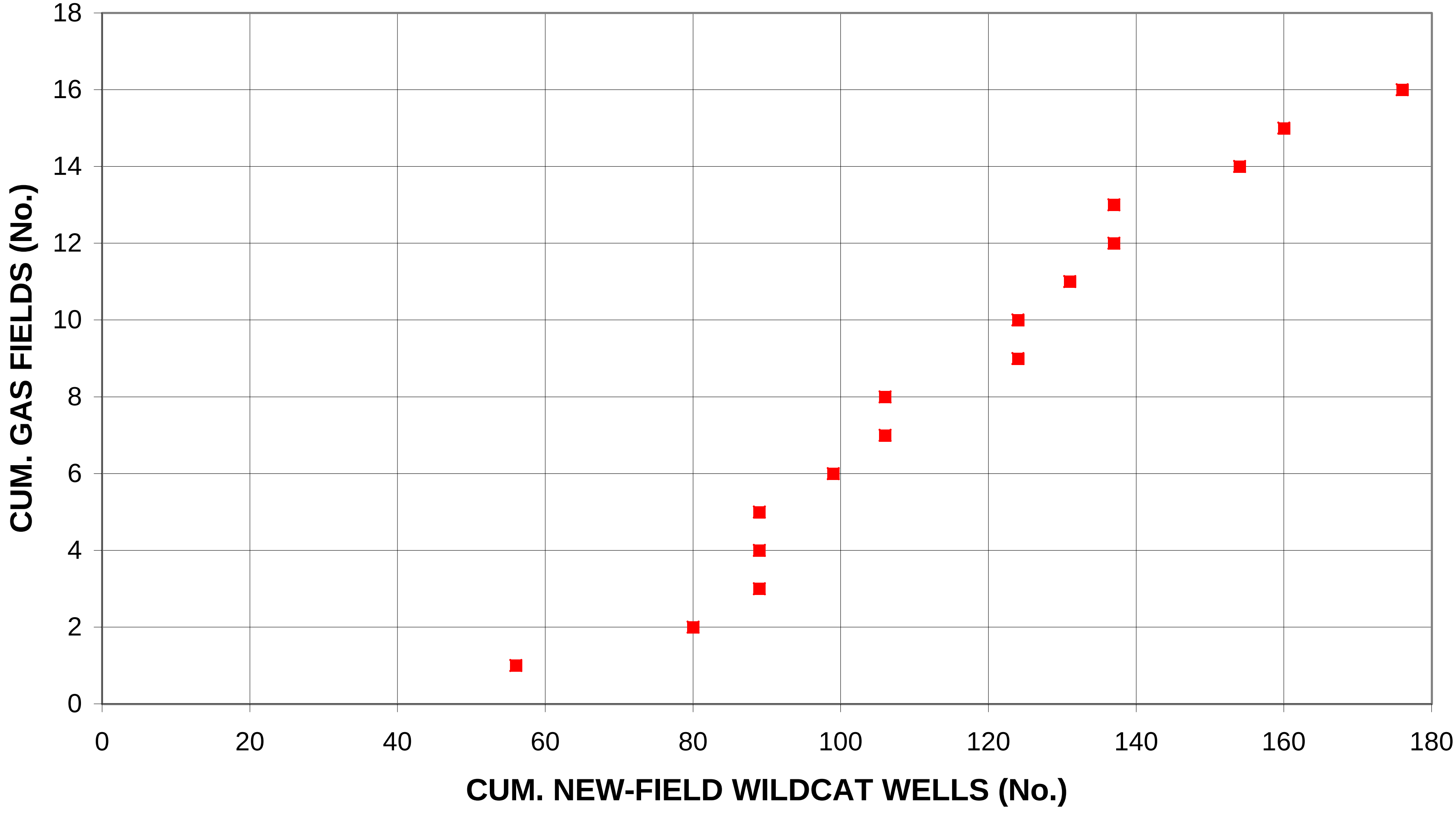
Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

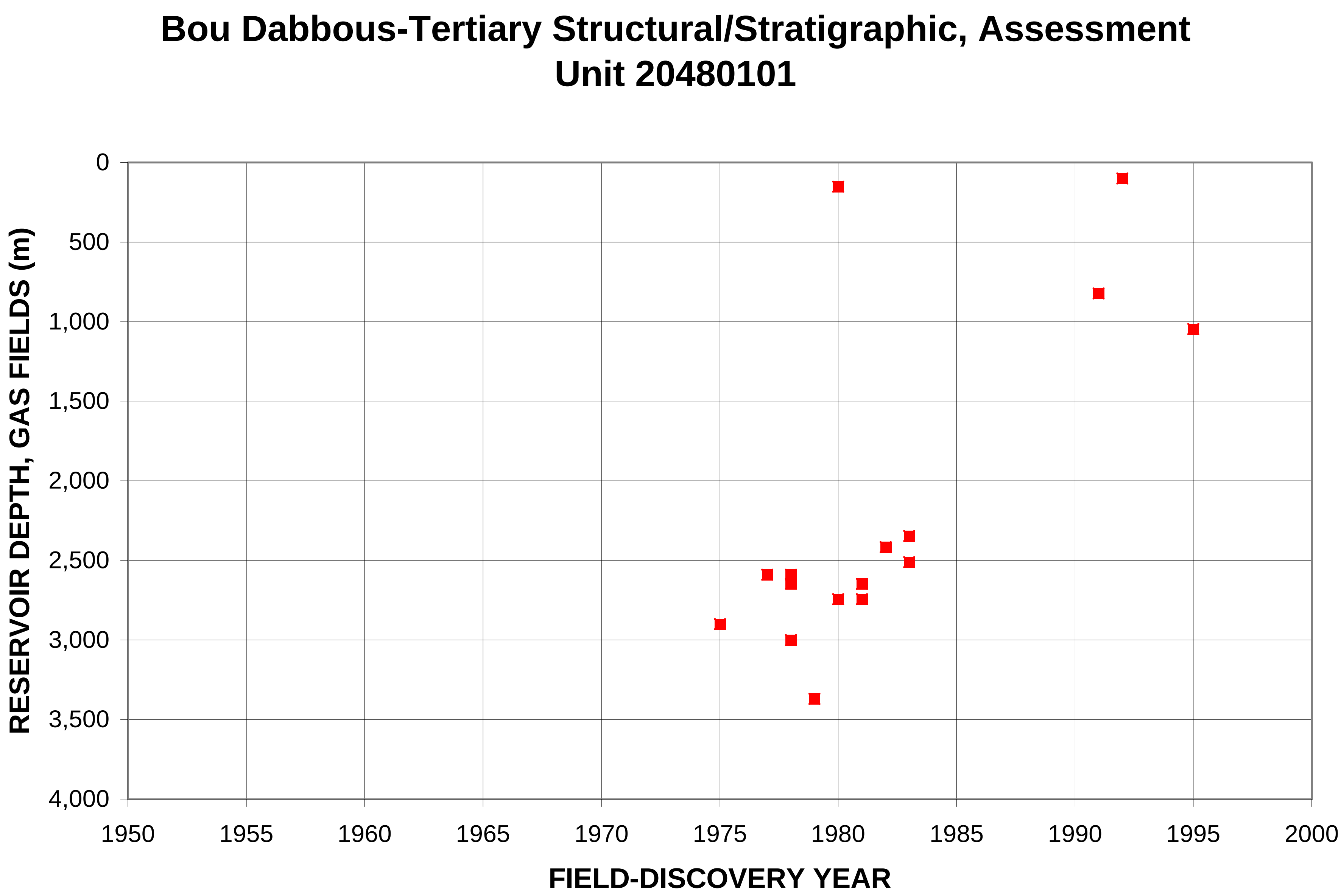


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

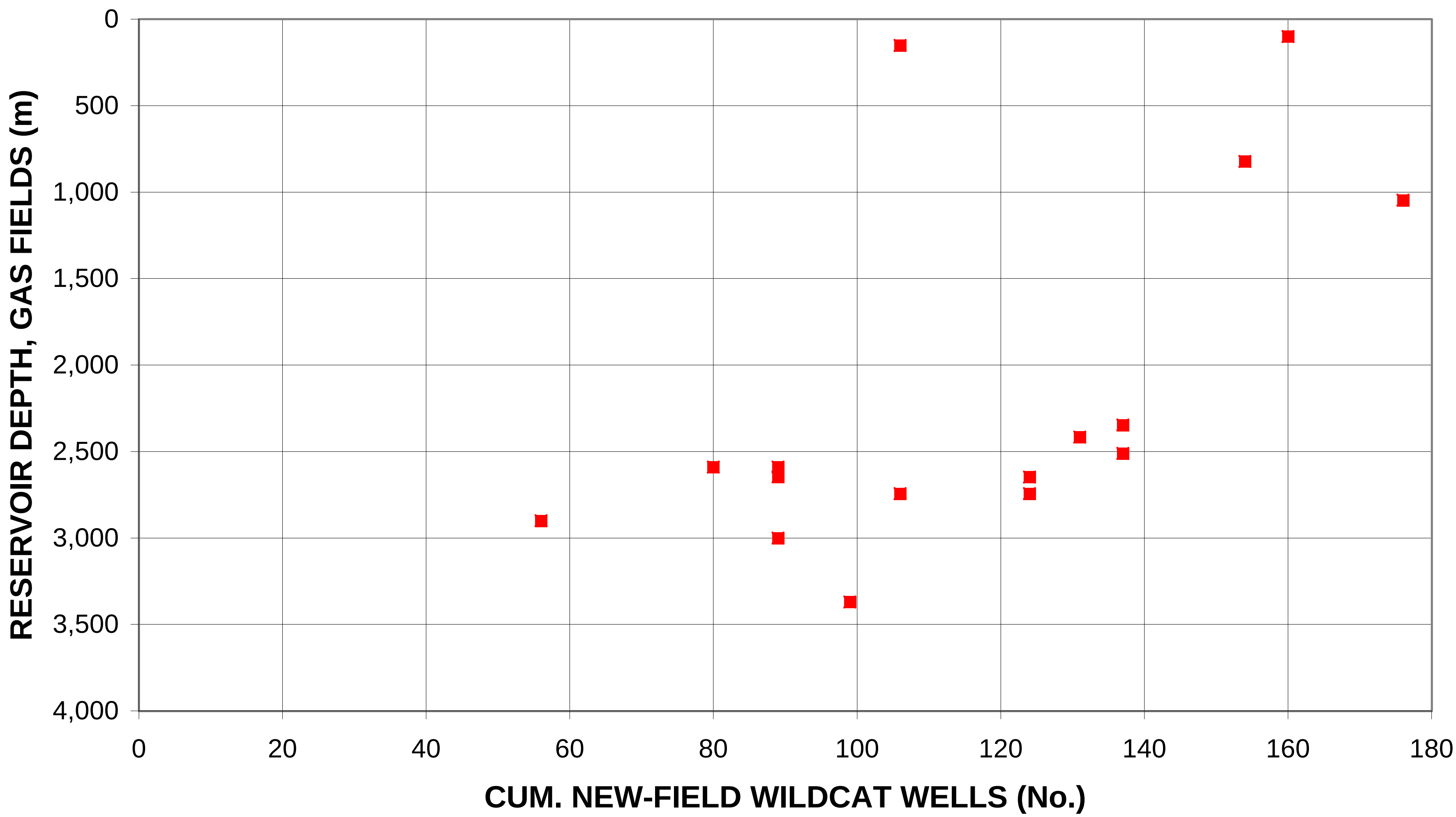


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

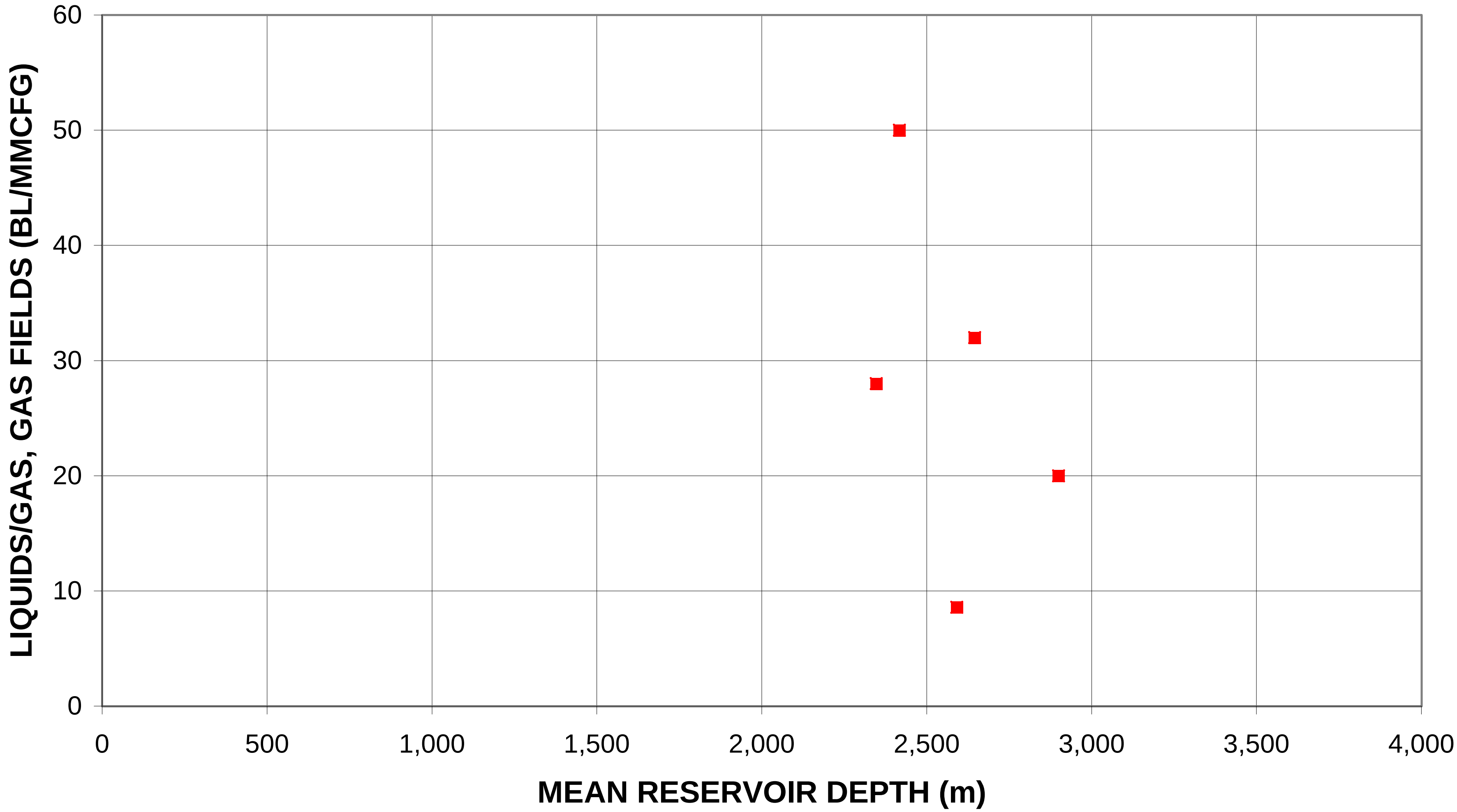



Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101
RESERVOIR DEPTH, GAS FIELDS (m)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
FIELD-DISCOVERY YEAR

Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

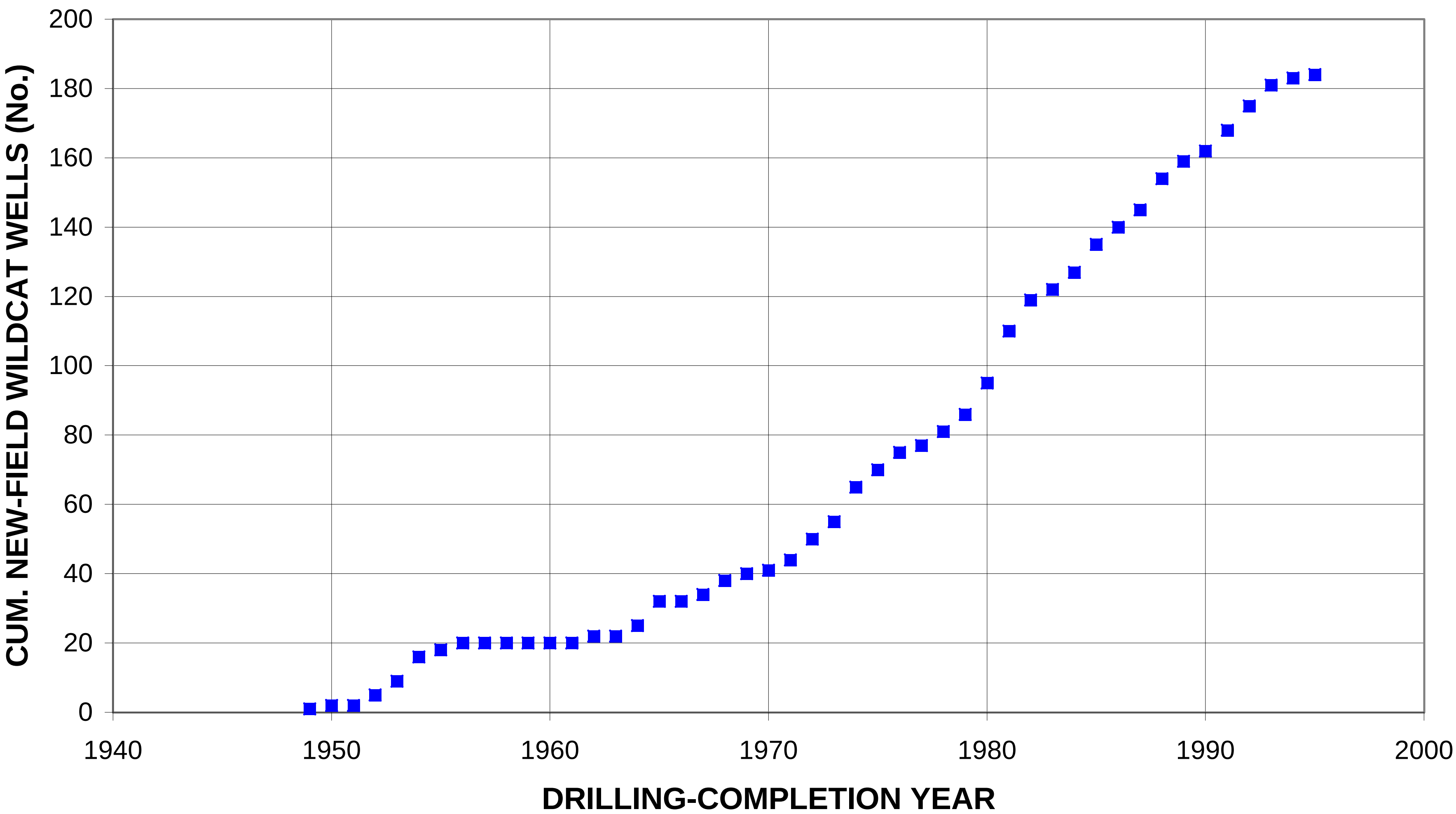


Bou Dabbous-Tertiary Structural/Stratigraphic, Assessment Unit 20480101

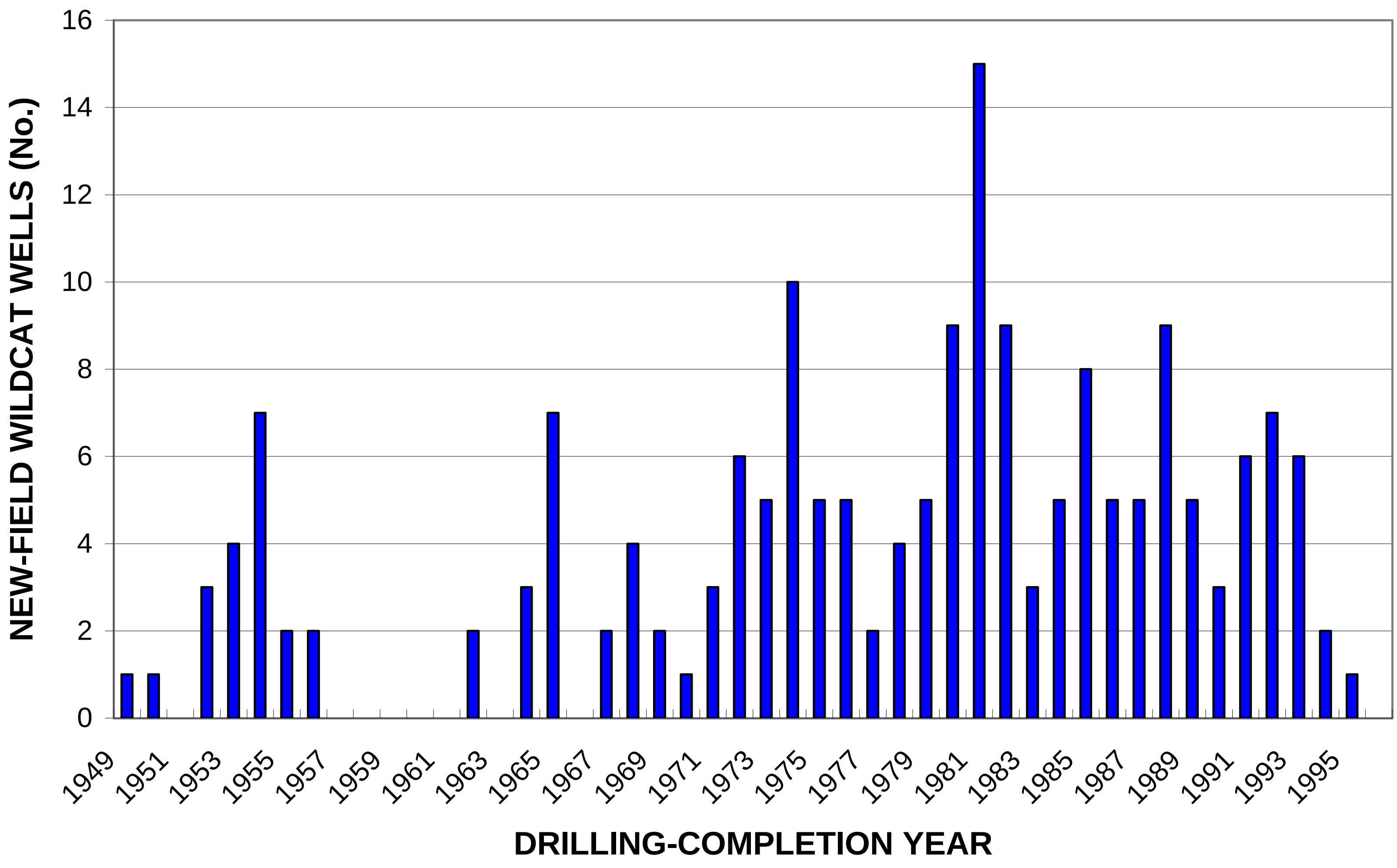


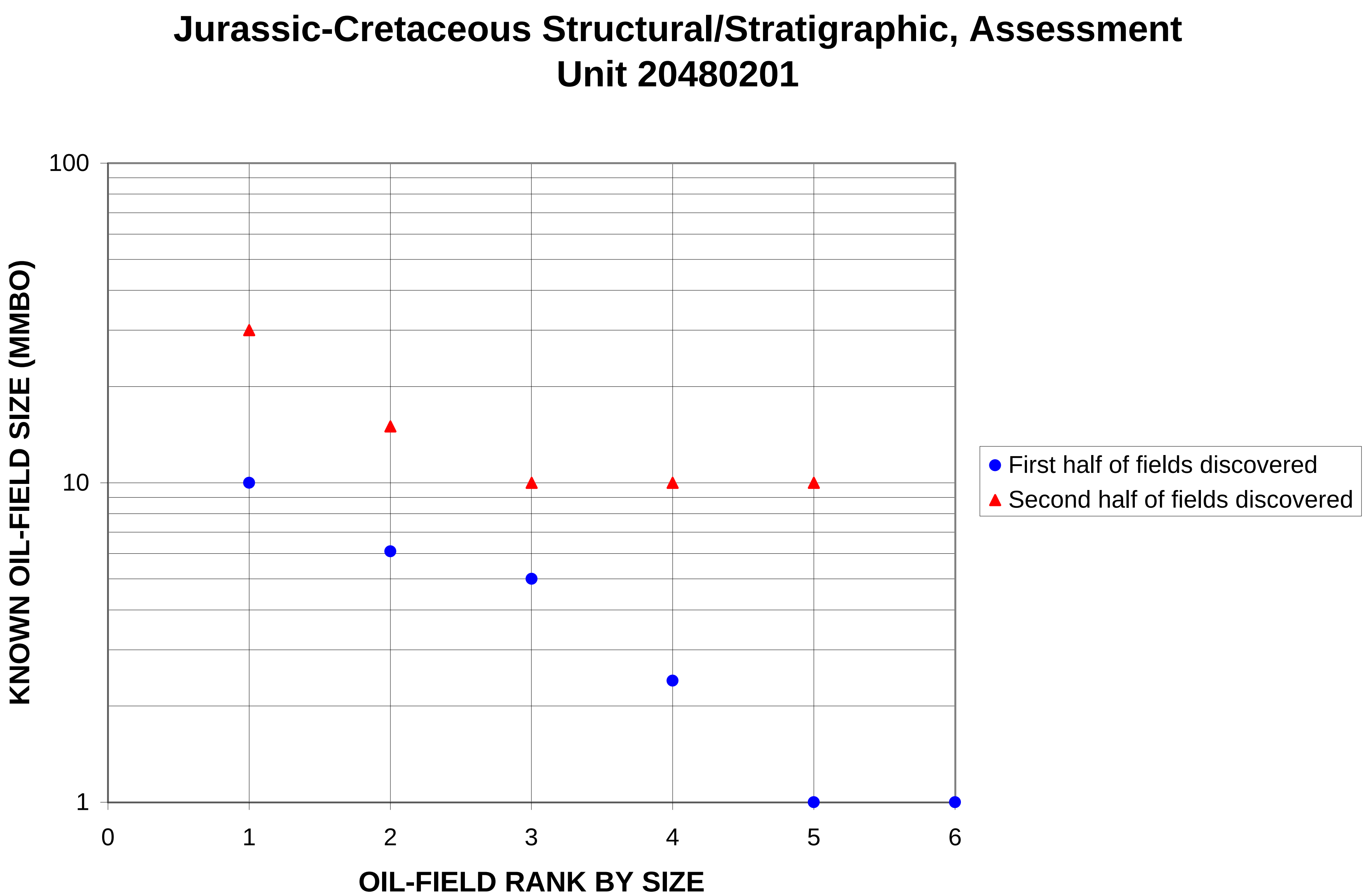
Appendix 2. Exploration-activity and discovery-history plots for the Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit (20480201). *A*. Plots of known oil and gas volumes.

Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

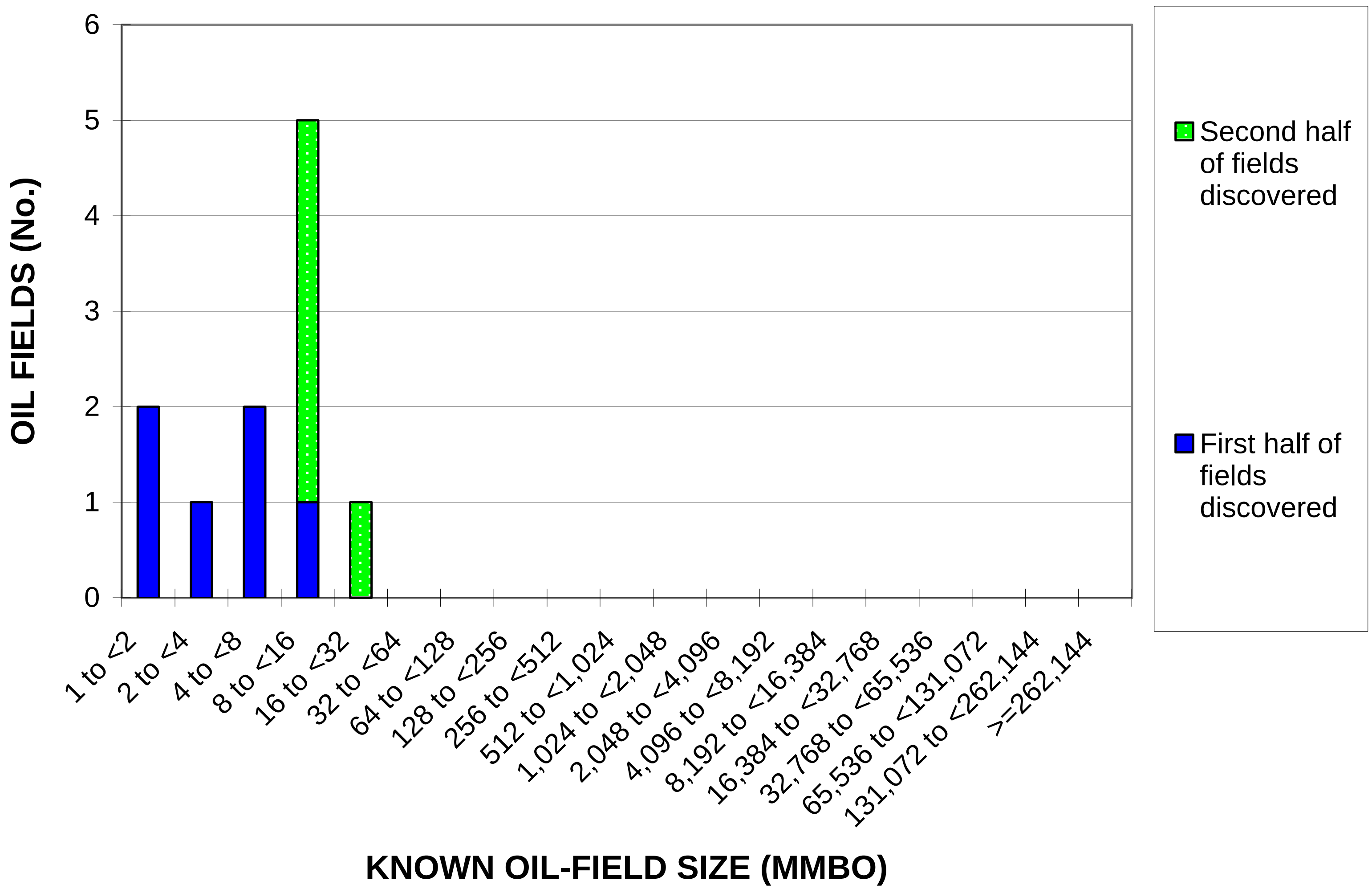


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

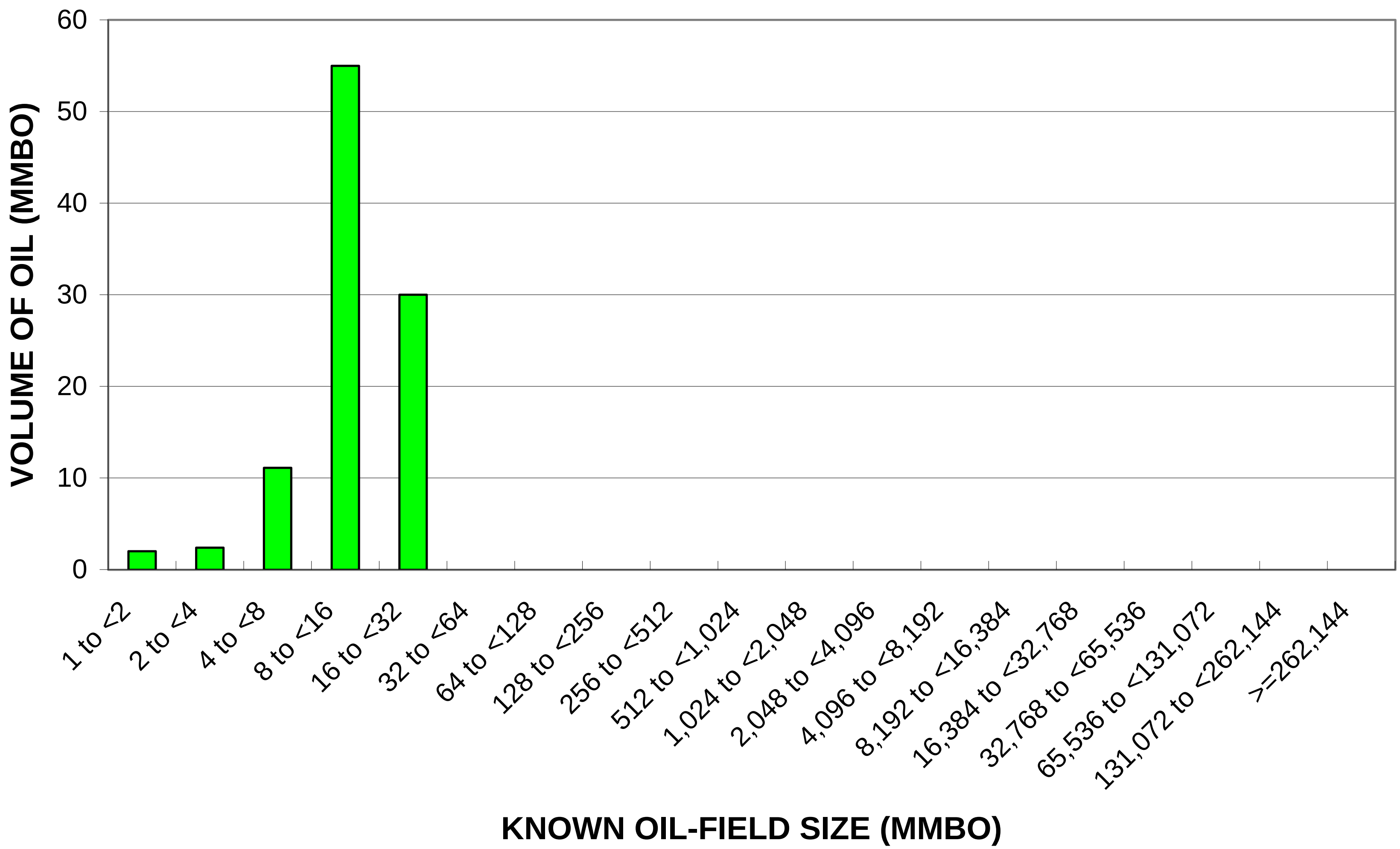



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
KNOWN OIL-FIELD SIZE (MMBO)
100
10
1
0
1
2
3
4
5
6
OIL-FIELD RANK BY SIZE
First half of fields discovered
Second half of fields discovered

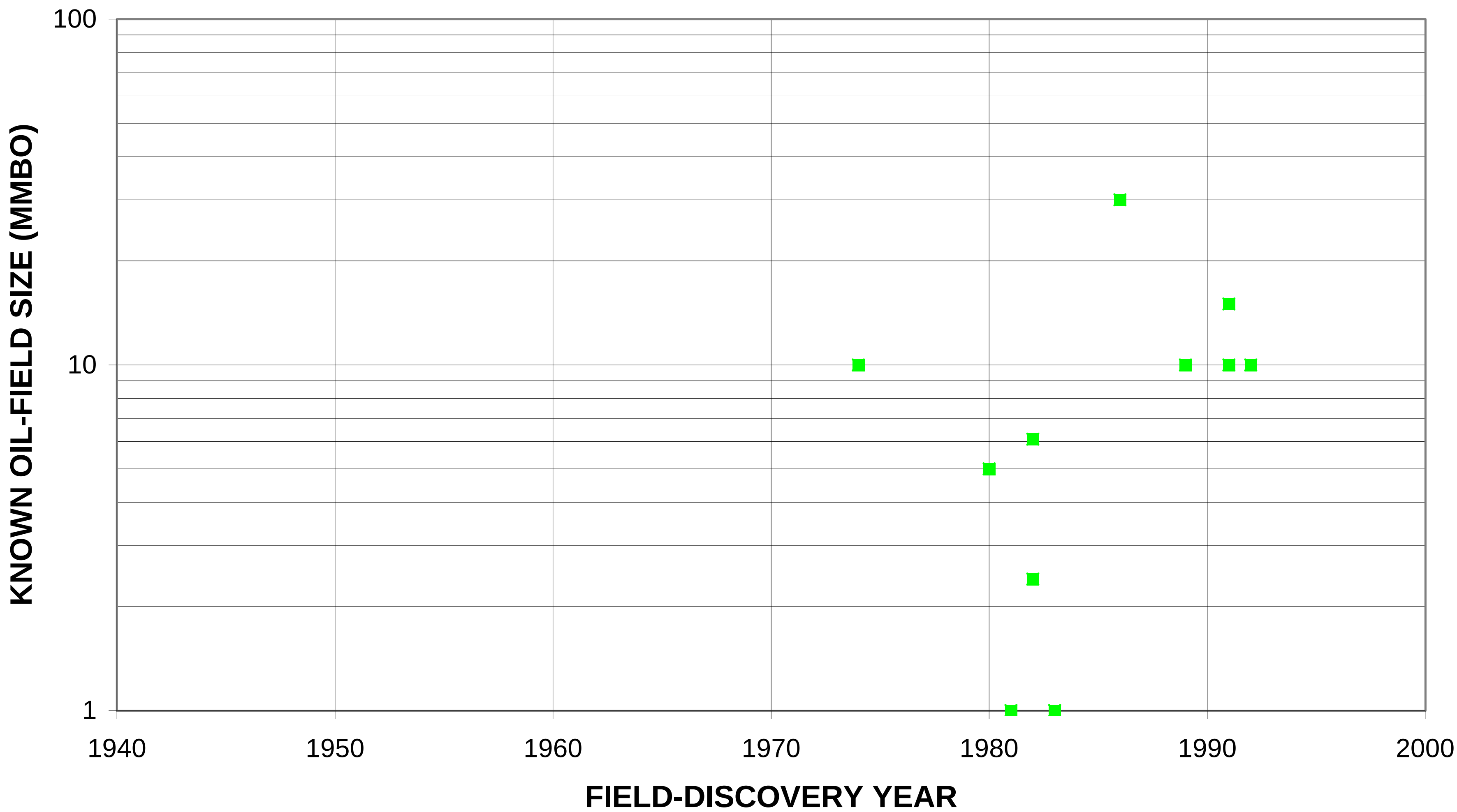
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



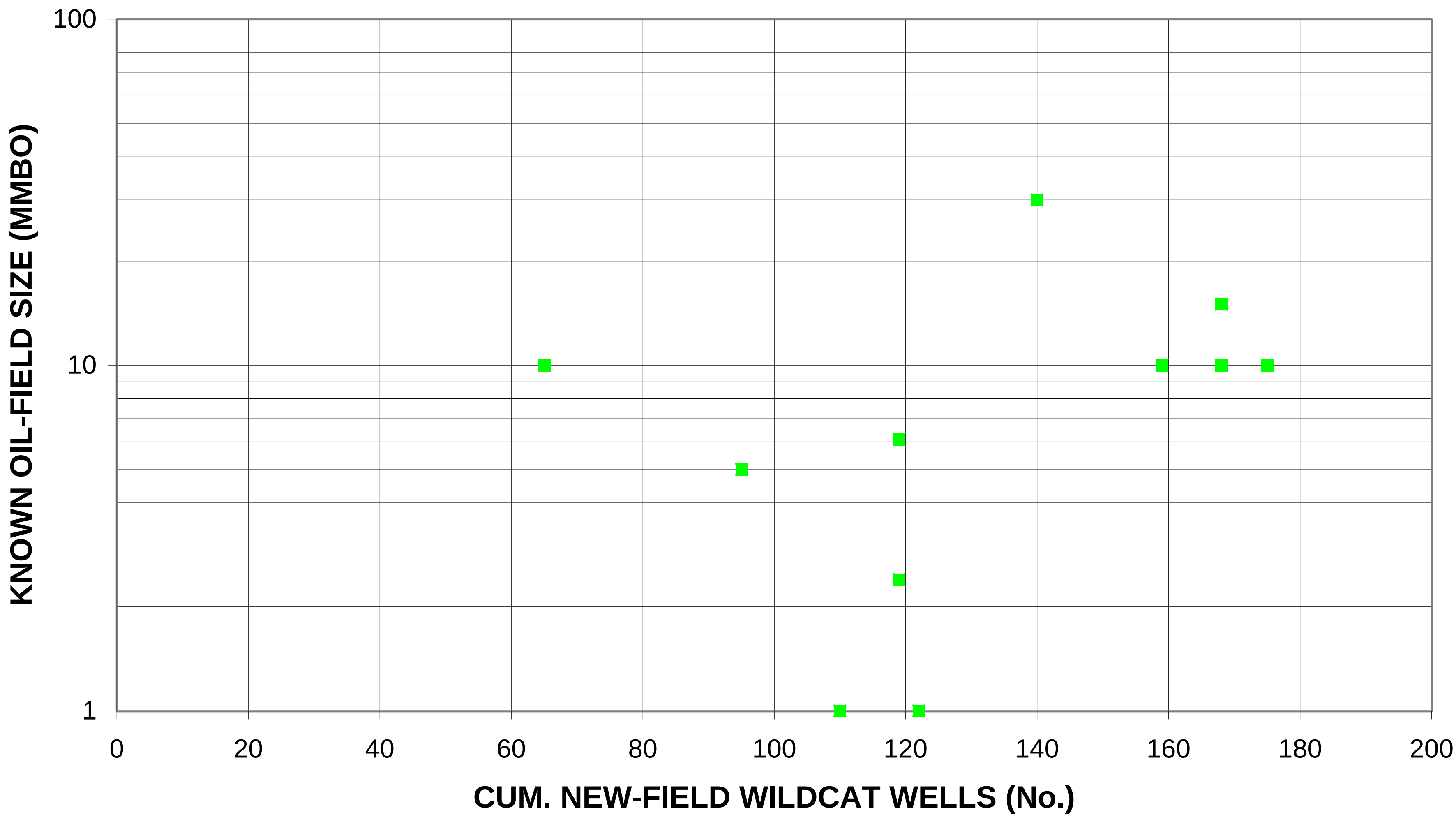
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



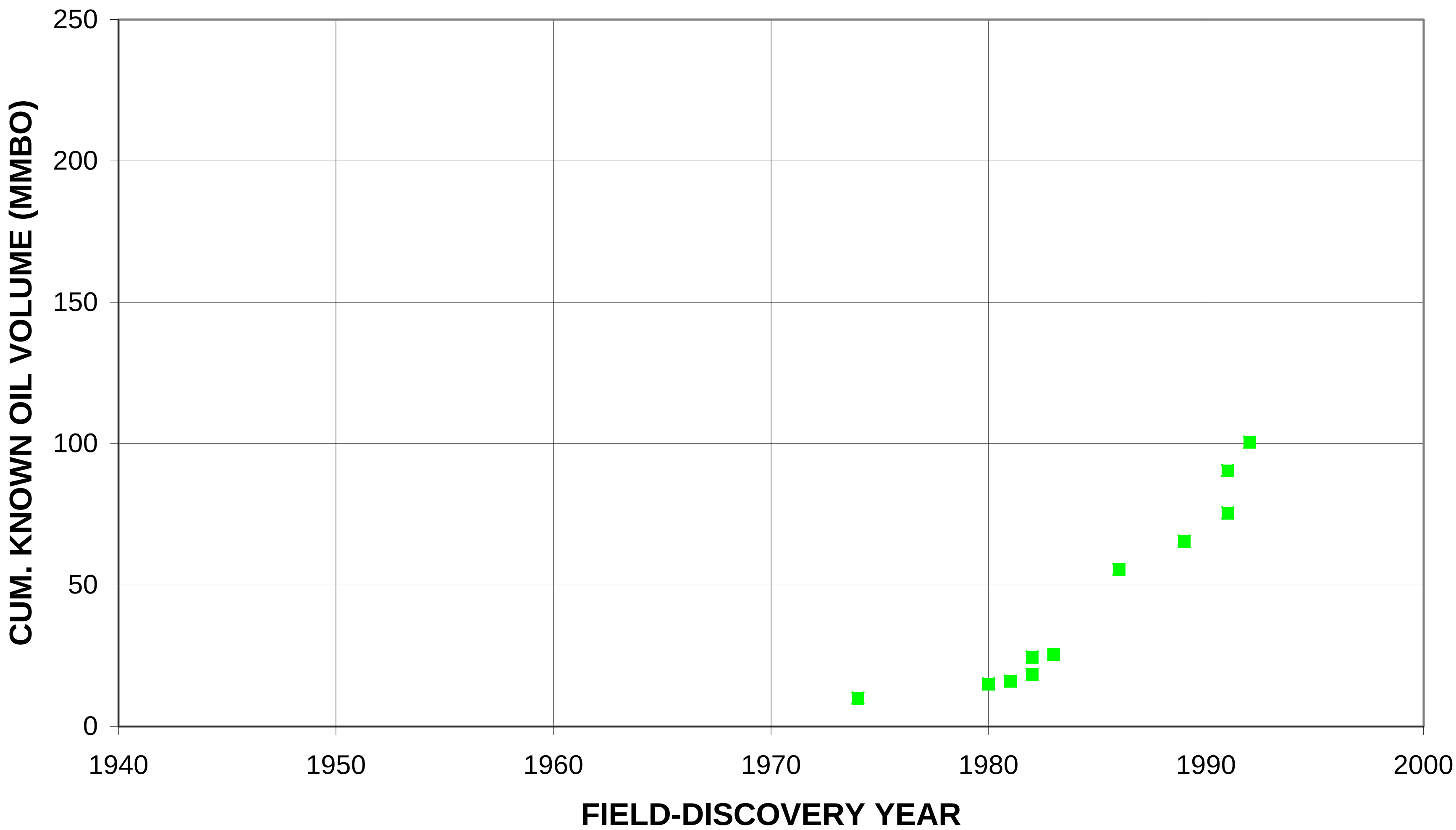
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



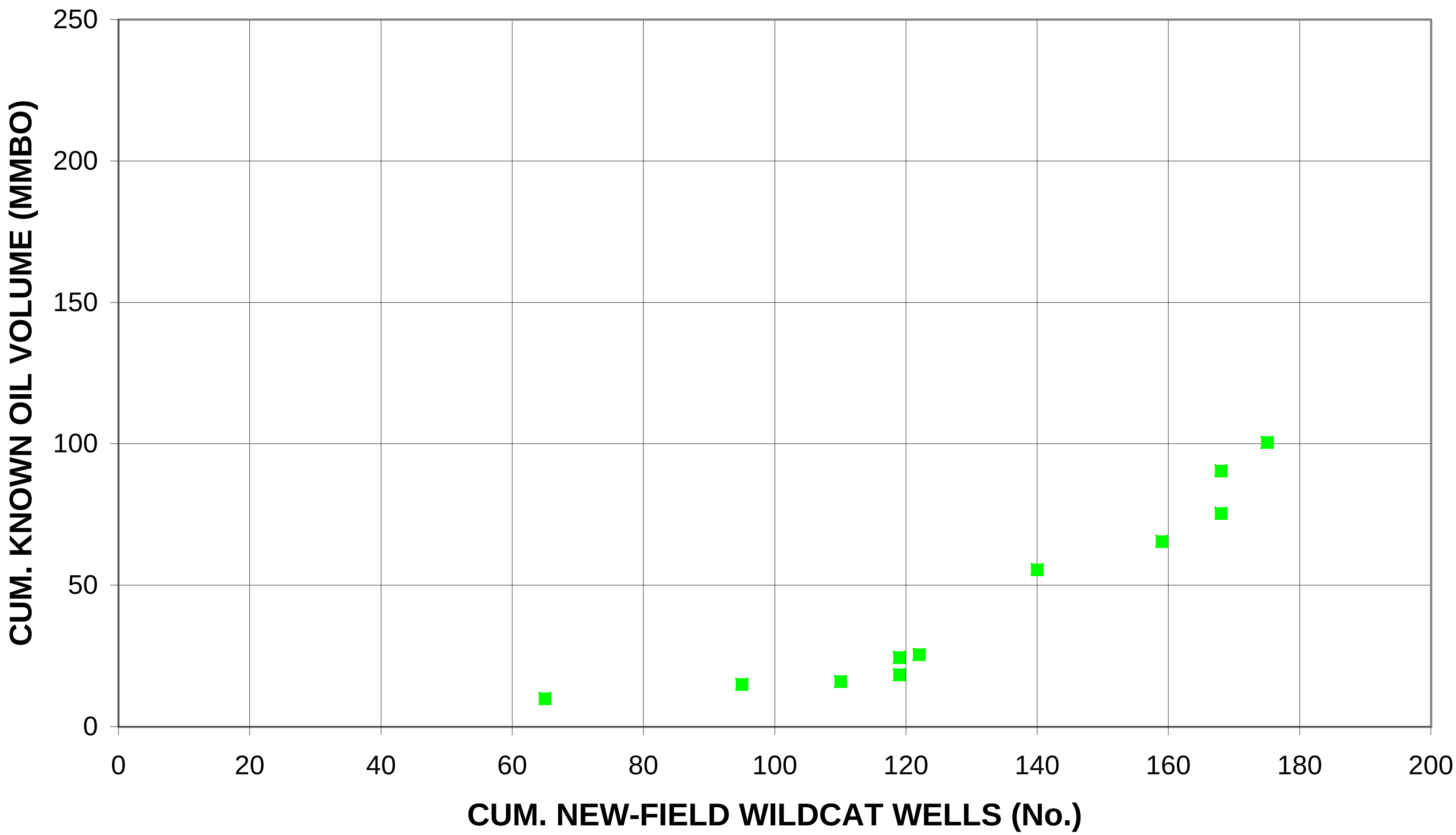
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

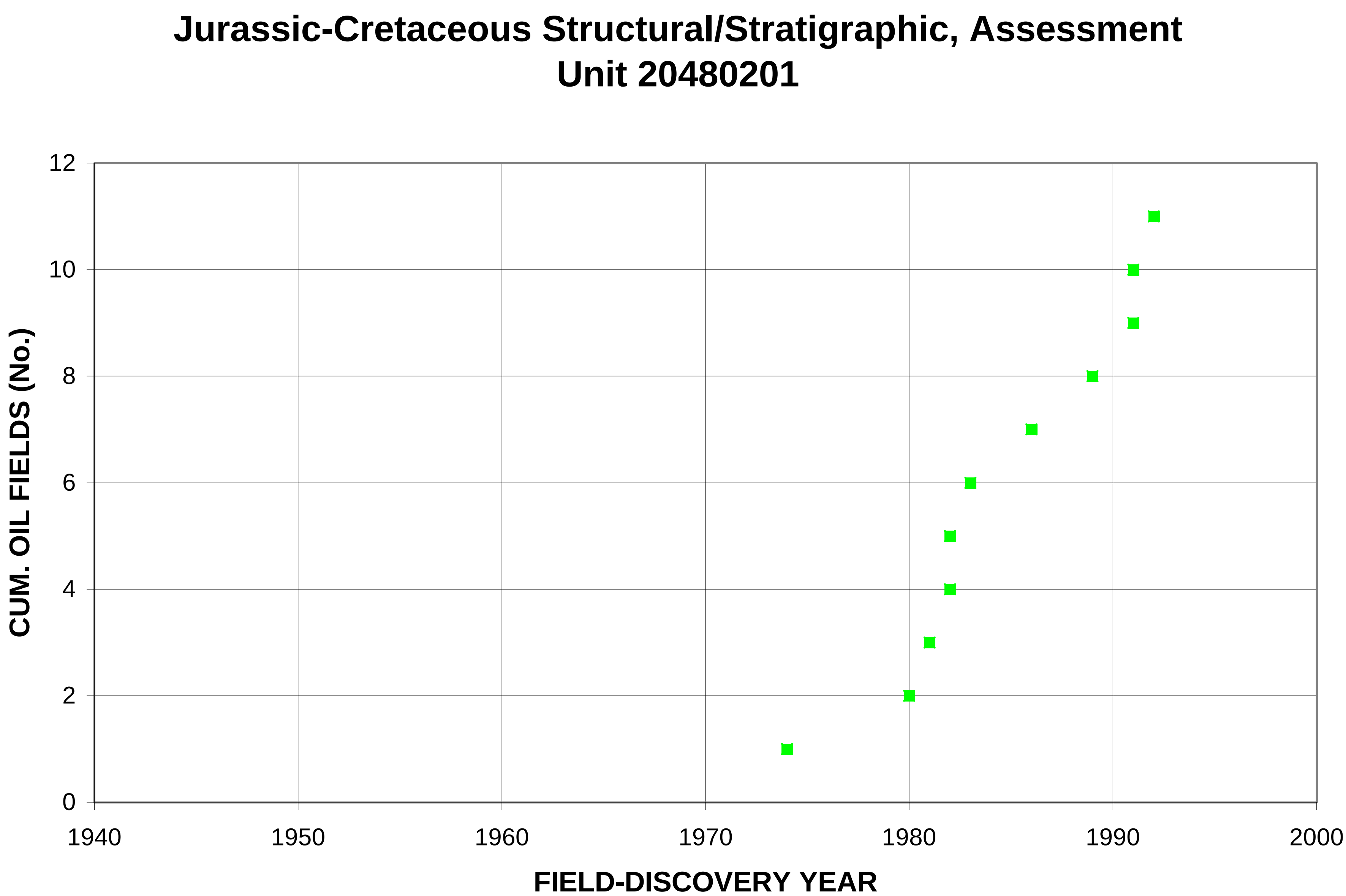


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

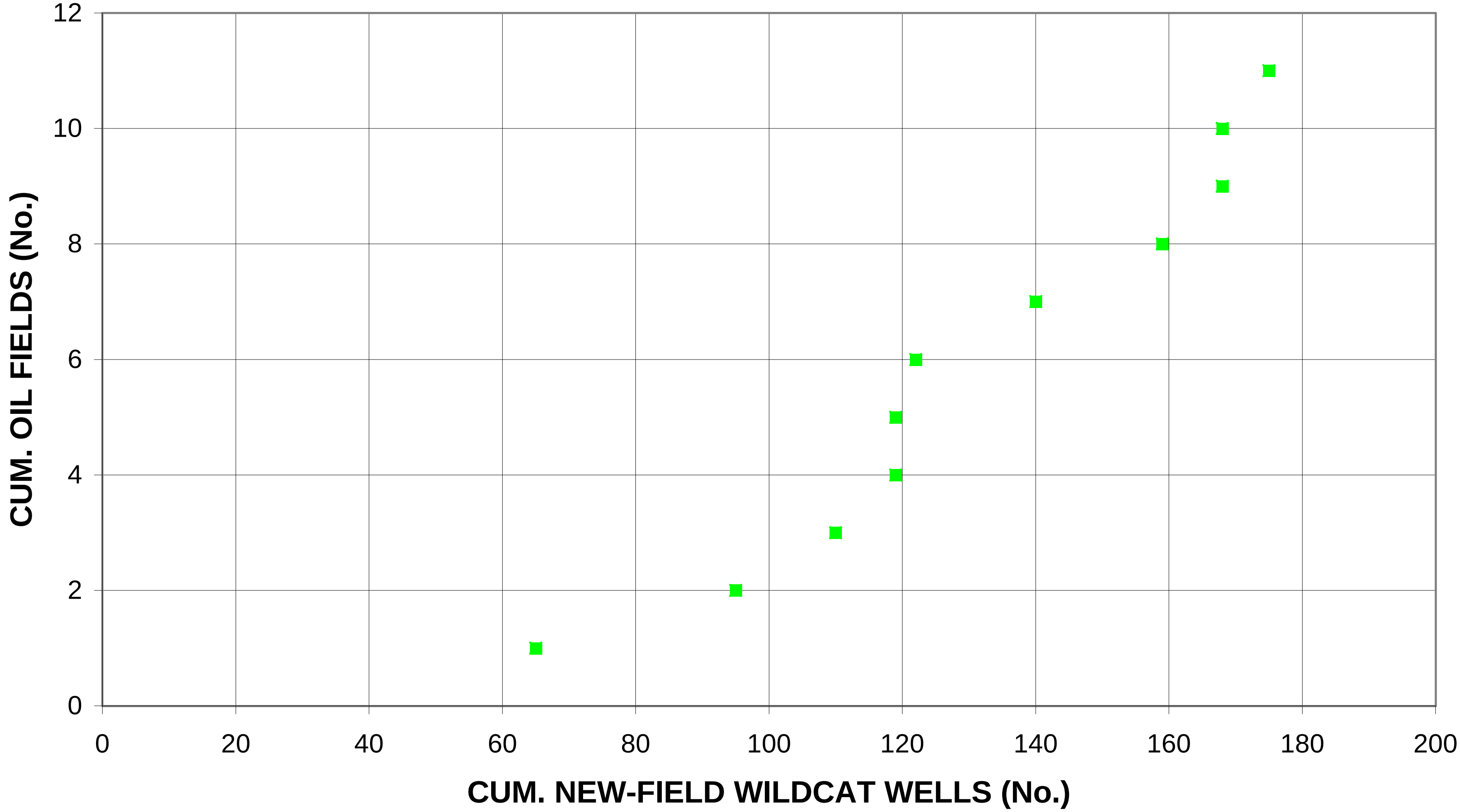


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

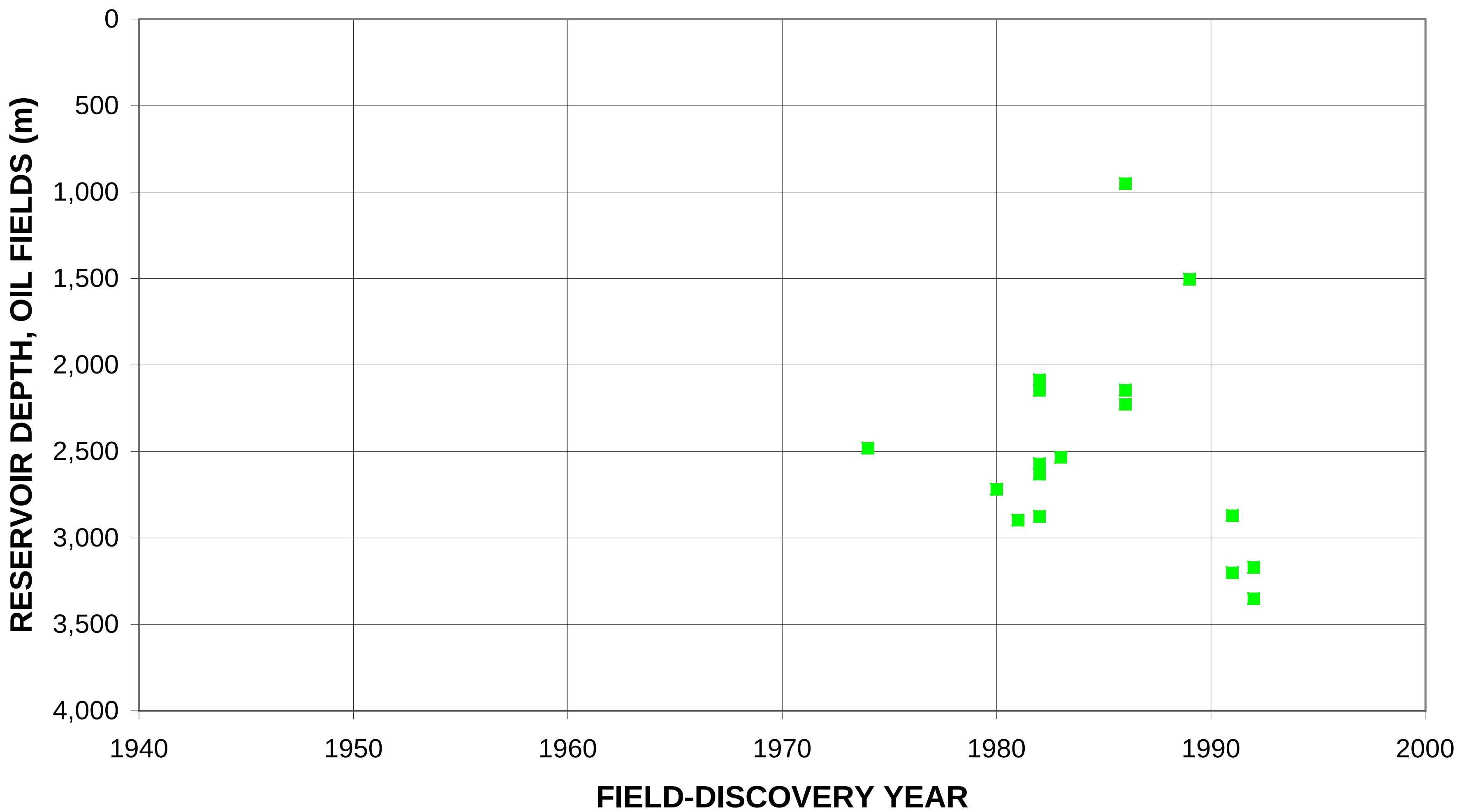



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
CUM. OIL FIELDS (No.)
FIELD-DISCOVERY YEAR
0
2
4
6
8
10
12
1940
1950
1960
1970
1980
1990
2000

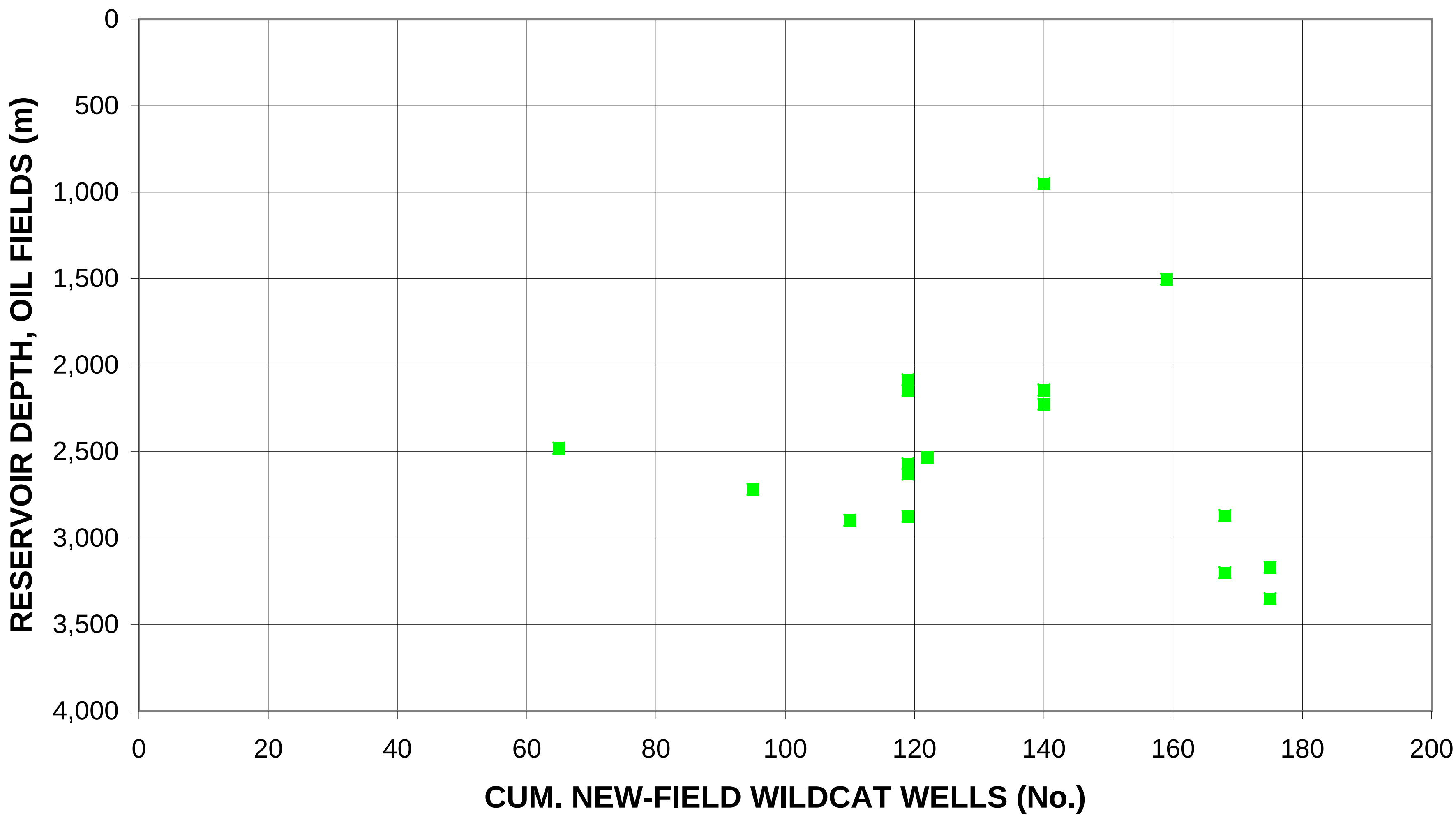
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

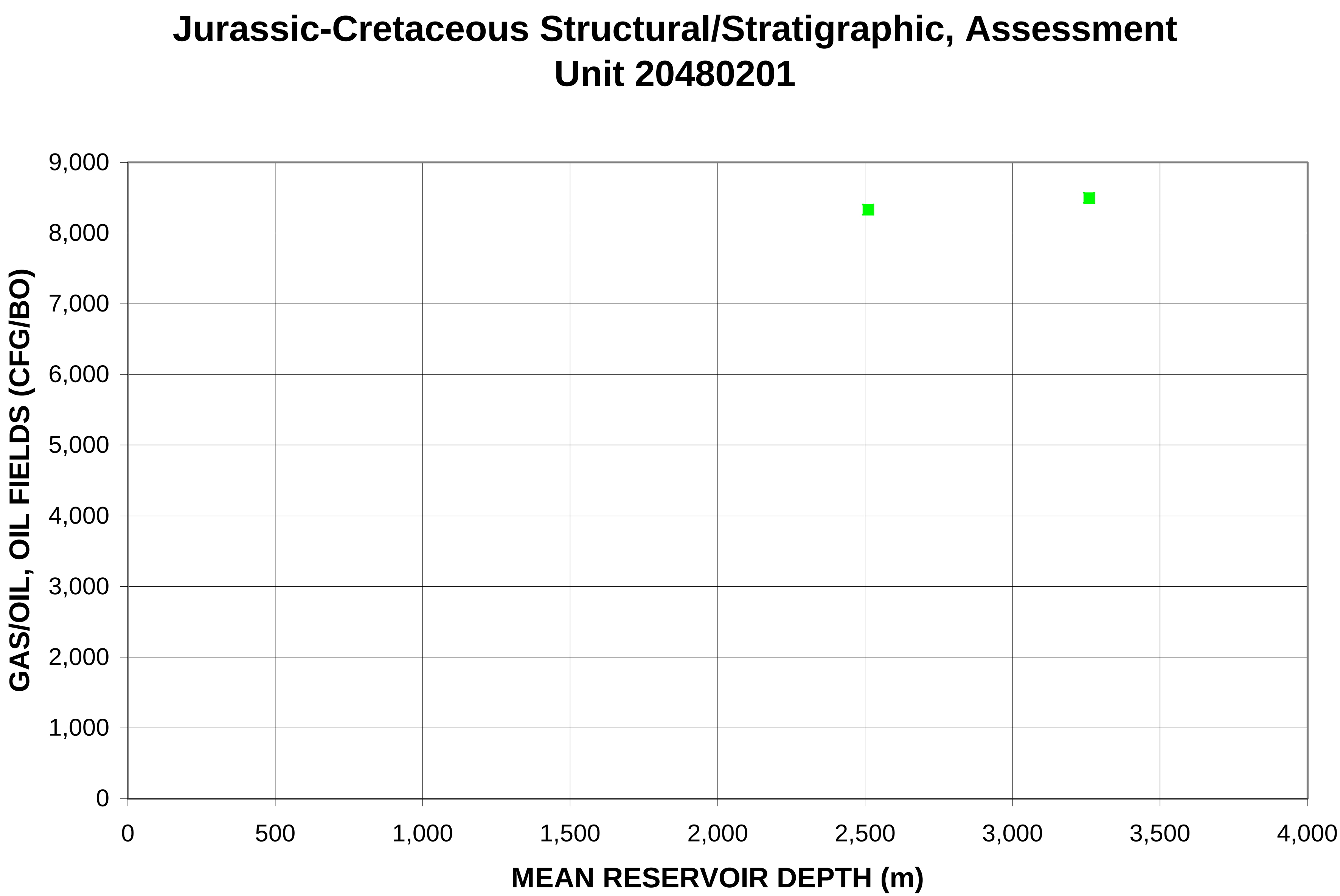


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

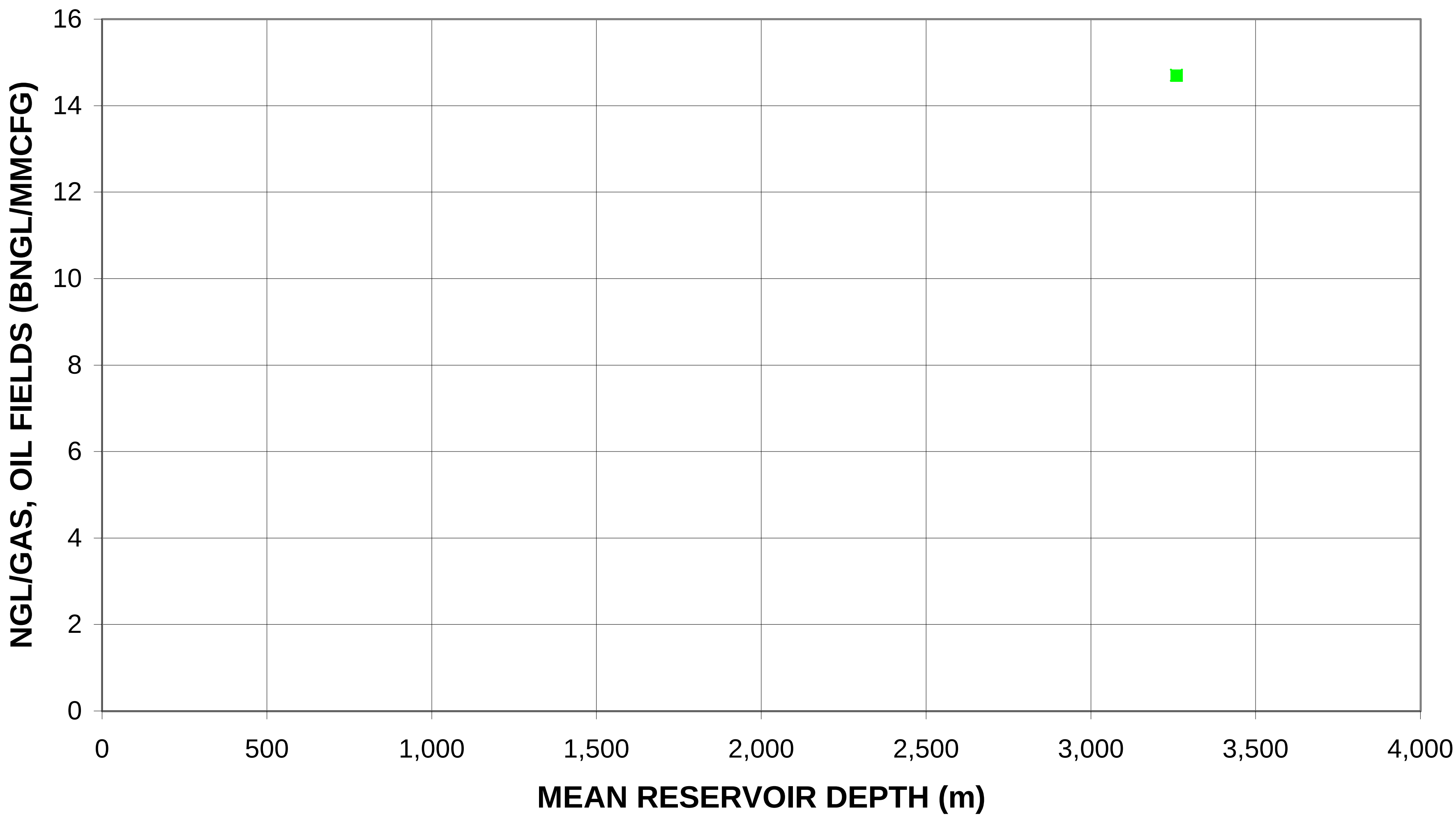


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

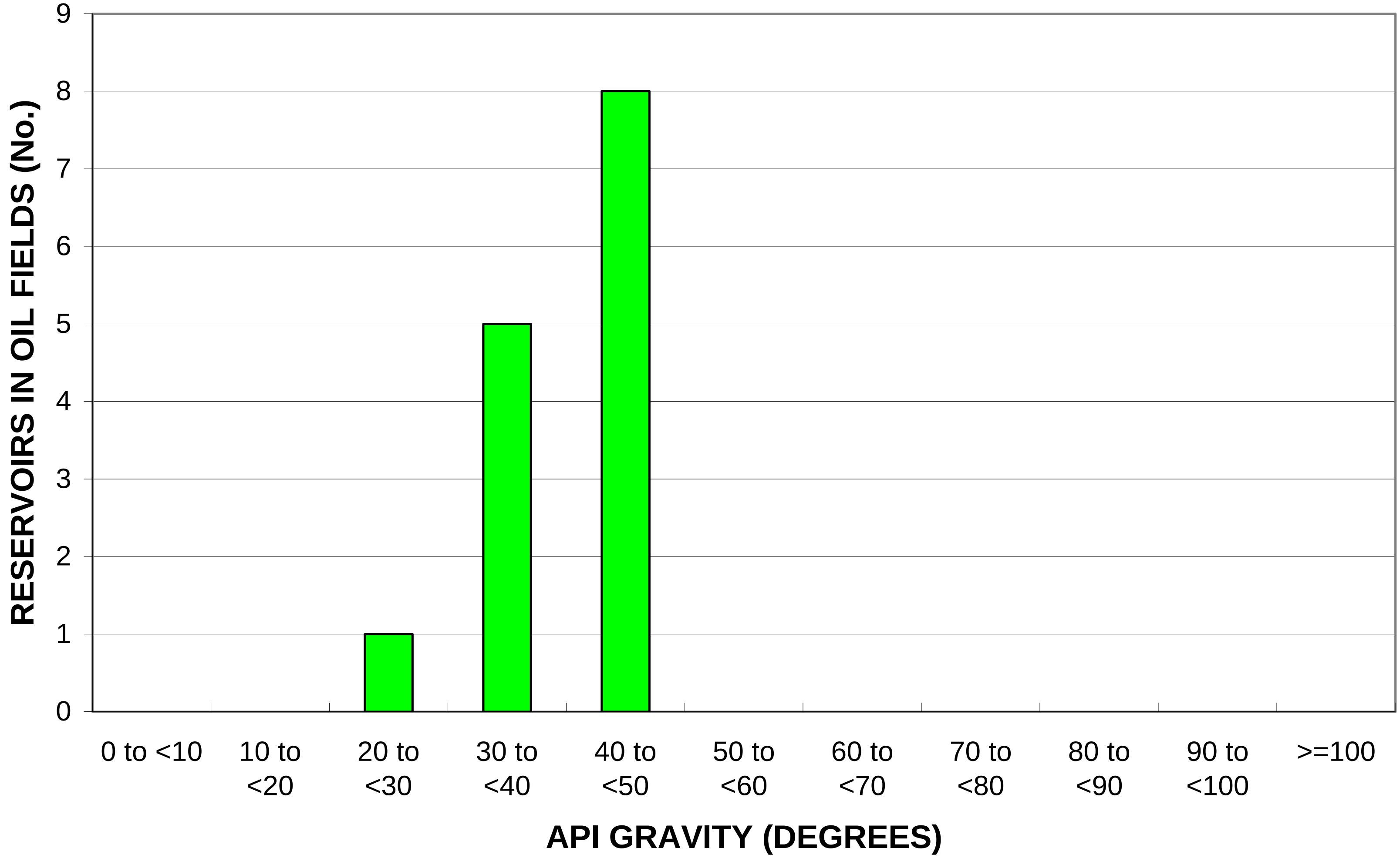



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
GAS/OIL, OIL FIELDS (CFG/BO)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
MEAN RESERVOIR DEPTH (m)

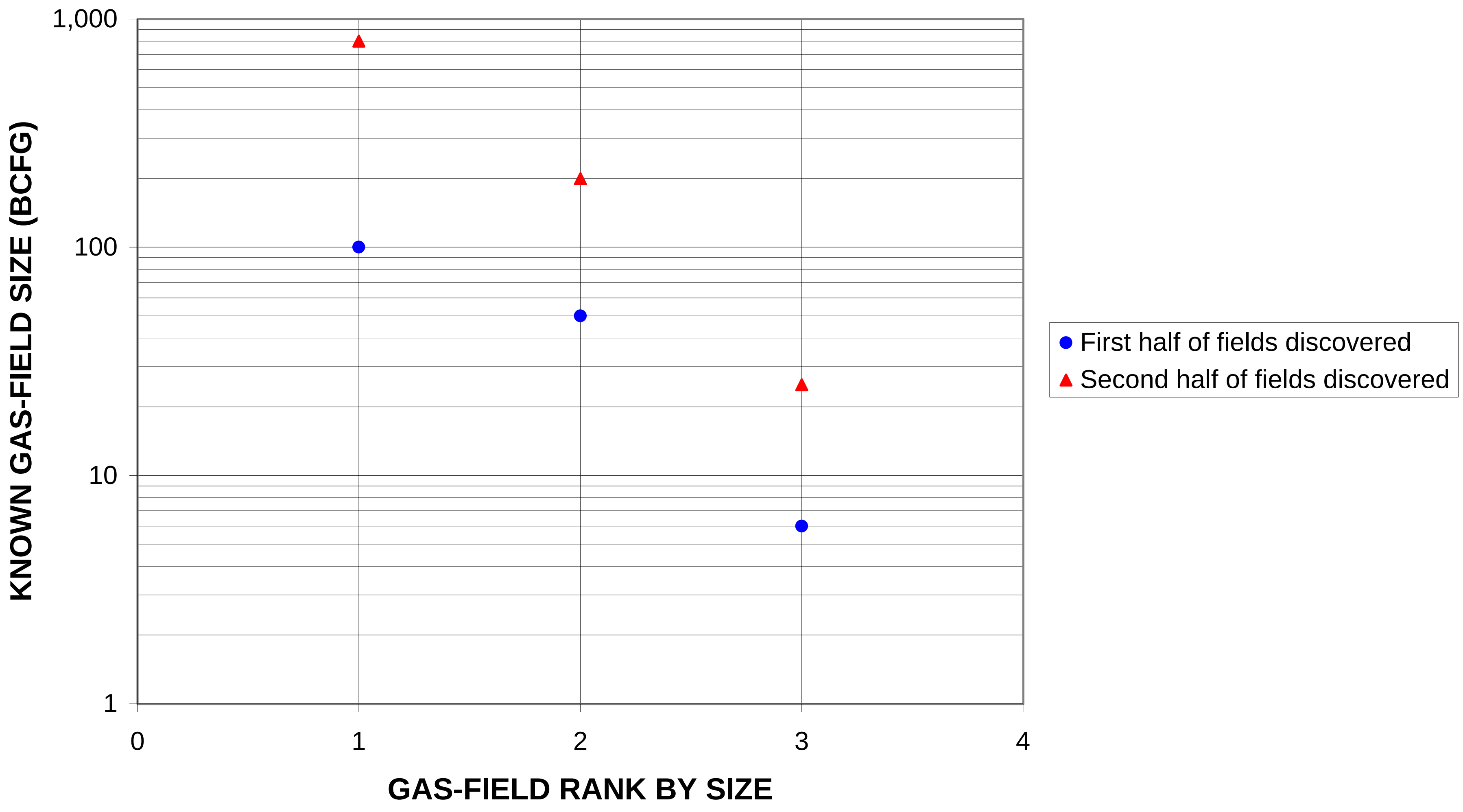
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



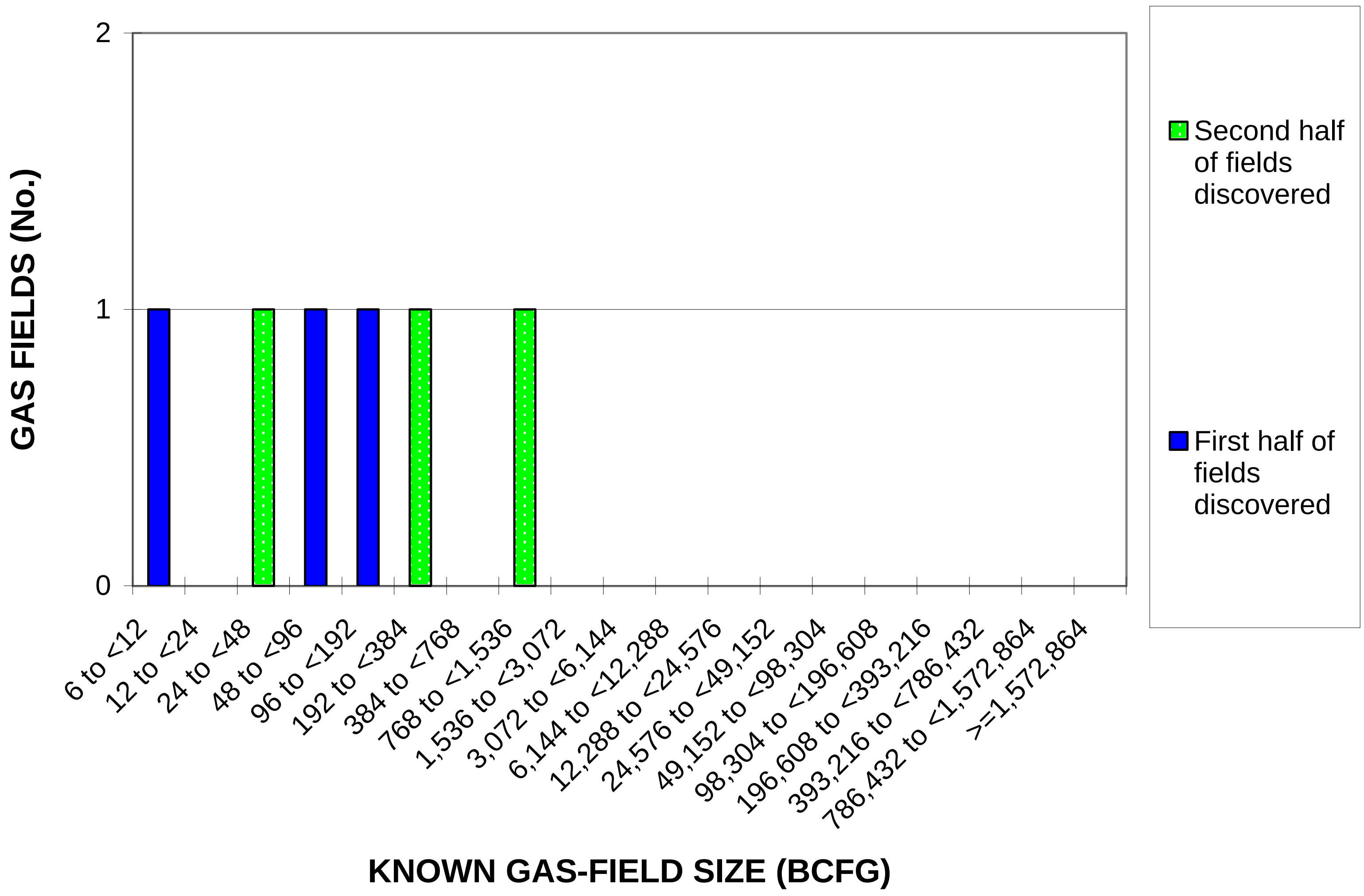
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

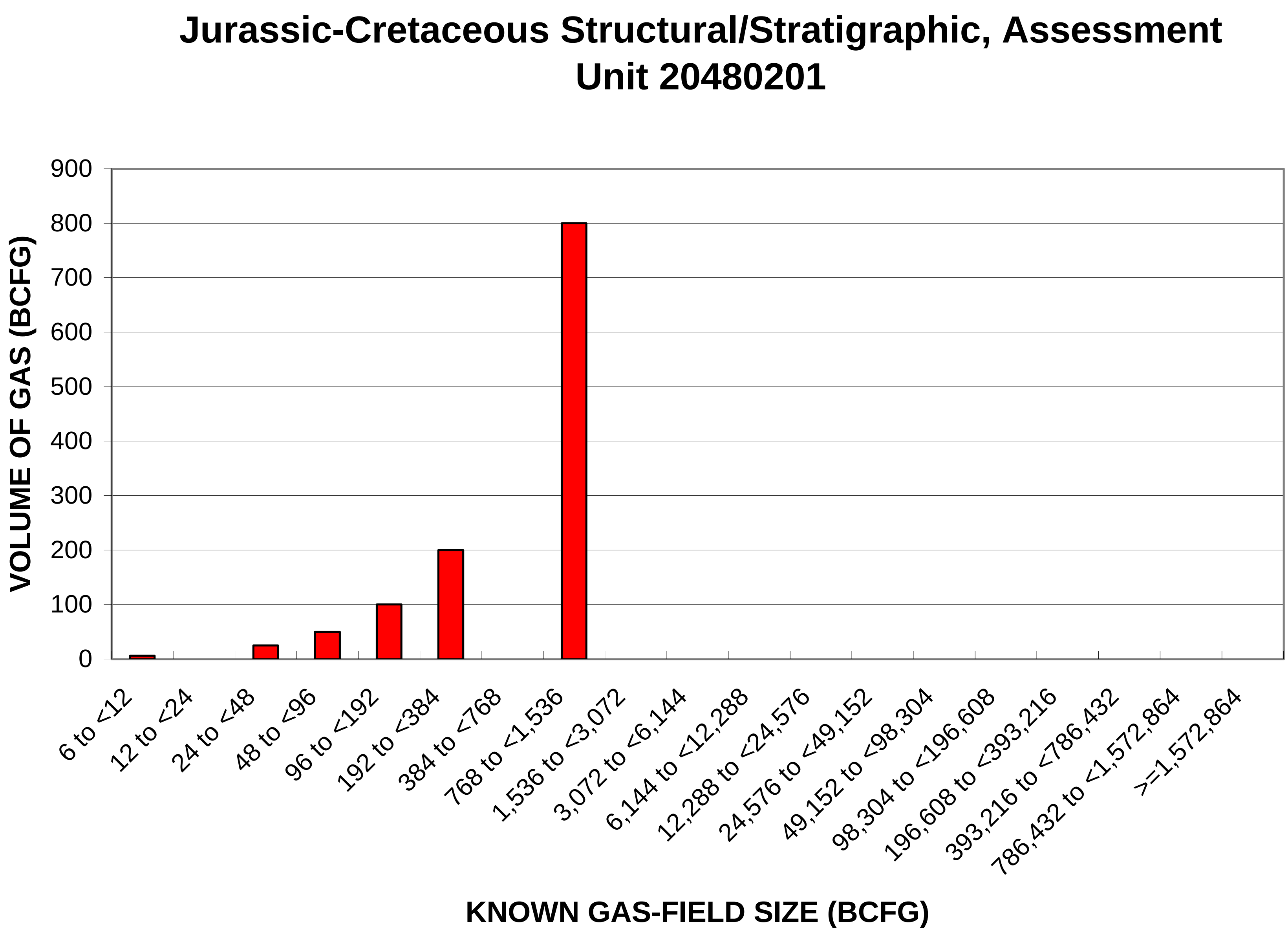


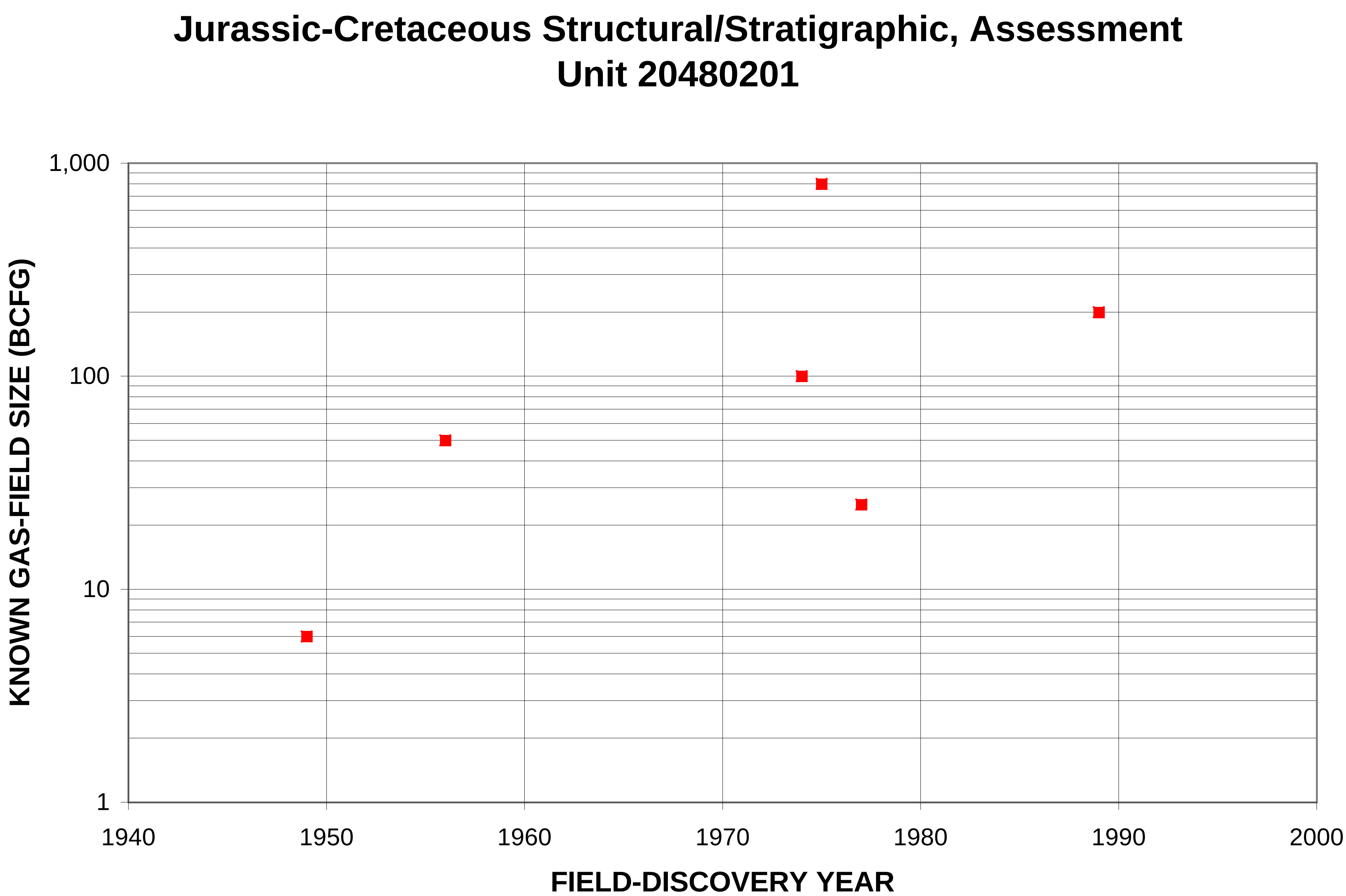
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



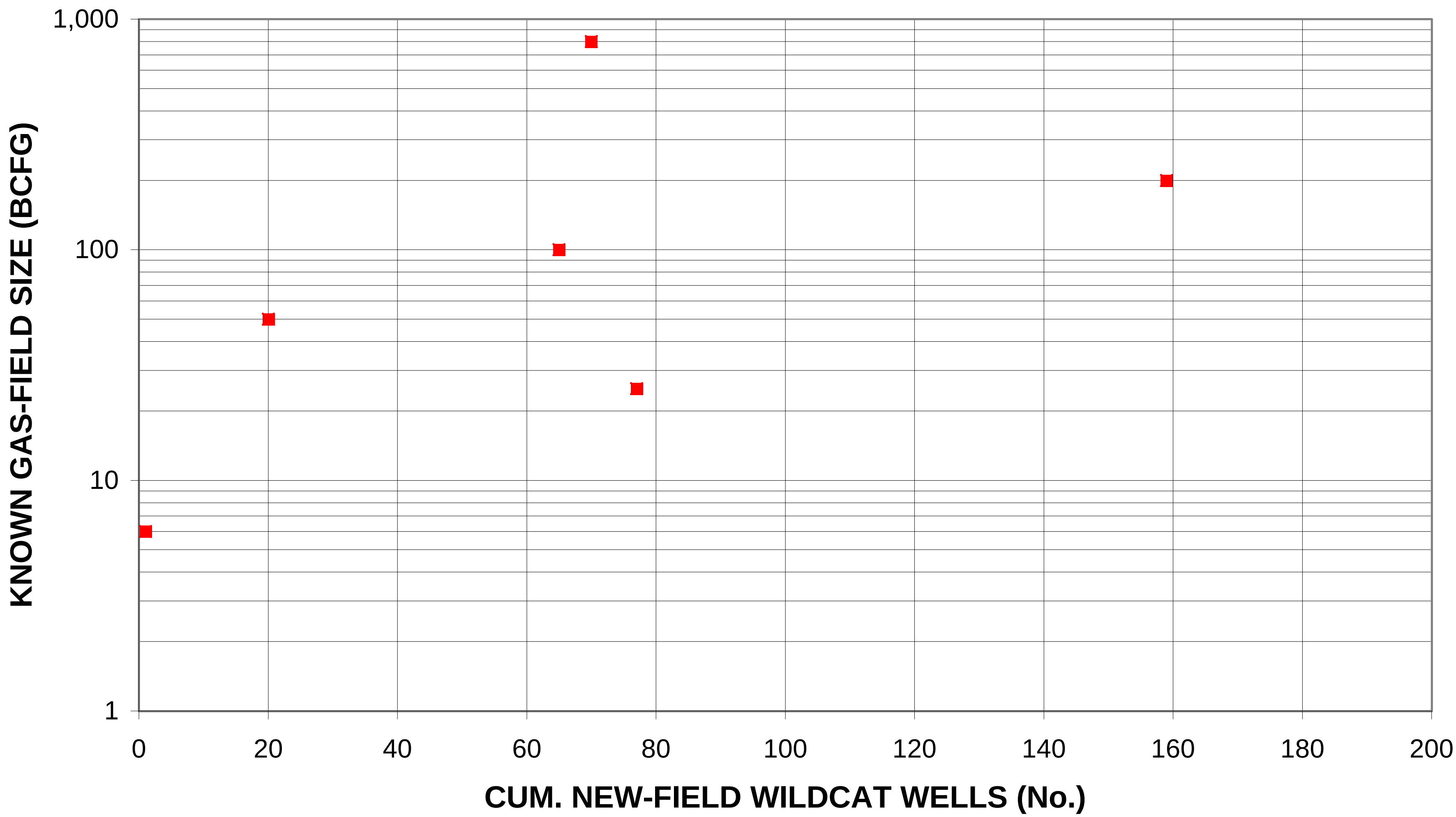
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

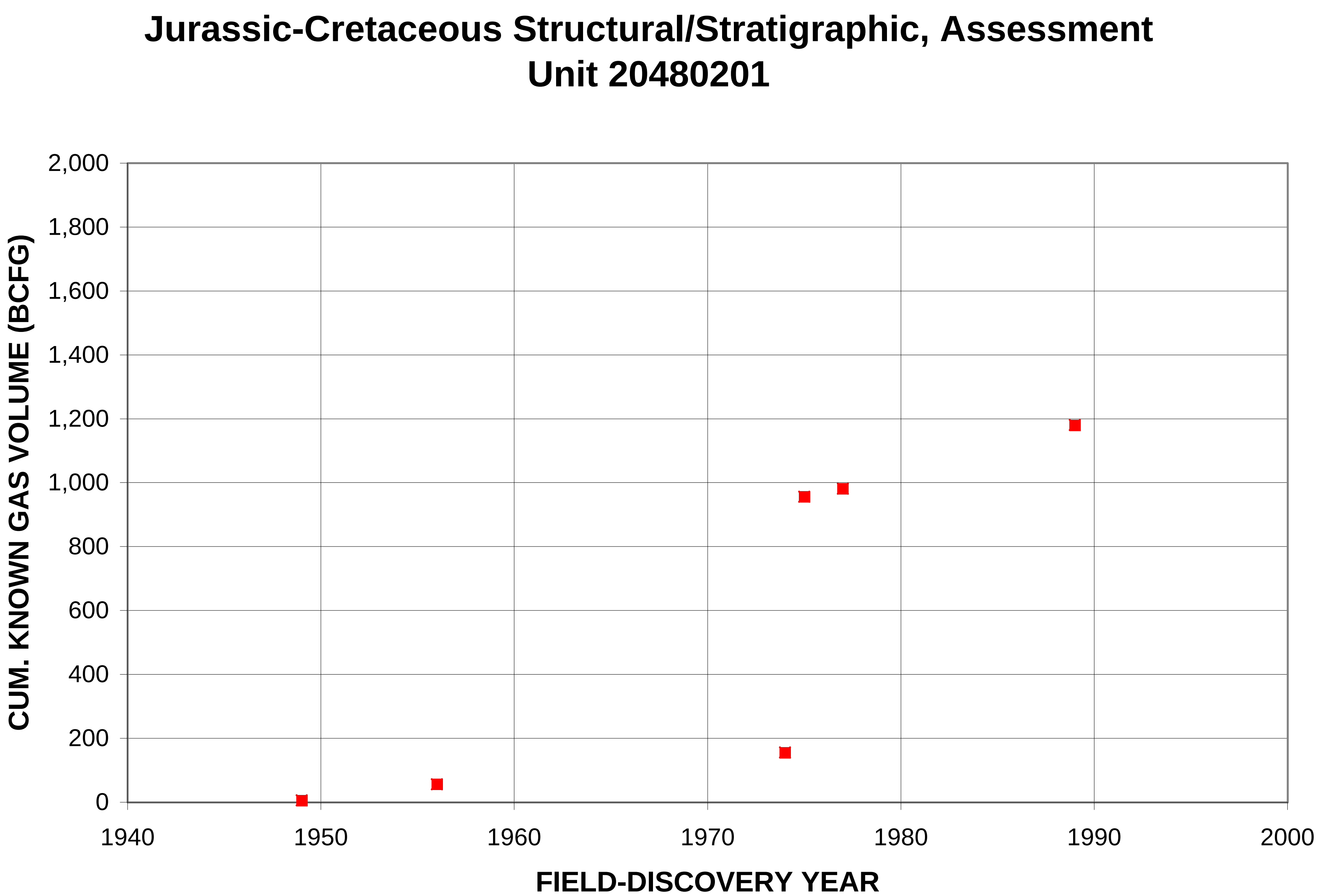



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
VOLUME OF GAS (BCFG)
0
100
200
300
400
500
600
700
800
900
6 to <12
12 to <24
24 to <48
48 to <96
96 to <192
192 to <384
384 to <768
768 to <1,536
1,536 to <3,072
3,072 to <6,144
6,144 to <12,288
12,288 to <24,576
24,576 to <49,152
49,152 to <98,304
98,304 to <196,608
196,608 to <393,216
393,216 to <786,432
786,432 to <1,572,864
>=1,572,864
KNOWN GAS-FIELD SIZE (BCFG)

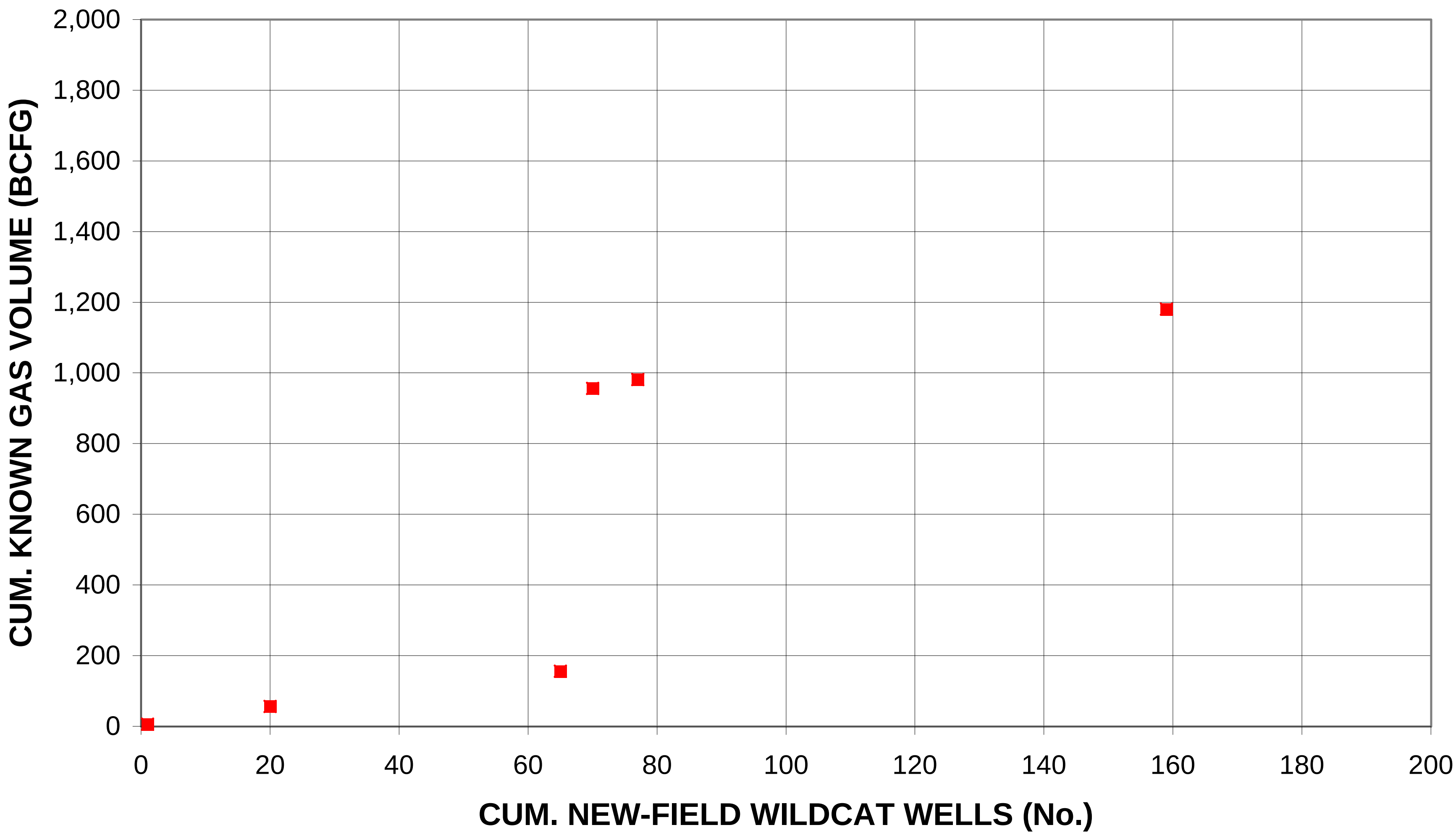

Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
KNOWN GAS-FIELD SIZE (BCFG)
1,000
100
10
1
1940
1950
1960
1970
1980
1990
2000
FIELD-DISCOVERY YEAR

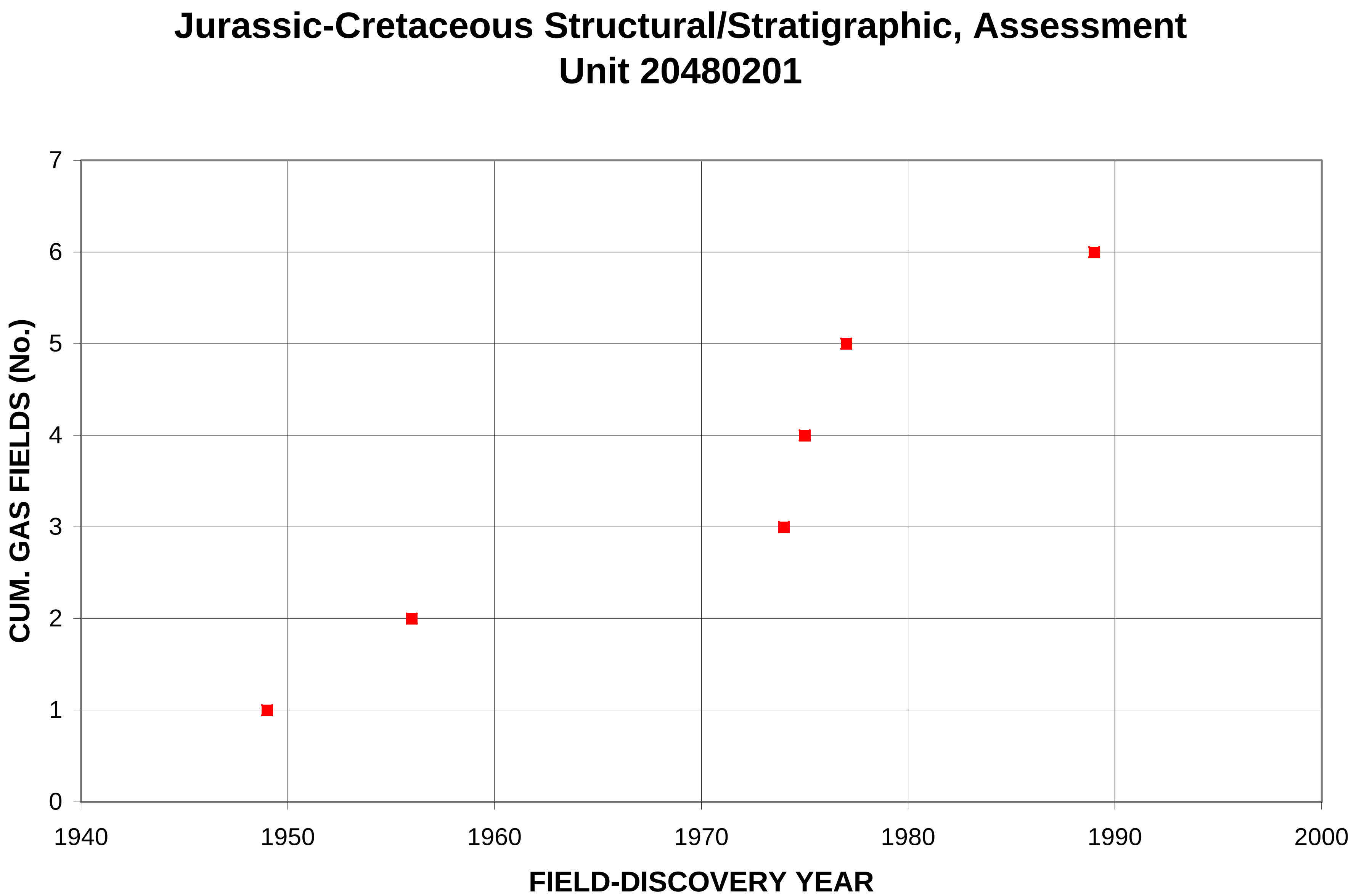
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

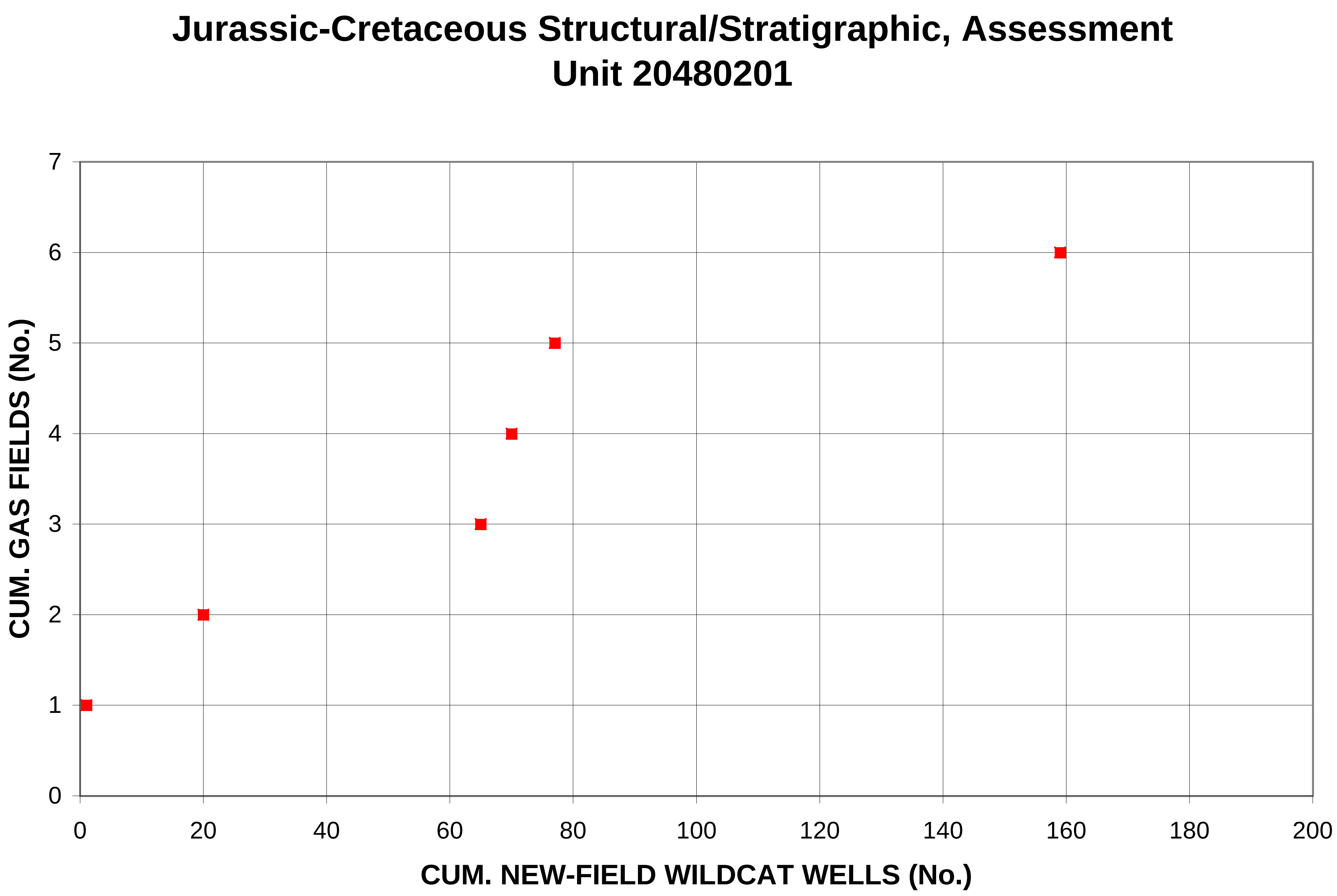



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
CUM. KNOWN GAS VOLUME (BCFG)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1940
1950
1960
1970
1980
1990
2000
FIELD-DISCOVERY YEAR

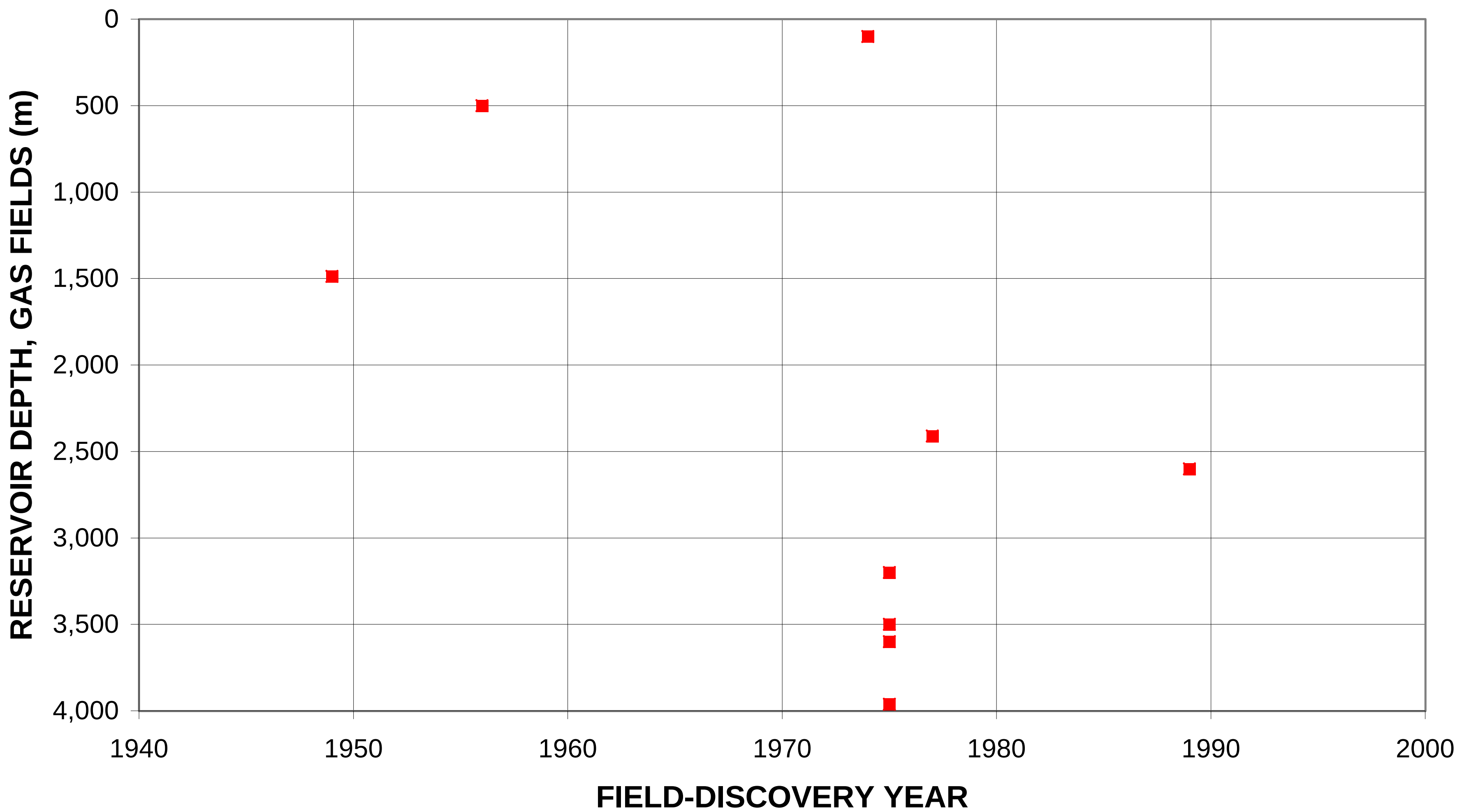
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



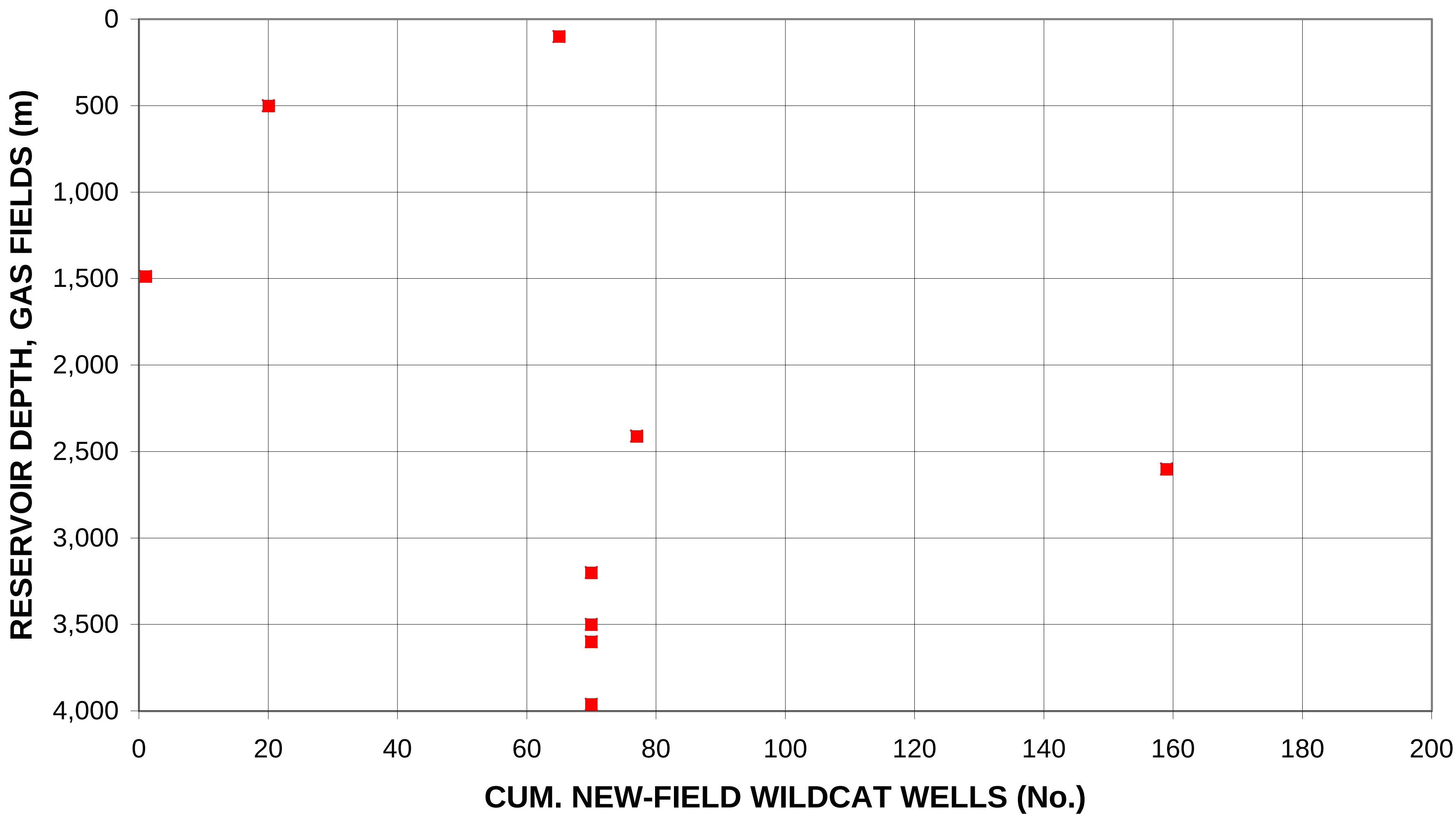

Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
CUM. GAS FIELDS (No.)
FIELD-DISCOVERY YEAR
0
1
2
3
4
5
6
7
1940
1950
1960
1970
1980
1990
2000


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
CUM. GAS FIELDS (No.)
0
1
2
3
4
5
6
7
0
20
40
60
80
100
120
140
160
180
200
CUM. NEW-FIELD WILDCAT WELLS (No.)

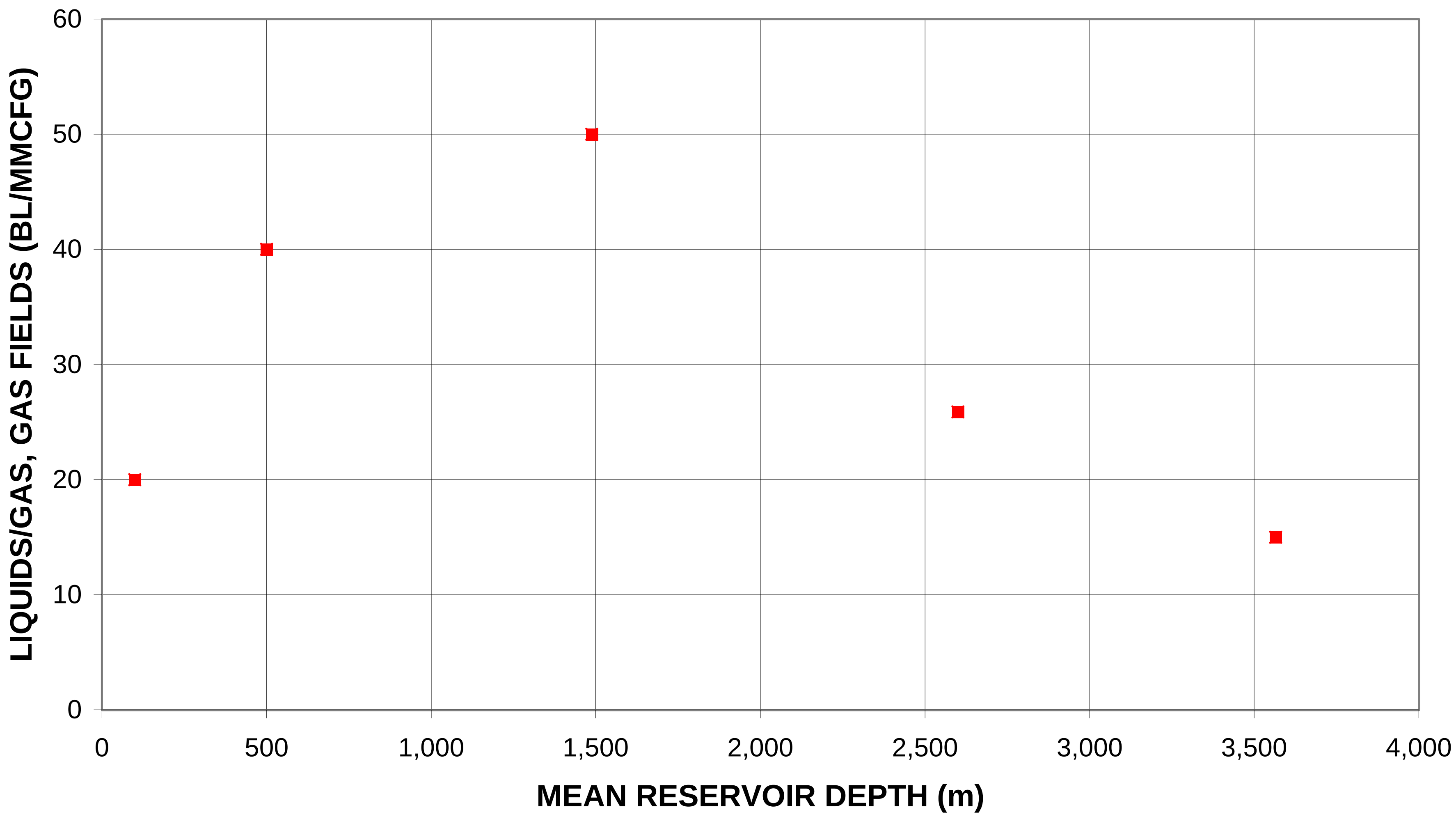
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

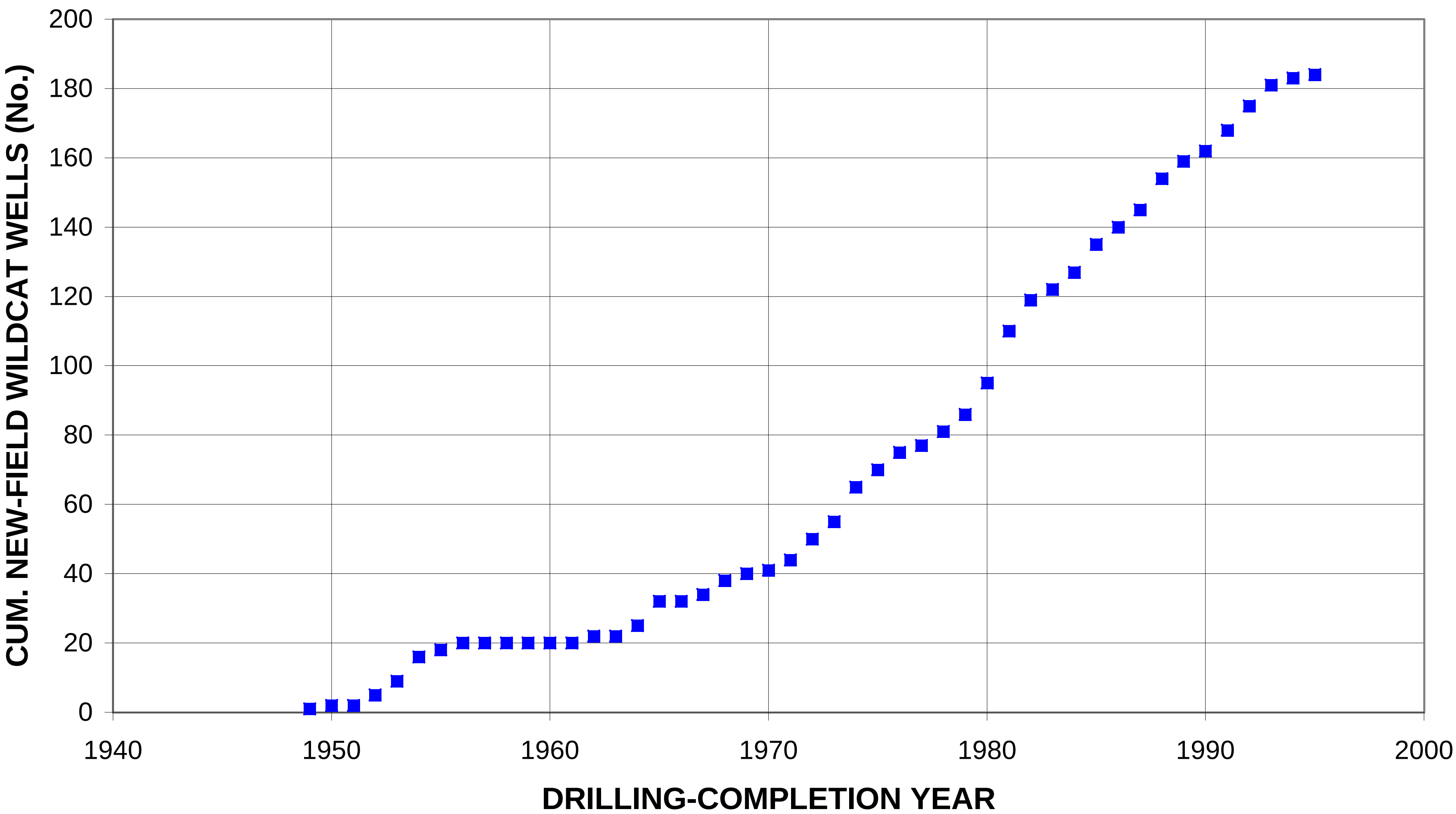


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

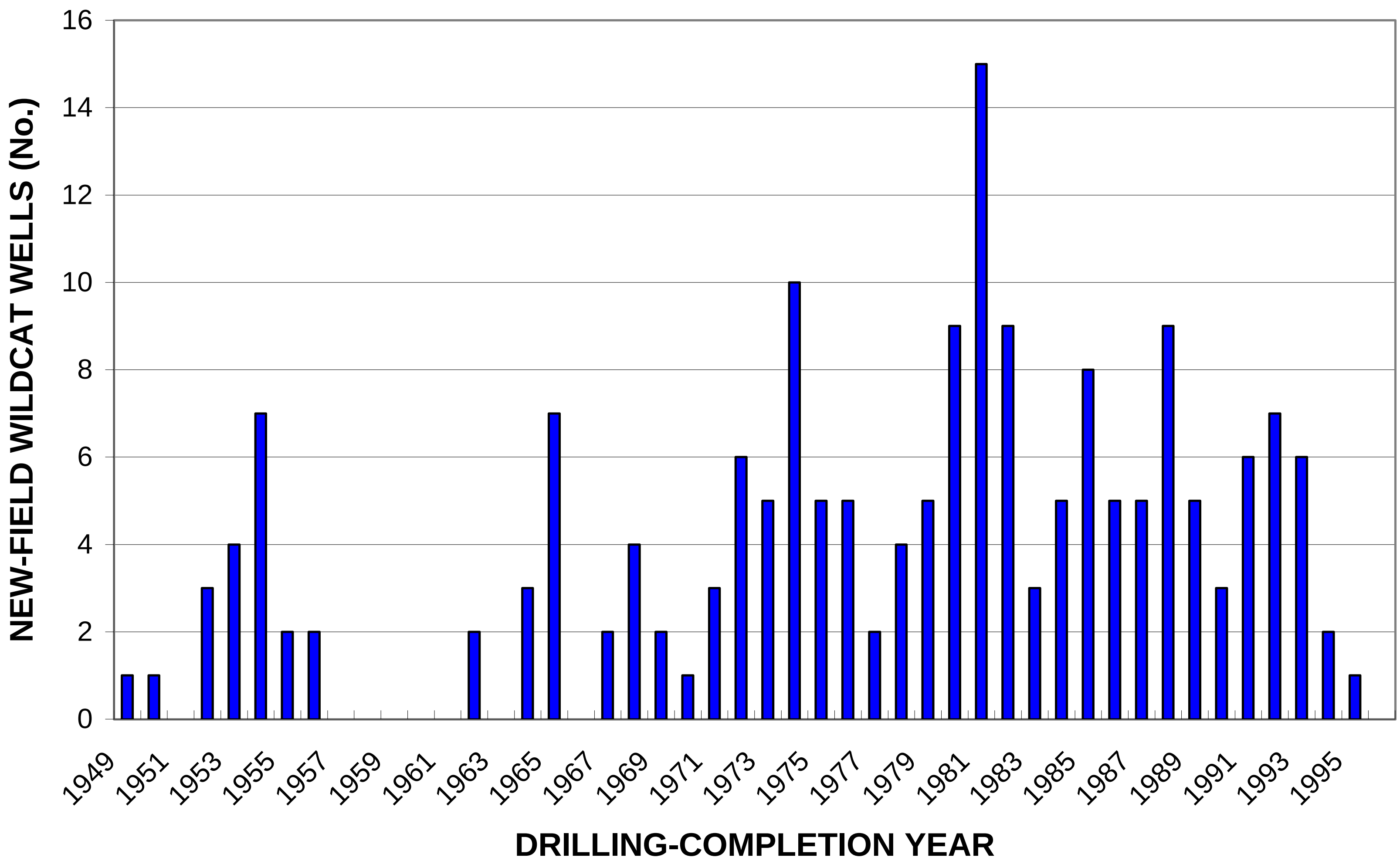


Appendix 2. Exploration-activity and discovery-history plots for the Jurassic-Cretaceous Structural/Stratigraphic Assessment Unit (20480201). *B*. Plots of grown oil and gas volumes.

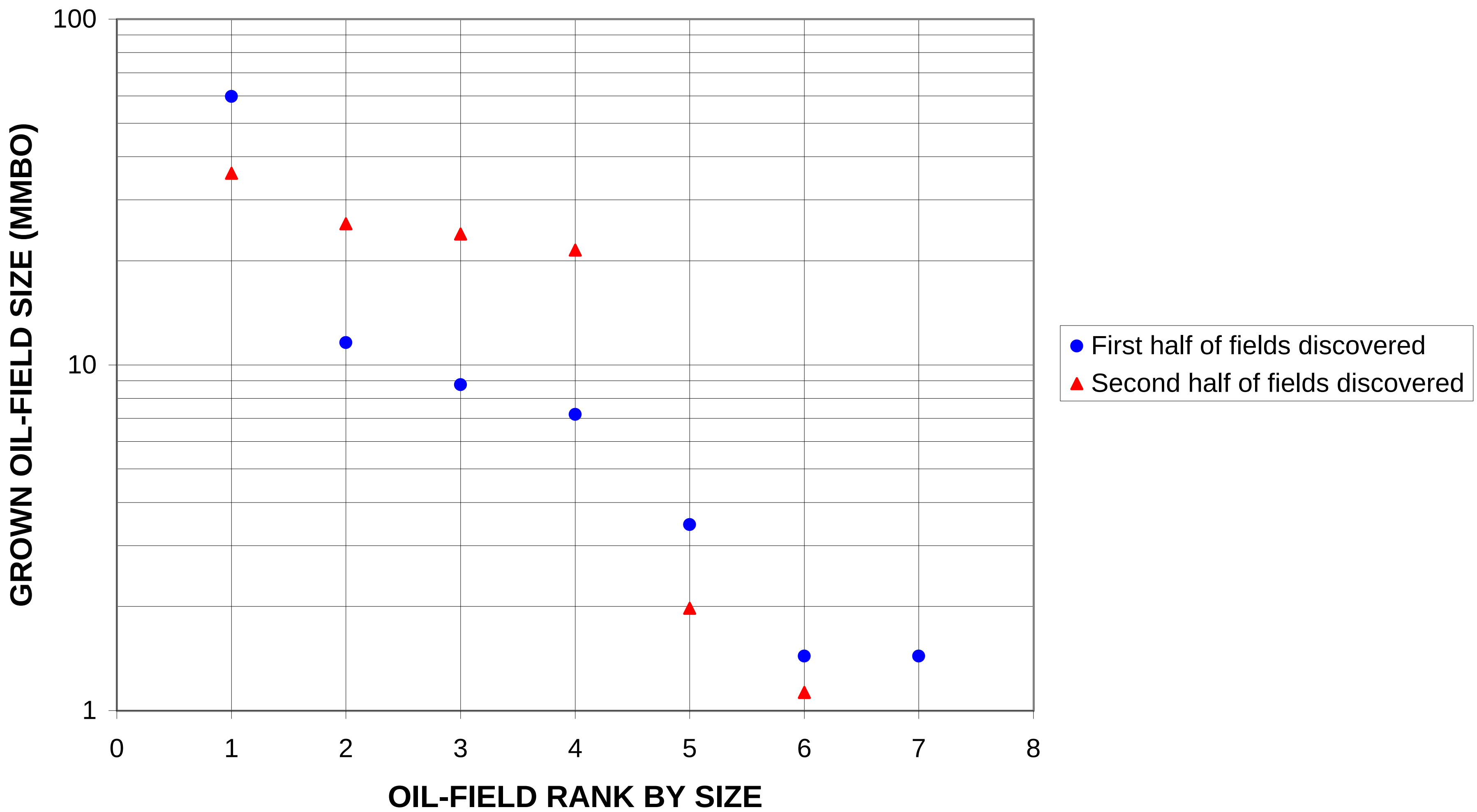
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

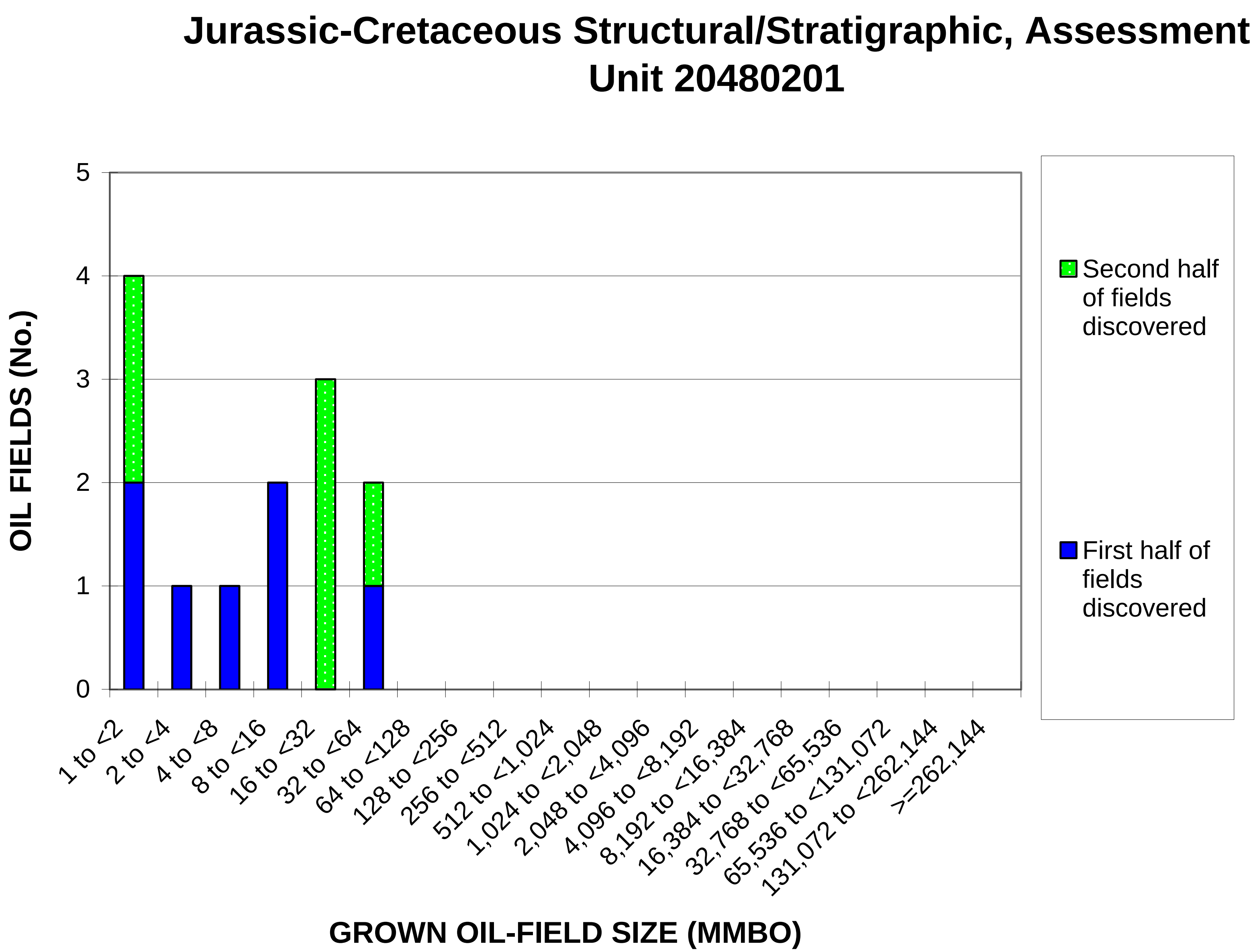


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

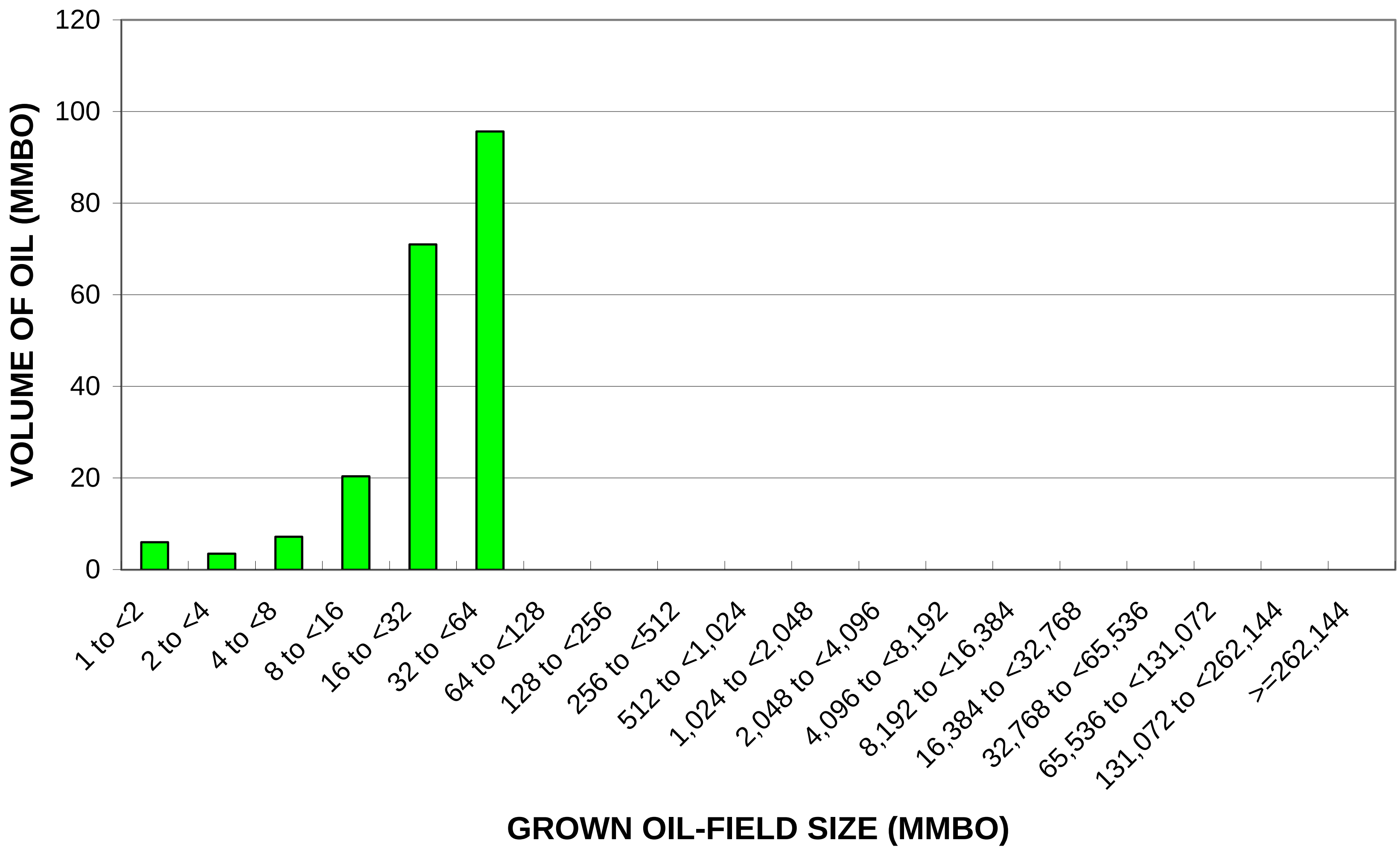


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

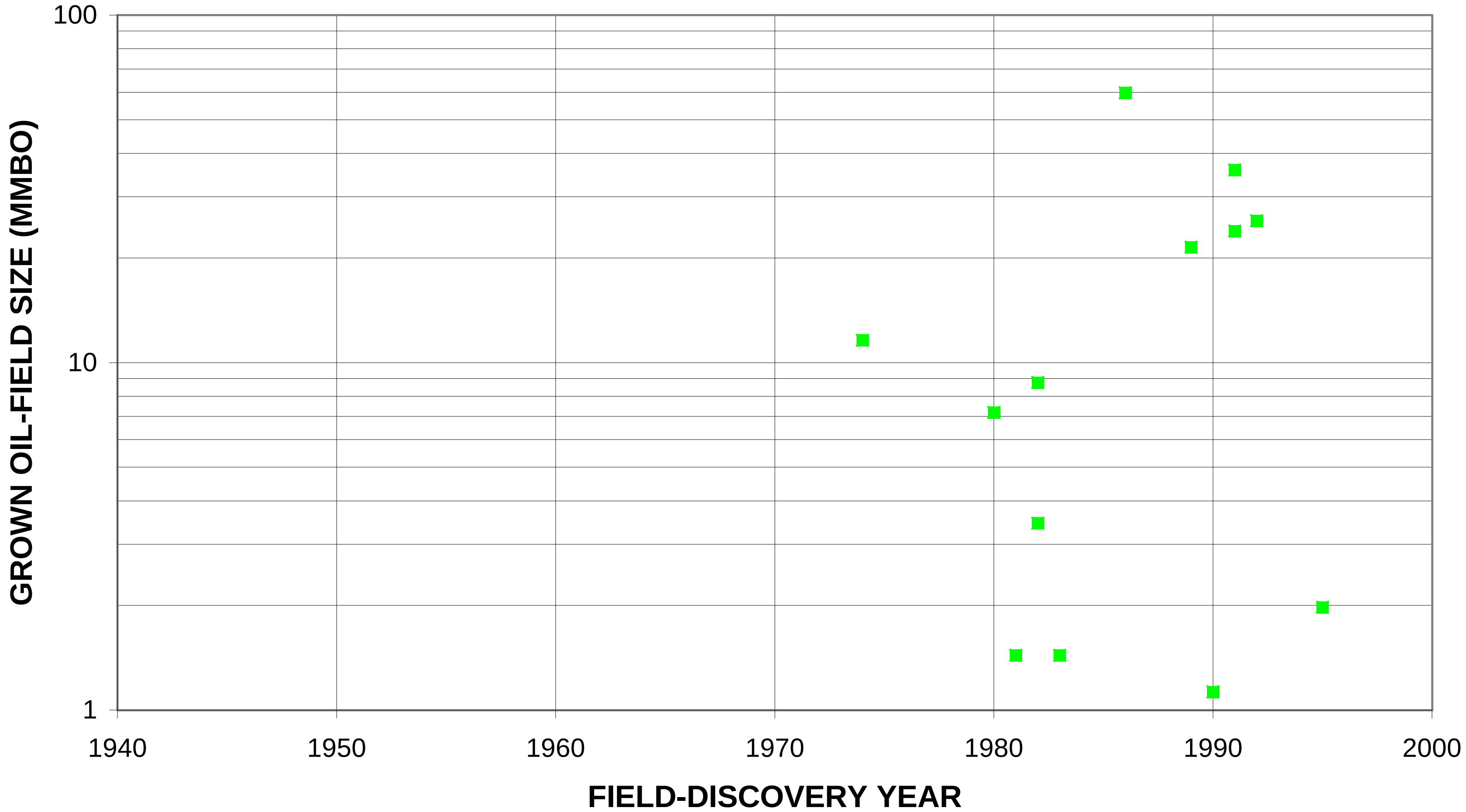



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
OIL FIELDS (No.)
0
1
2
3
4
5
1 to <2
2 to <4
4 to <8
8 to <16
16 to <32
32 to <64
64 to <128
128 to <256
256 to <512
512 to <1,024
1,024 to <2,048
2,048 to <4,096
4,096 to <8,192
8,192 to <16,384
16,384 to <32,768
32,768 to <65,536
65,536 to <131,072
131,072 to <262,144
>=262,144
GROWN OIL-FIELD SIZE (MMBO)
Second half of fields discovered
First half of fields discovered

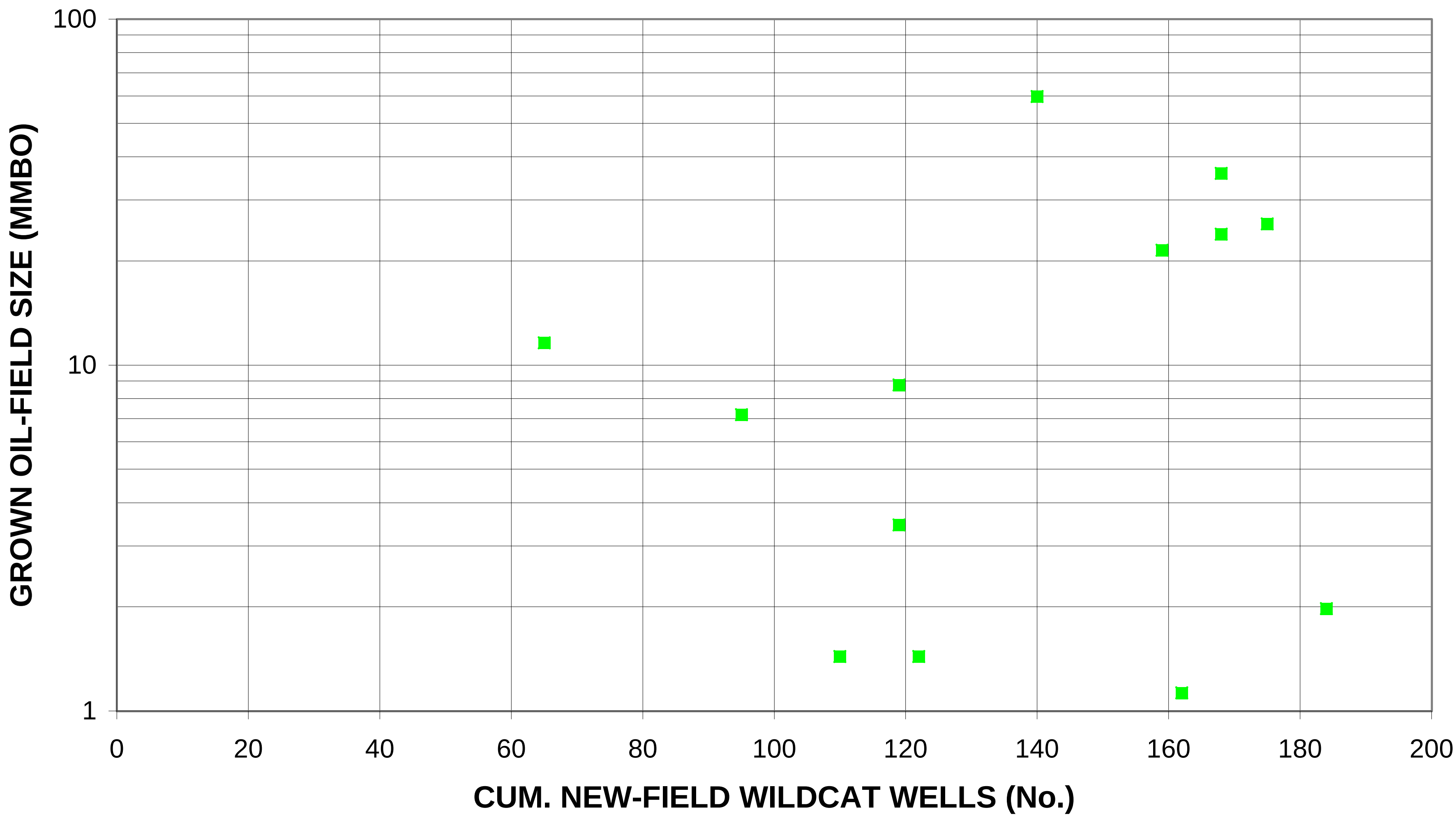
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

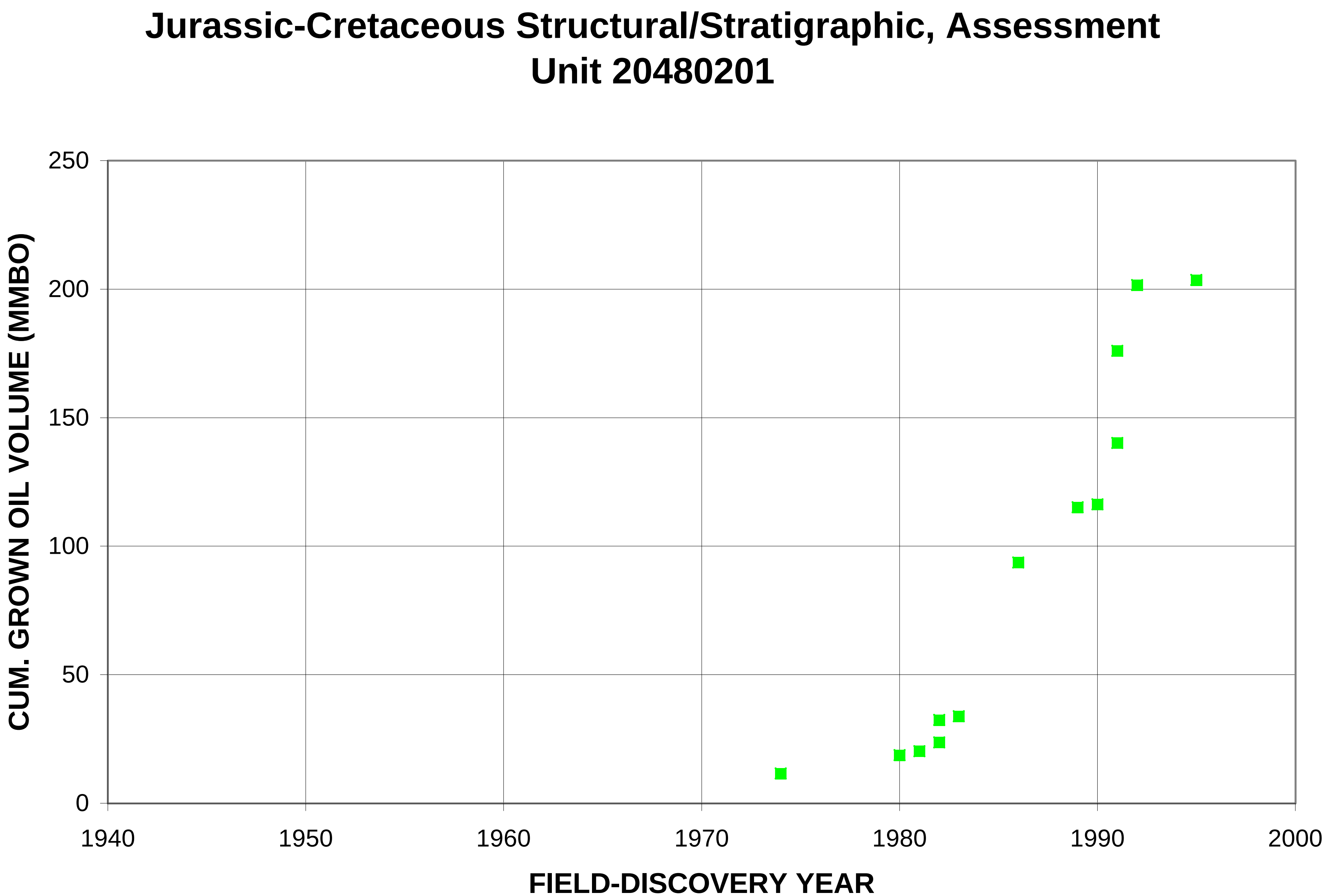


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



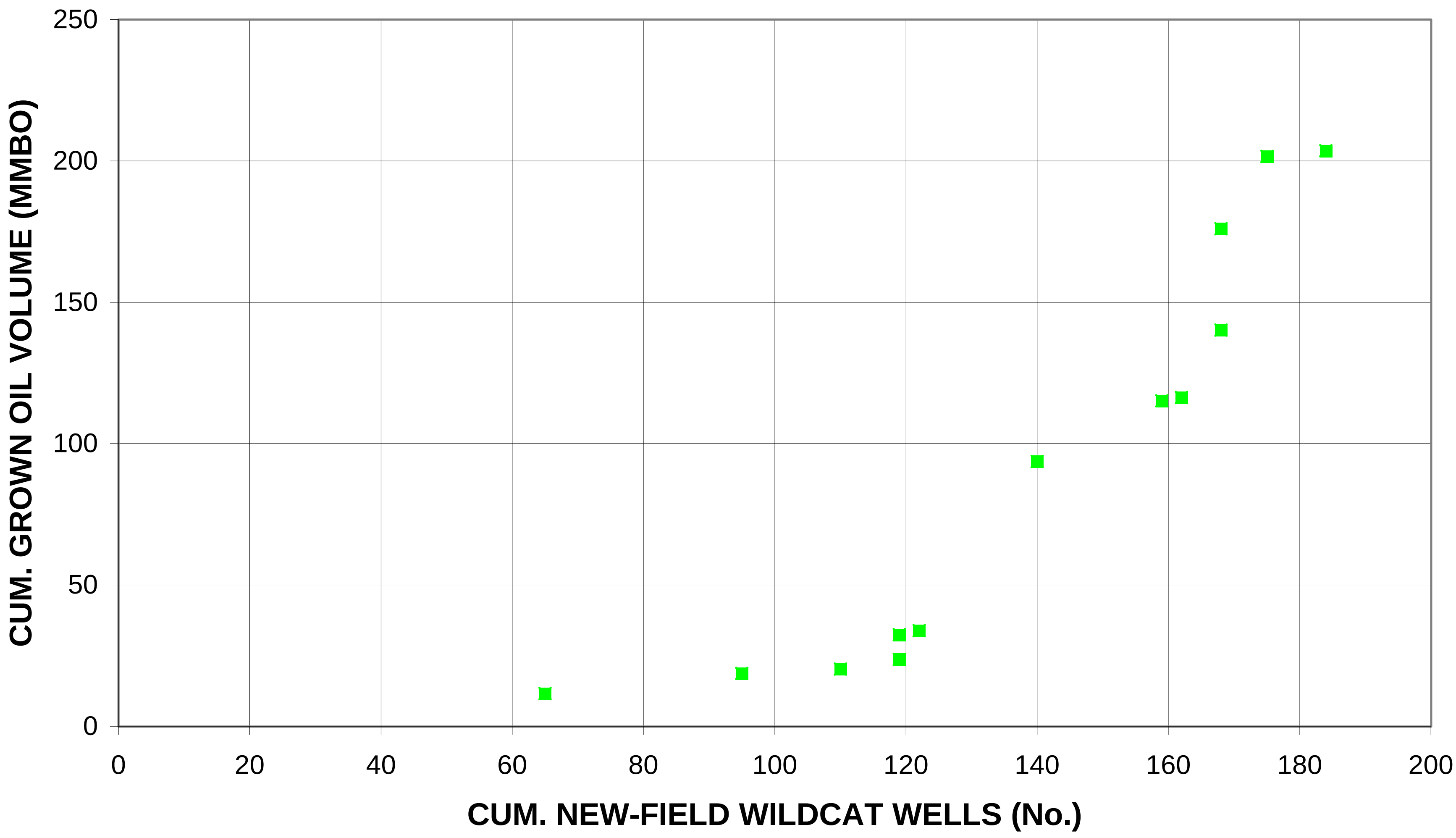
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



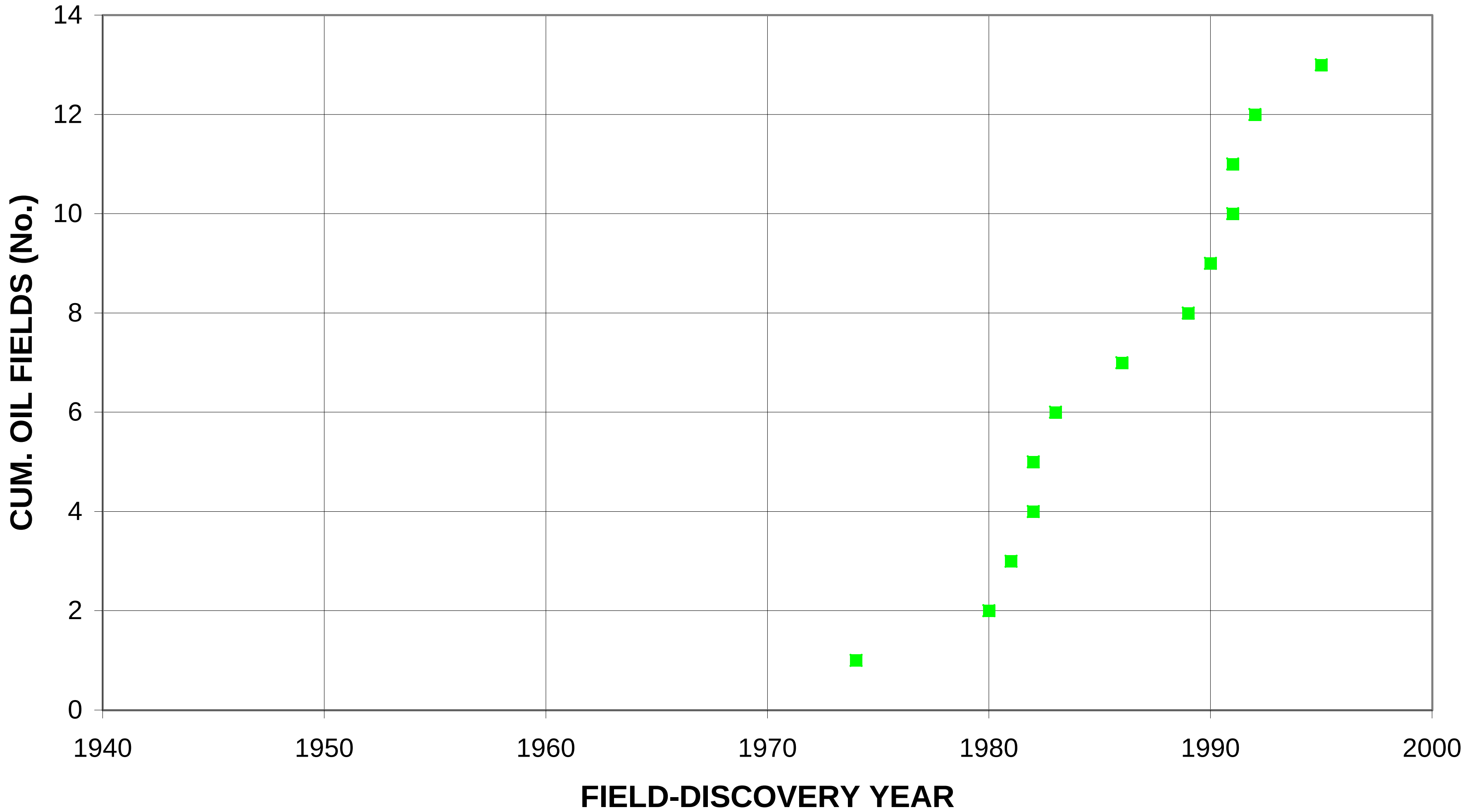


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
CUM. GROWN OIL VOLUME (MMBO)
250
200
150
100
50
0
1940
1950
1960
1970
1980
1990
2000
FIELD-DISCOVERY YEAR

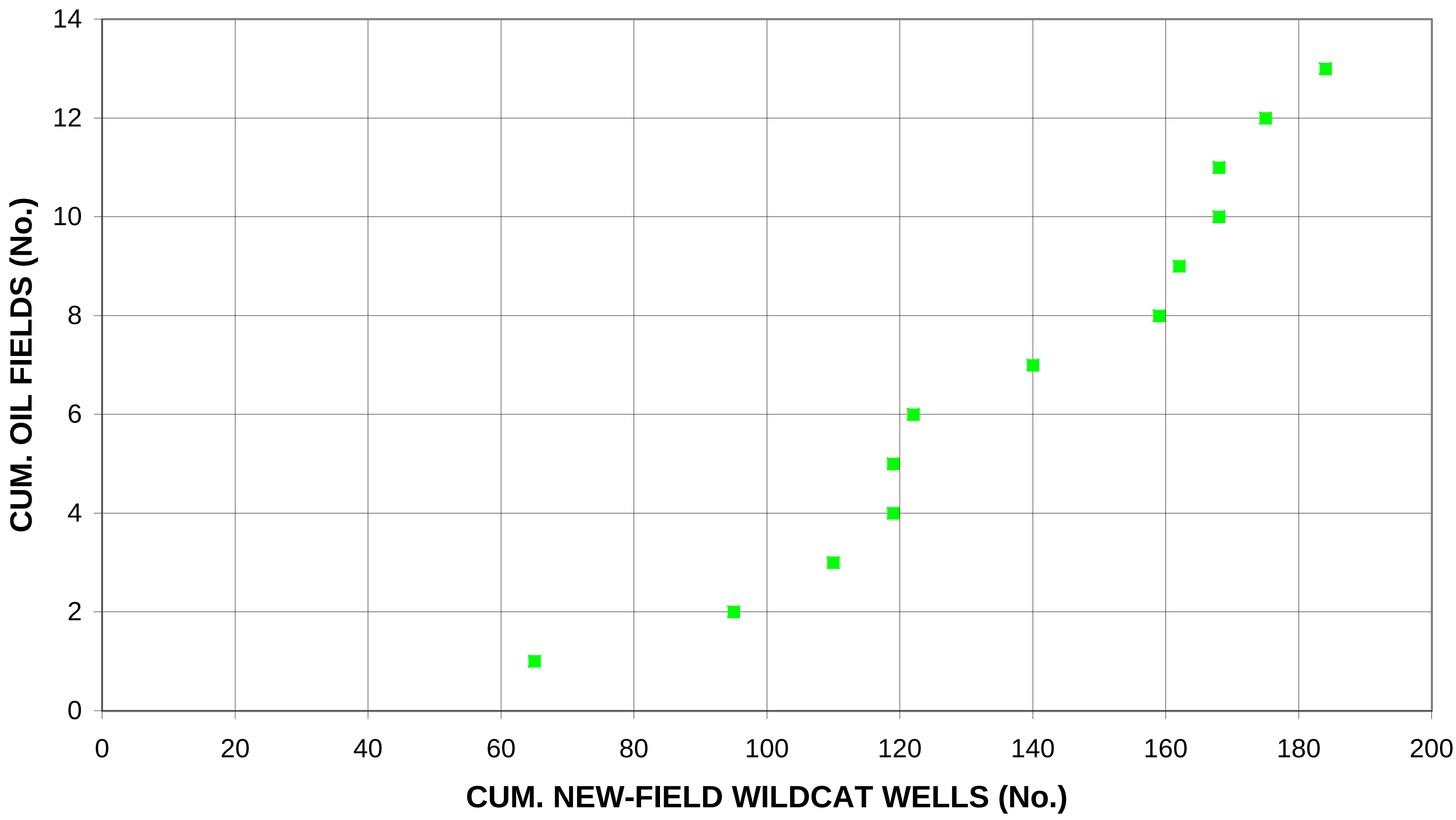
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



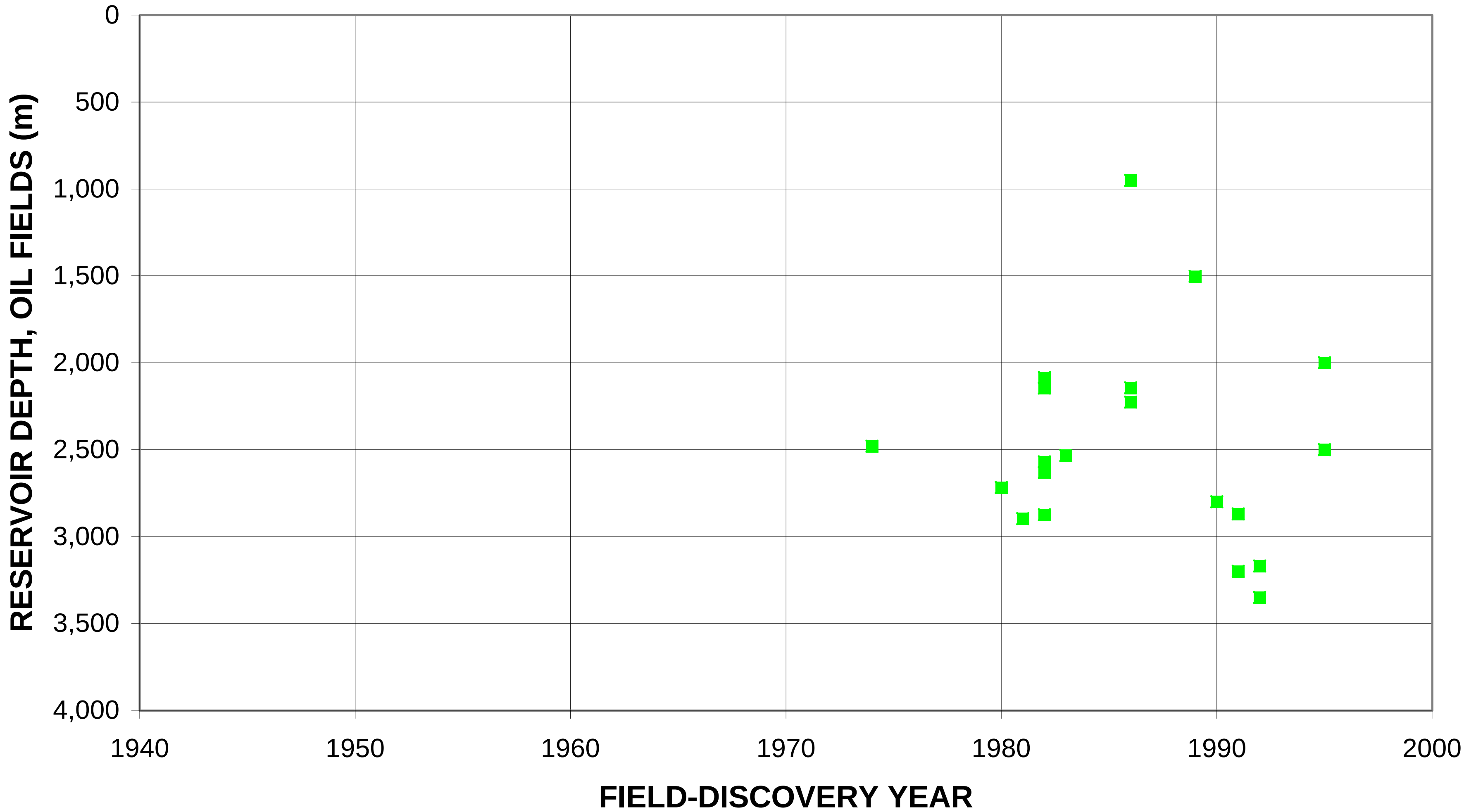
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

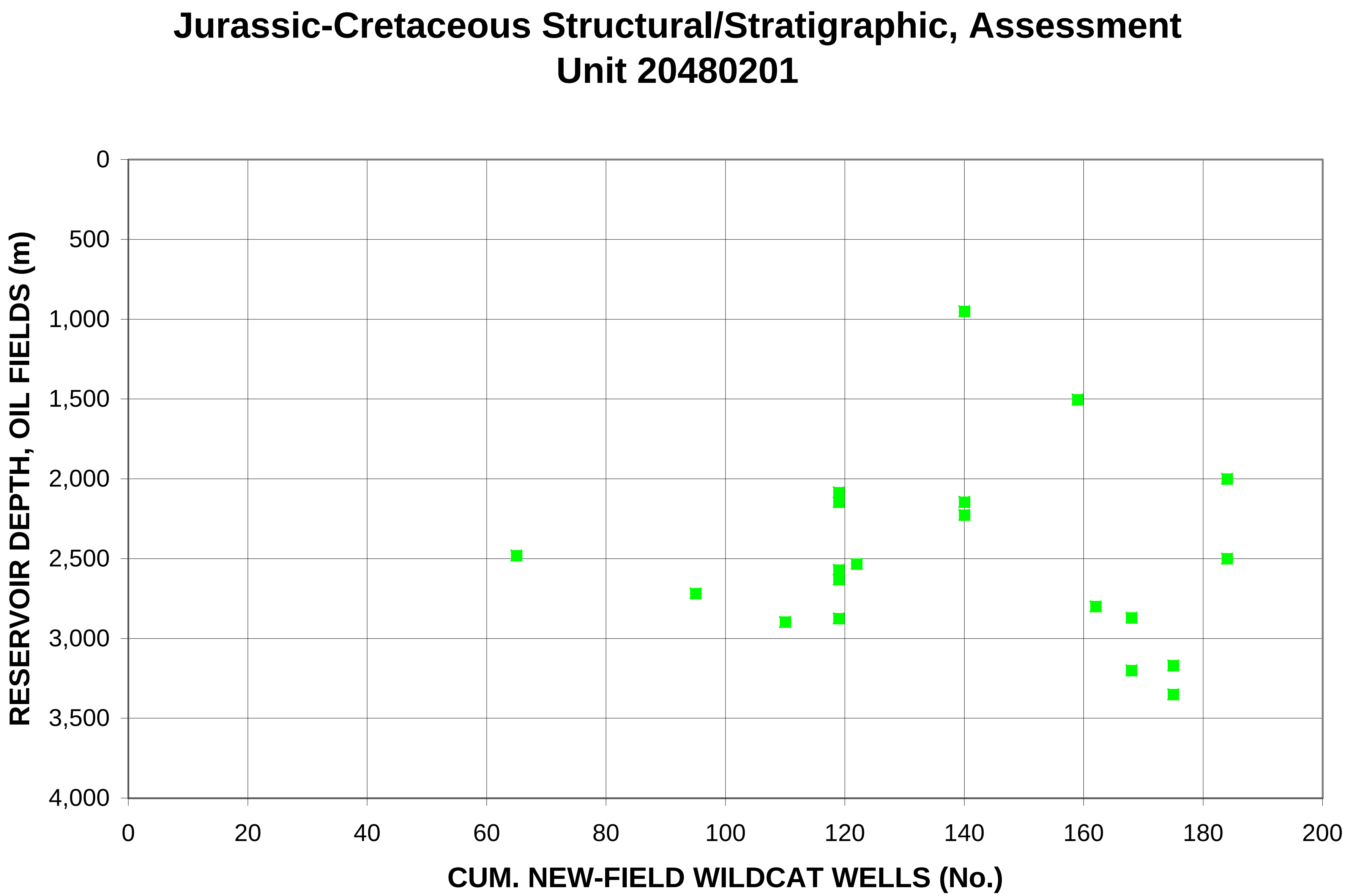


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



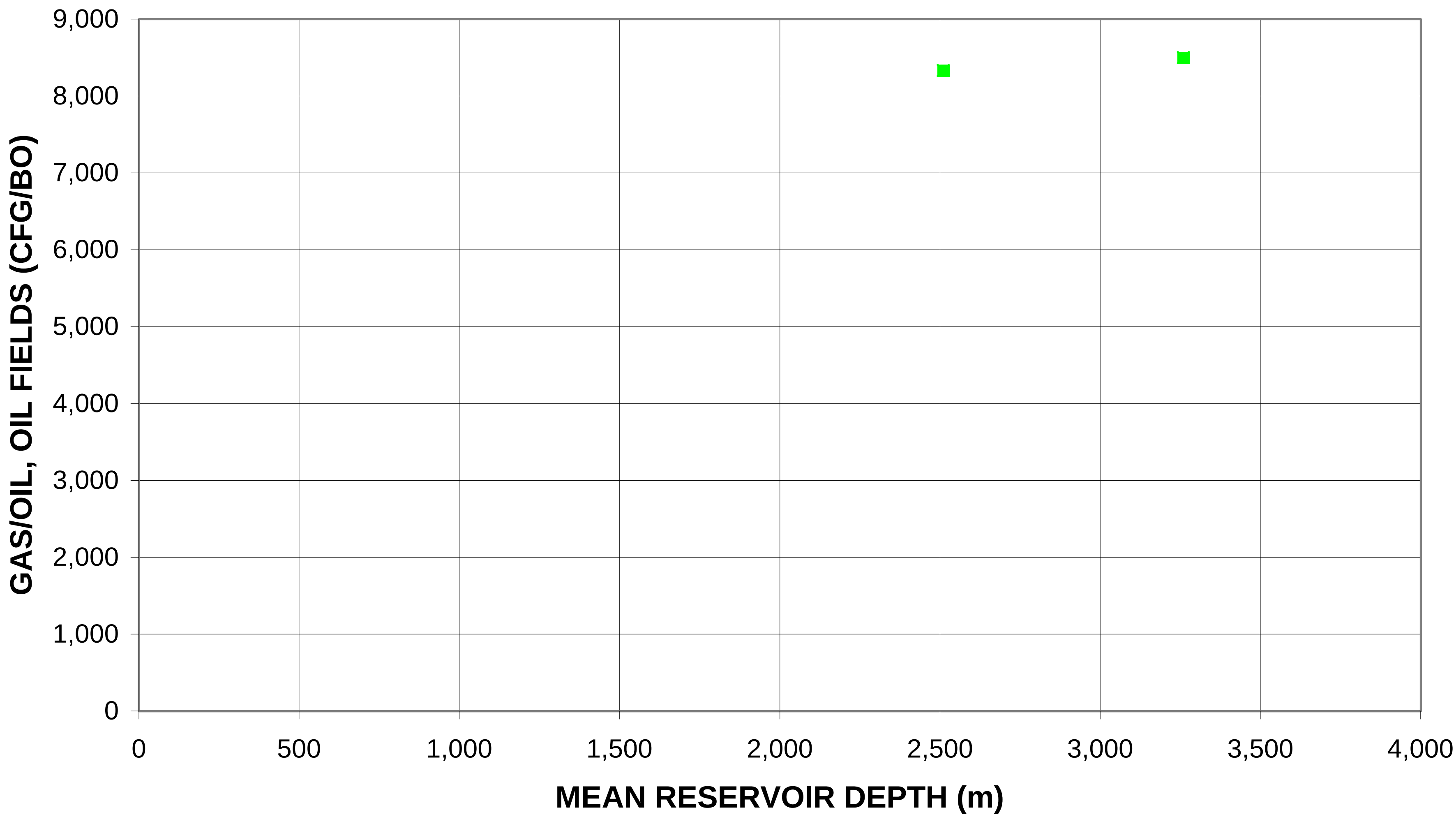
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



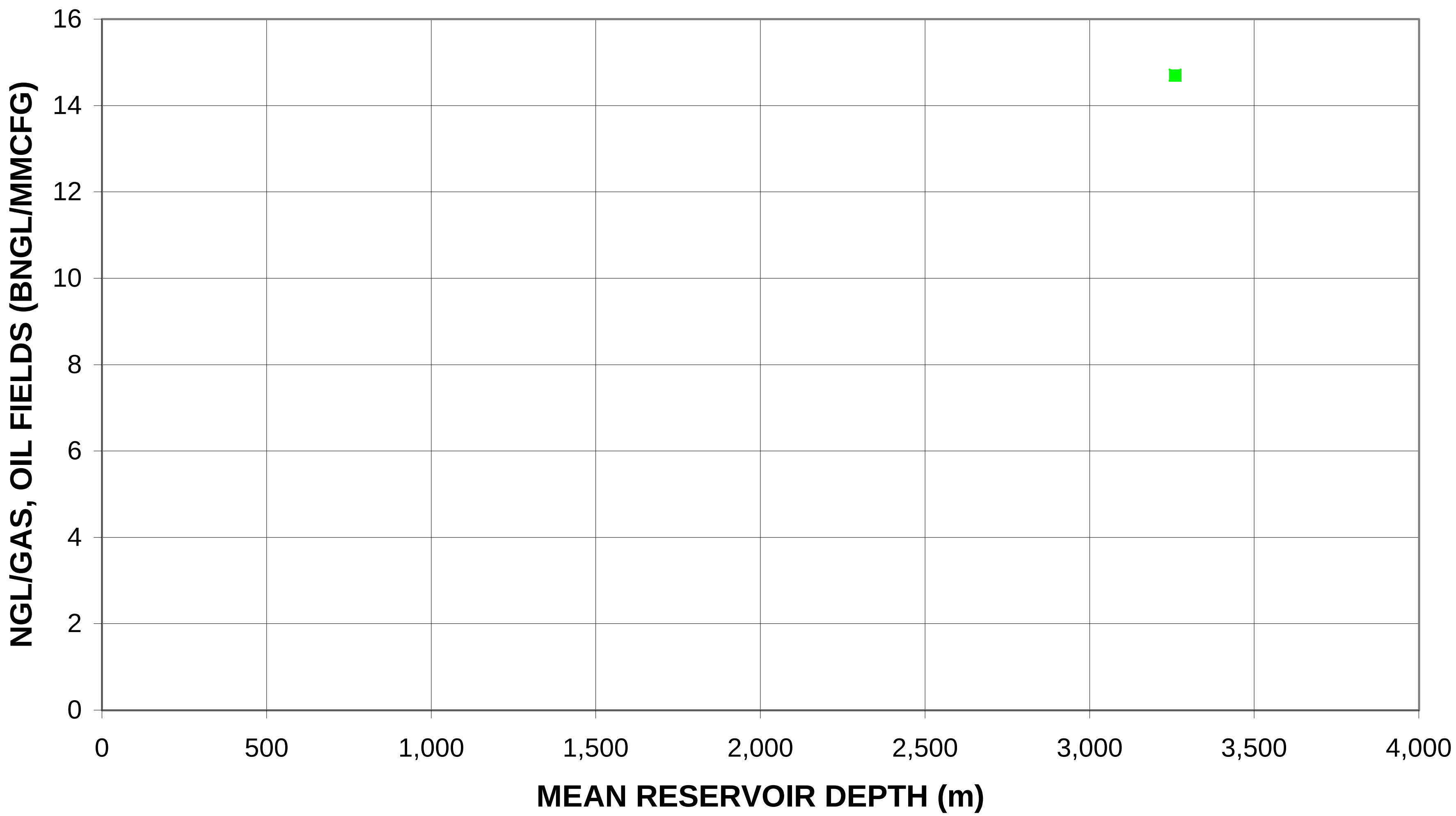


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
RESERVOIR DEPTH, OIL FIELDS (m)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
0
20
40
60
80
100
120
140
160
180
200
CUM. NEW-FIELD WILDCAT WELLS (No.)

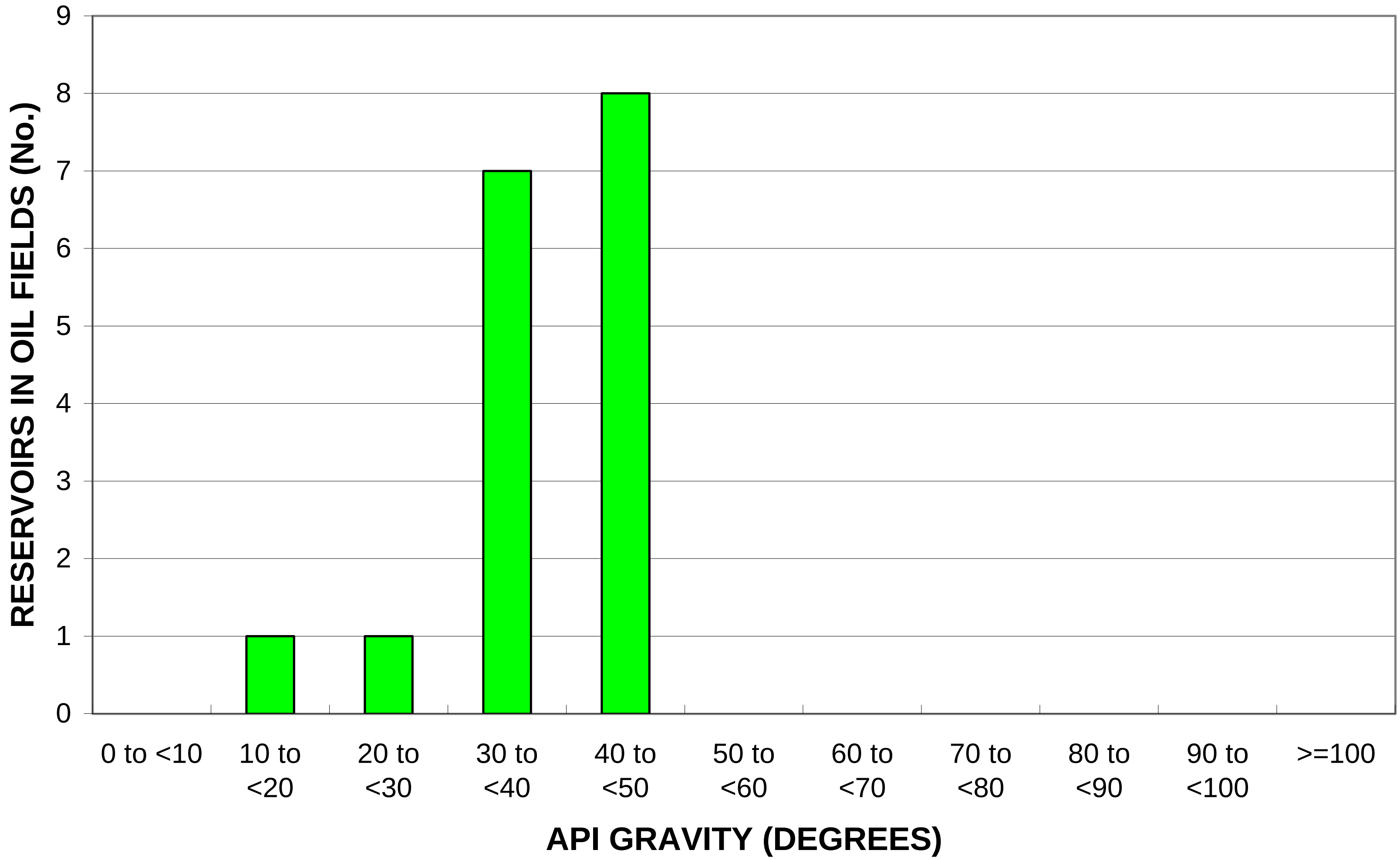
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



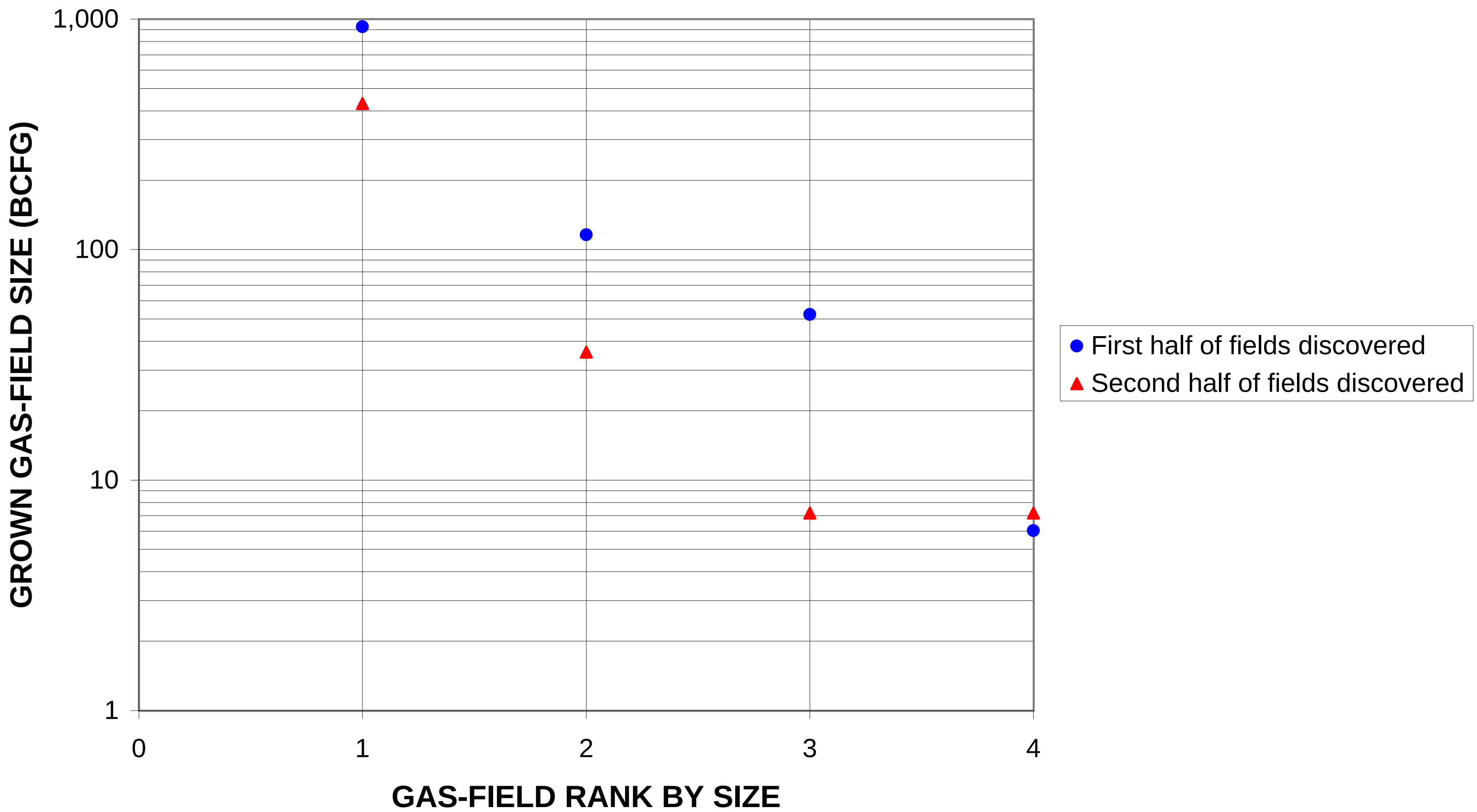
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



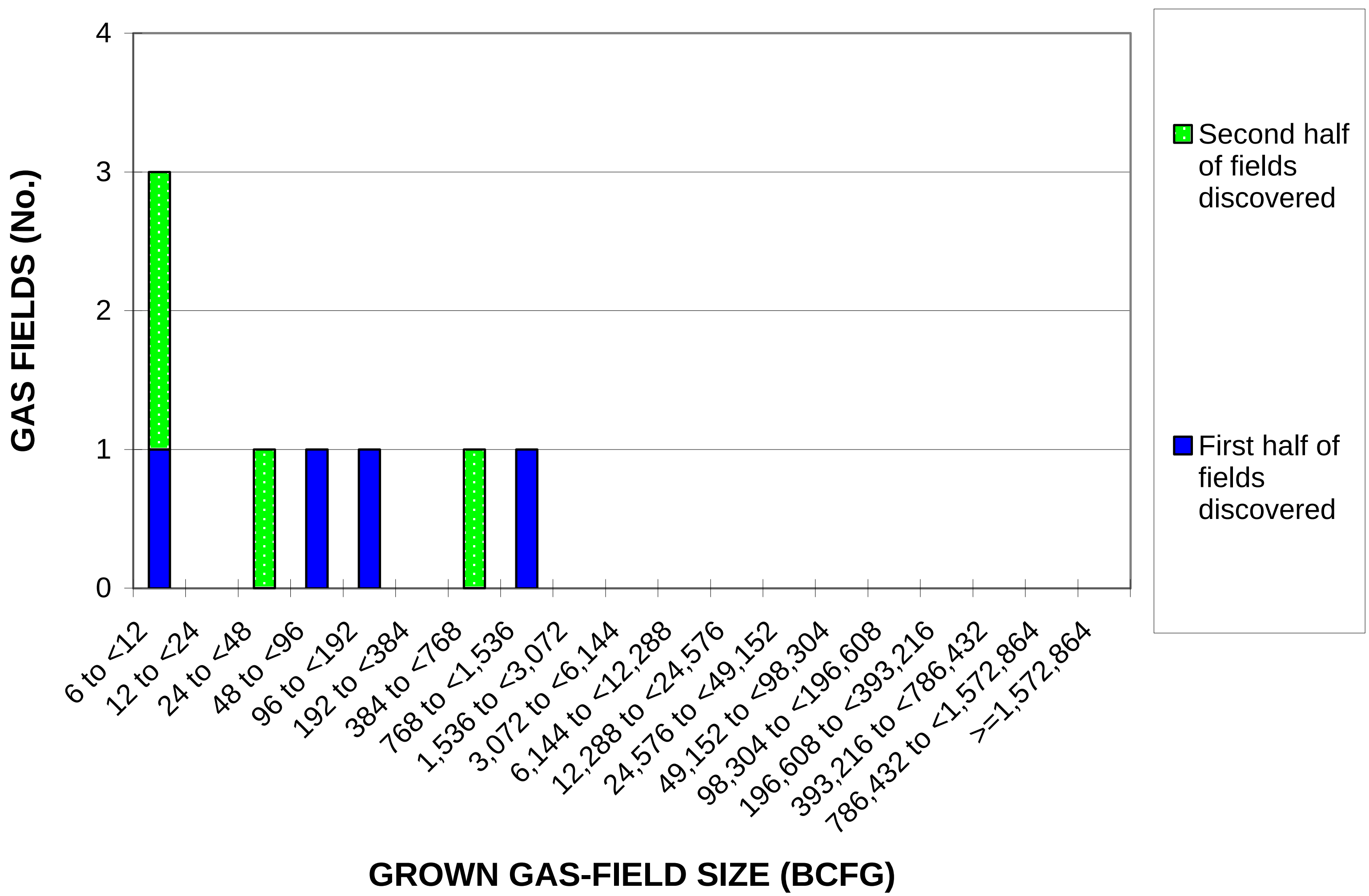
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



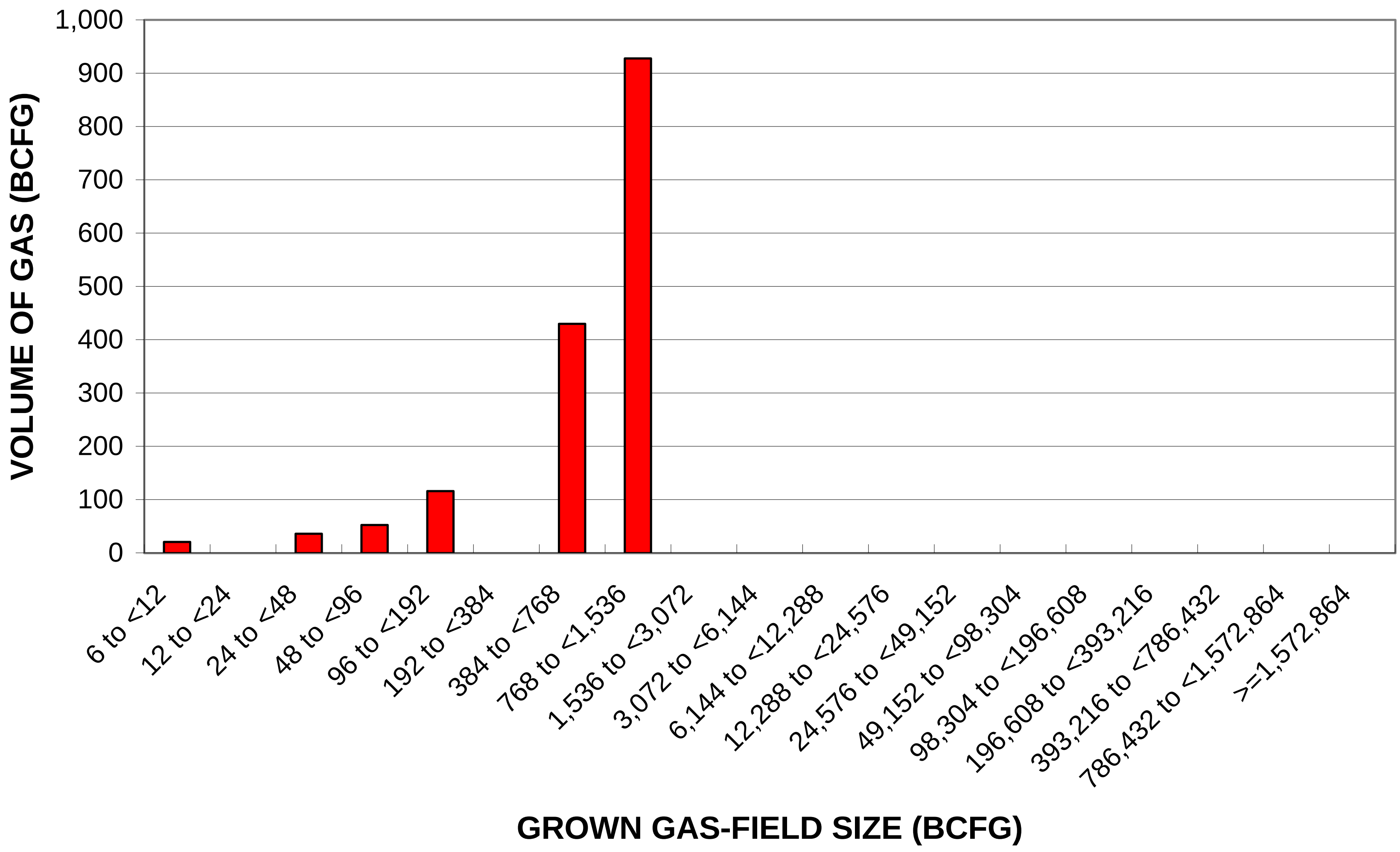
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



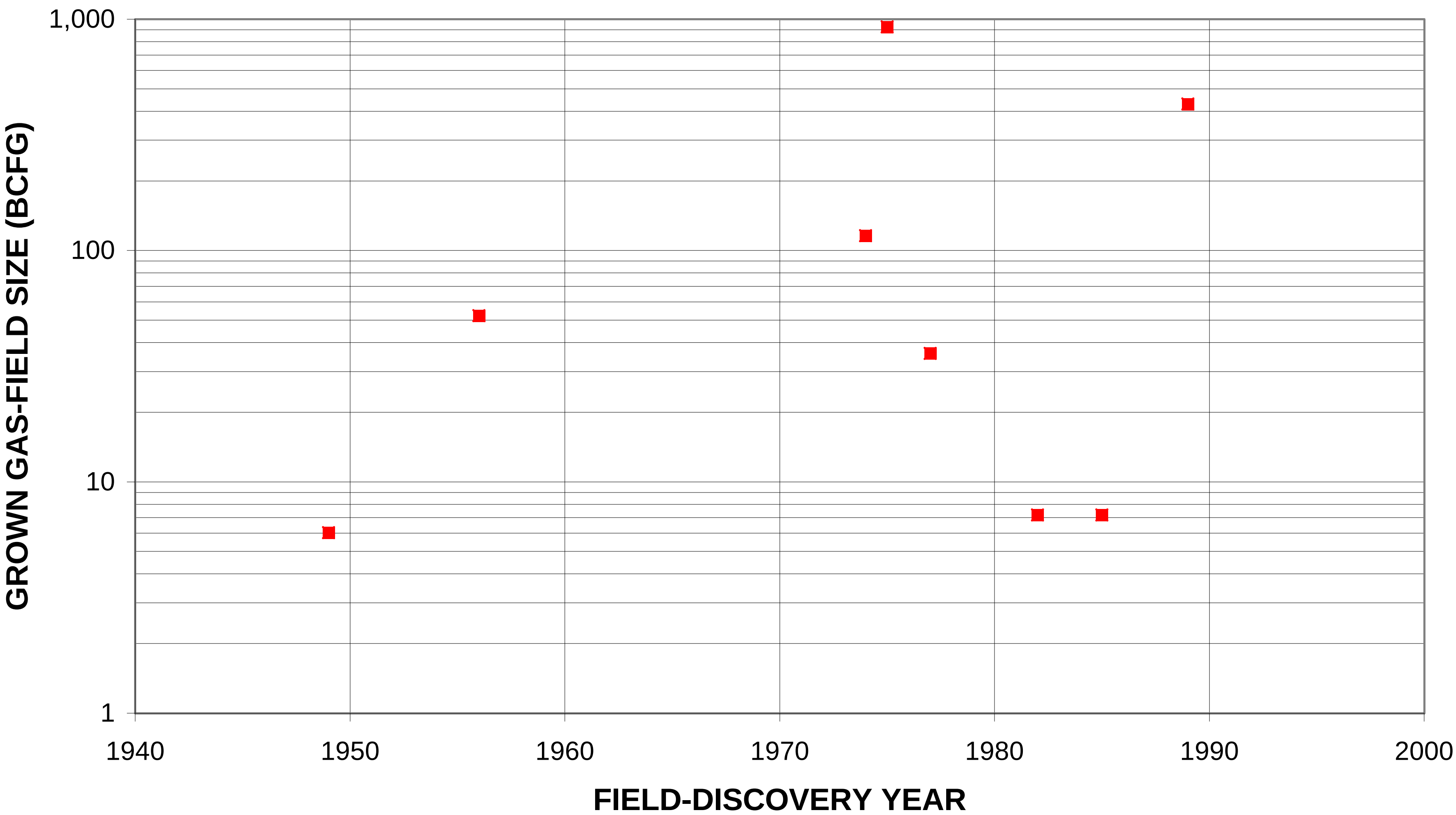
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



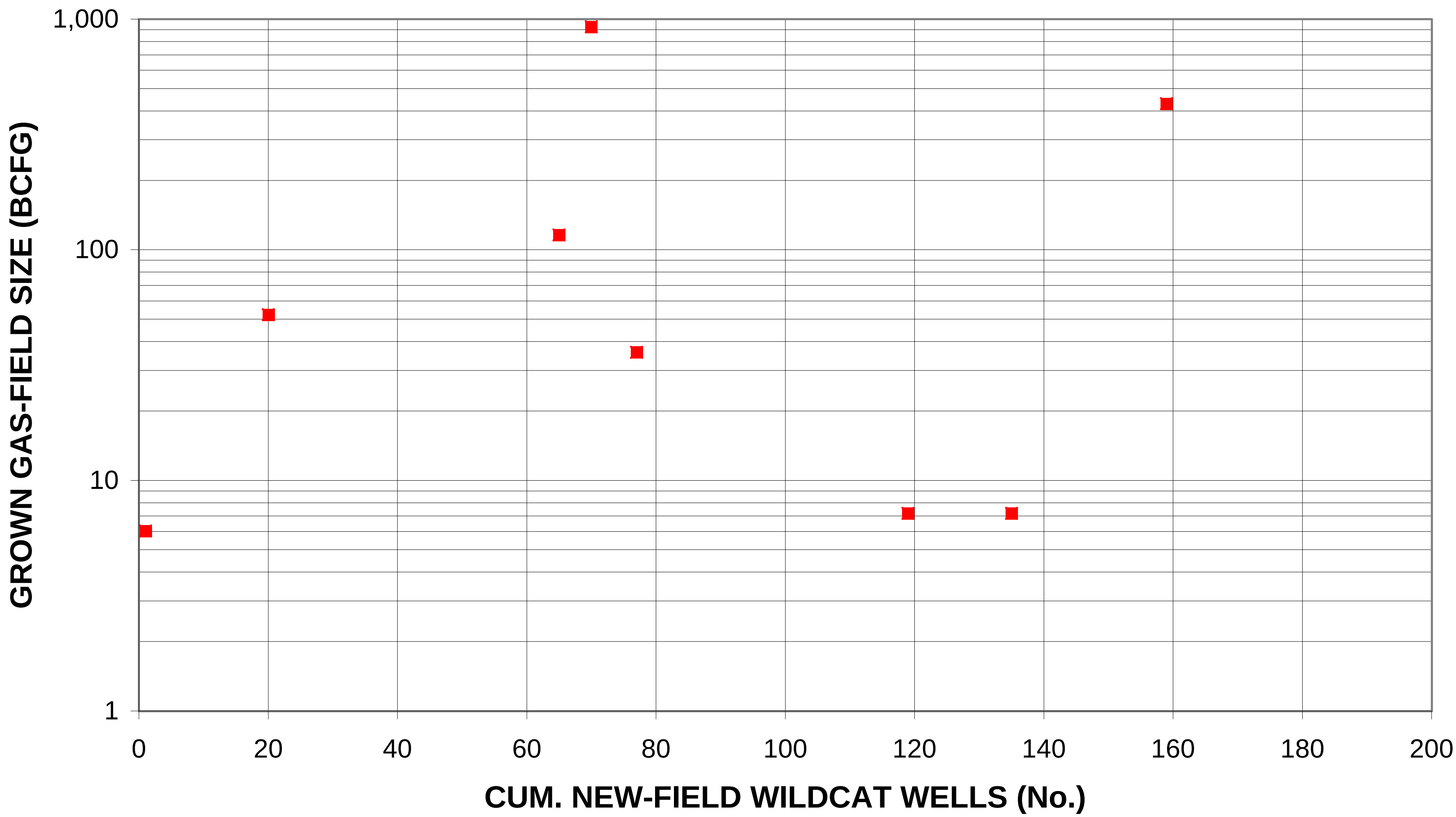
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

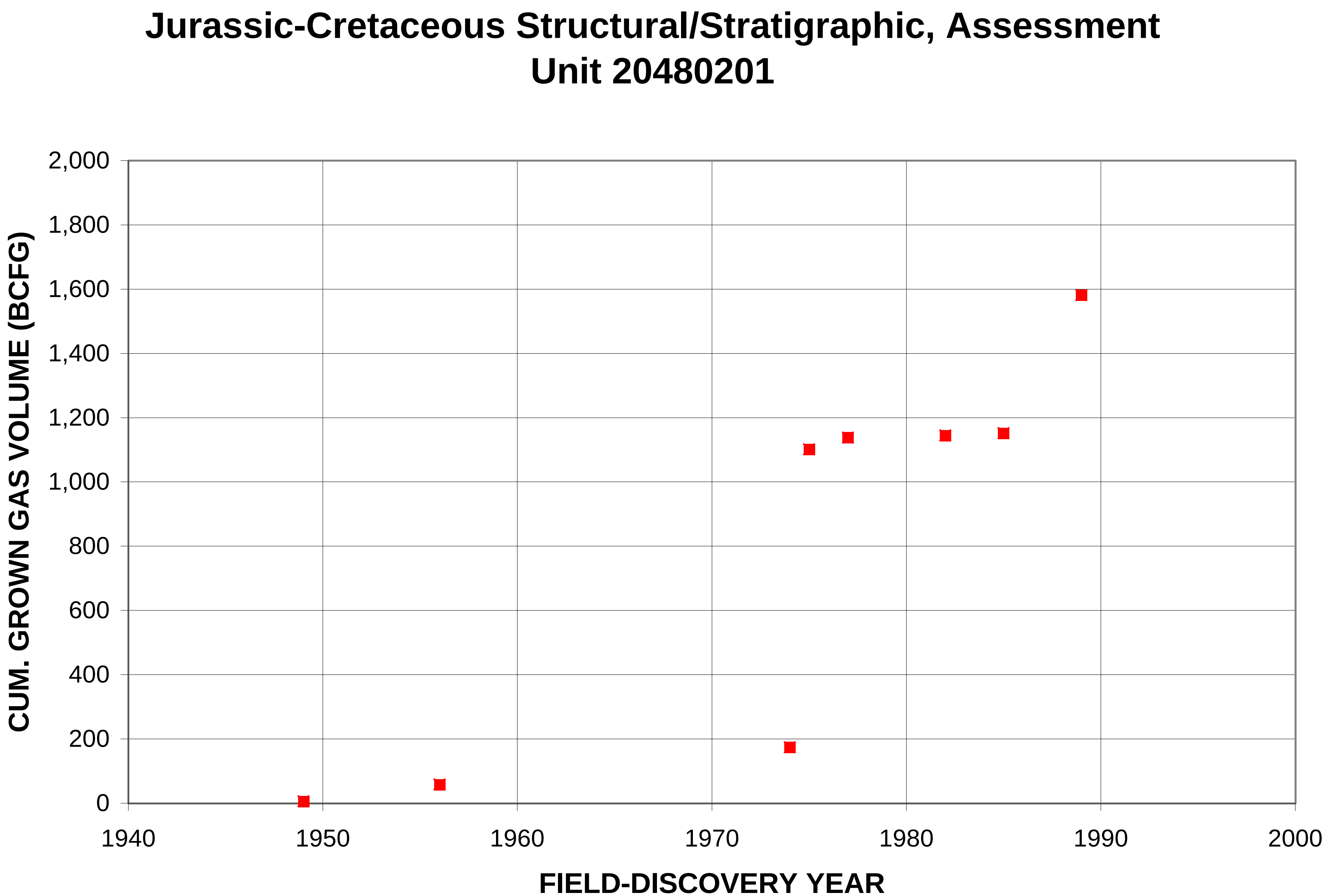


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

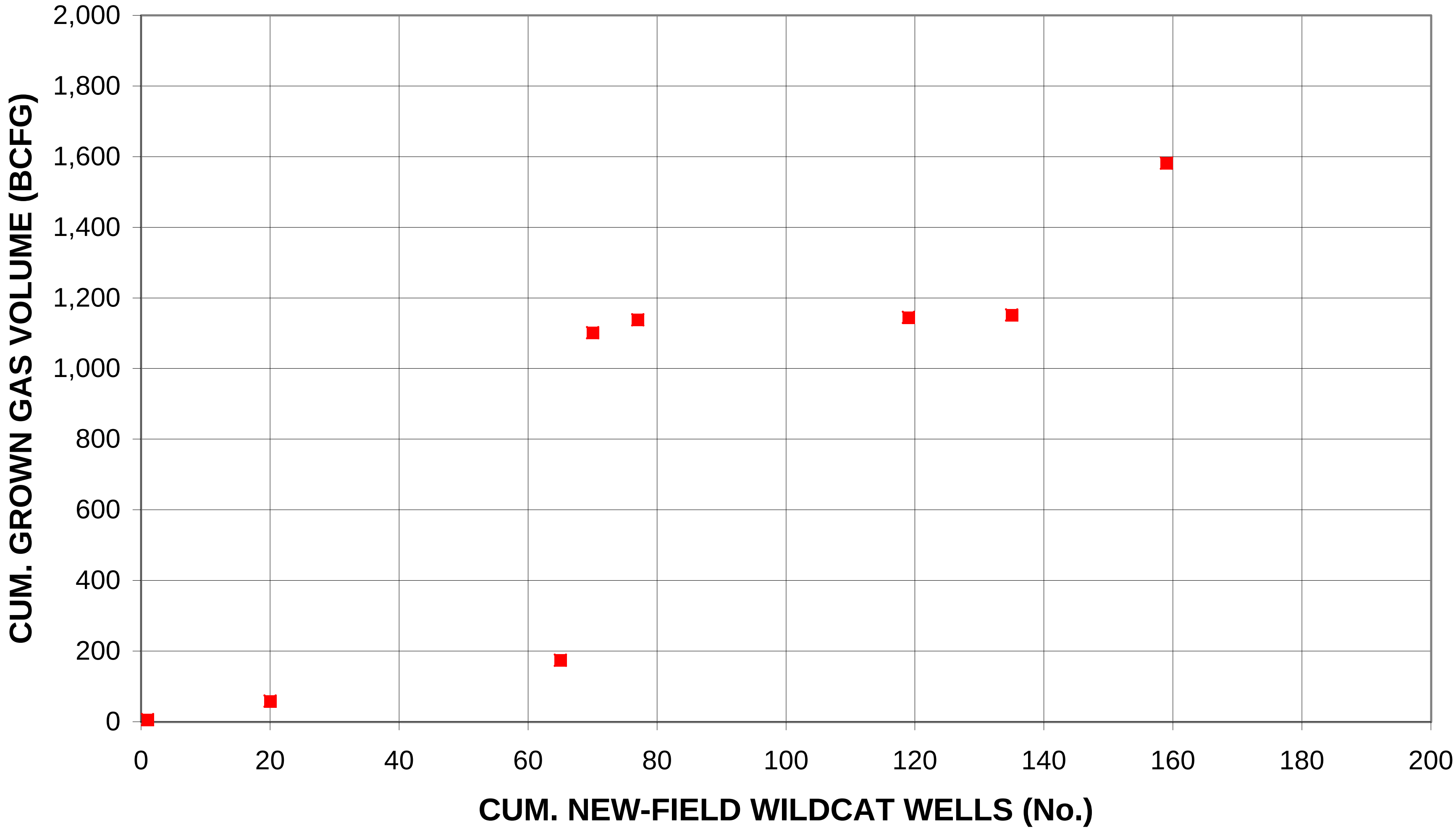


Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201

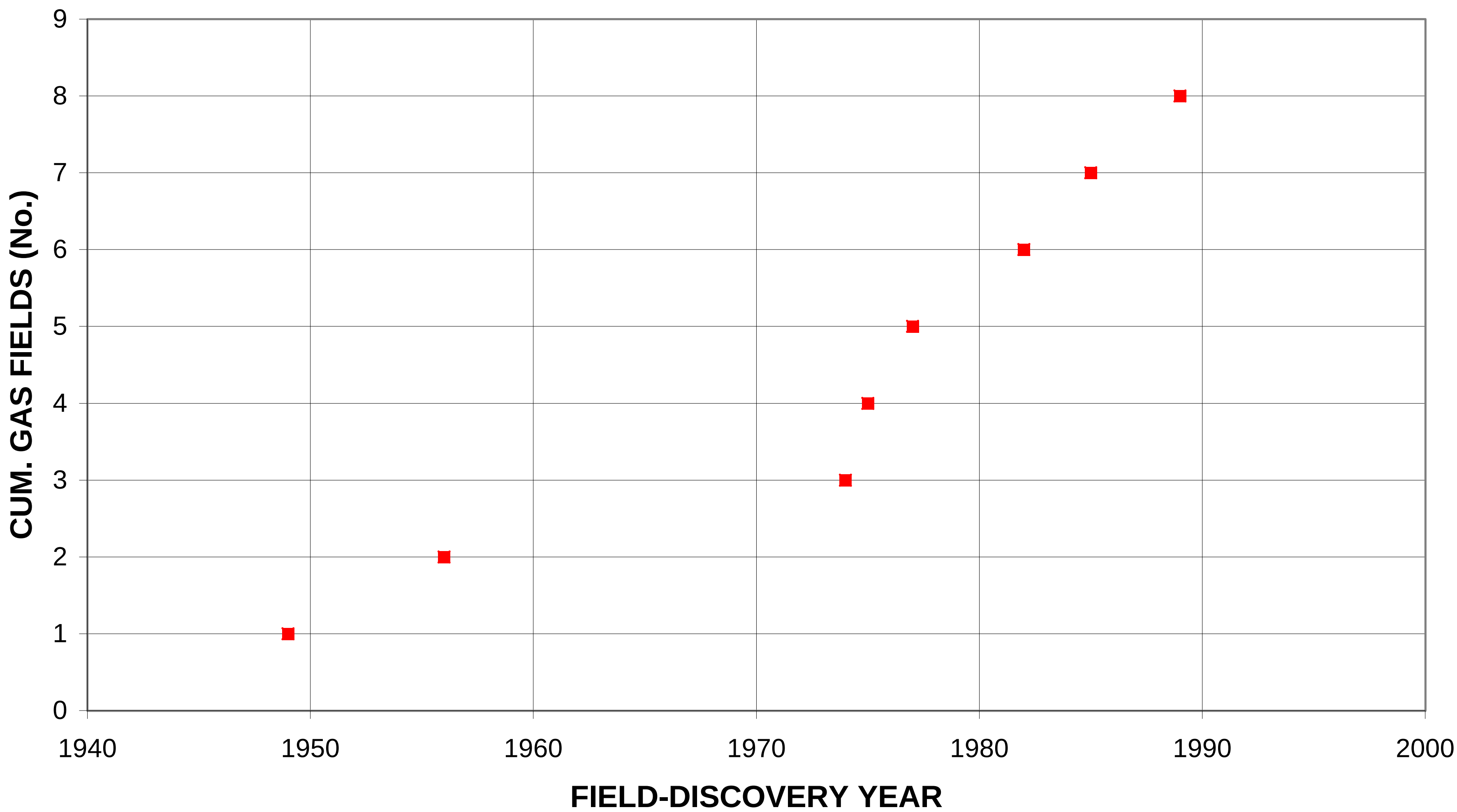



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201
CUM. GROWN GAS VOLUME (BCFG)
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
1940
1950
1960
1970
1980
1990
2000
FIELD-DISCOVERY YEAR

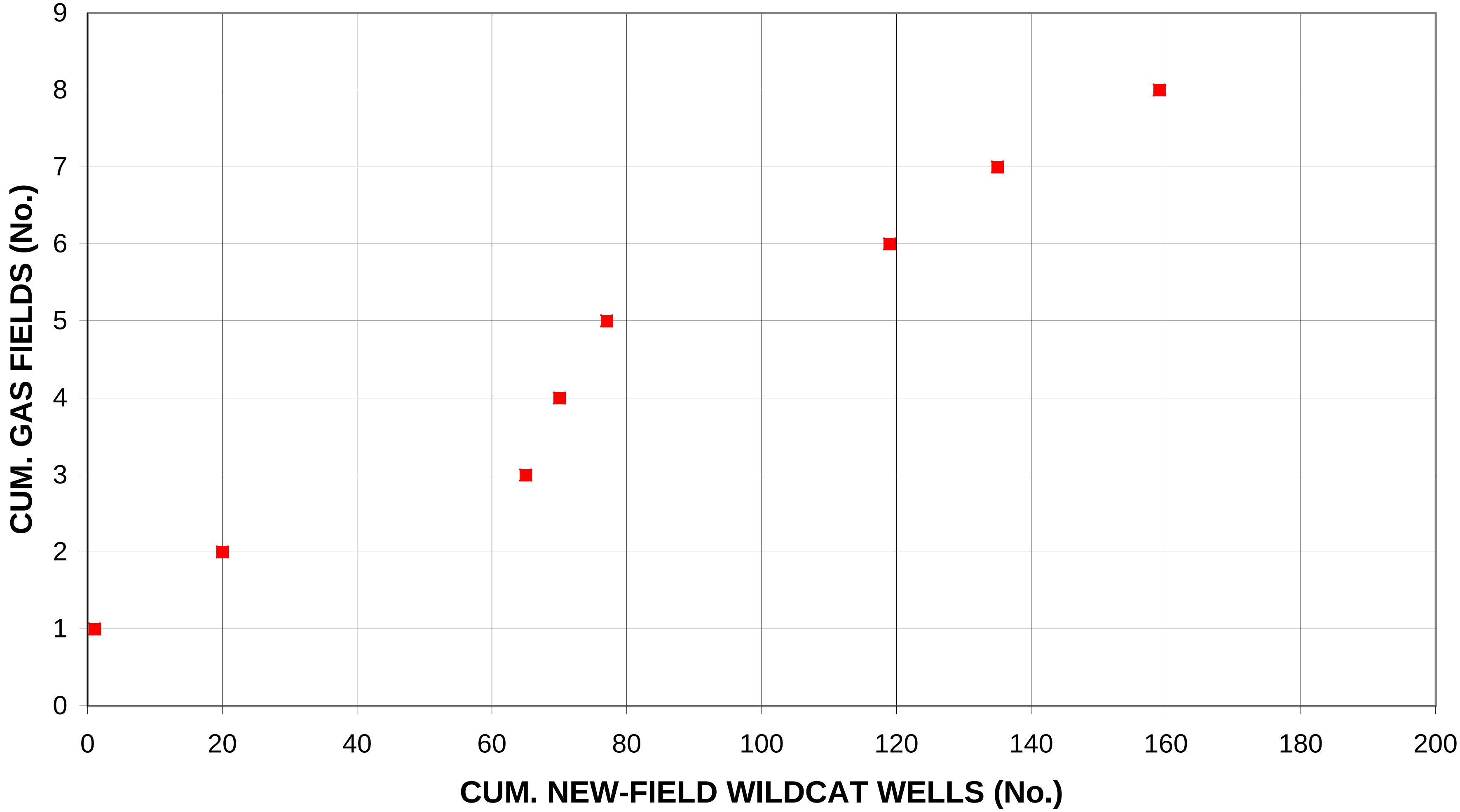
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



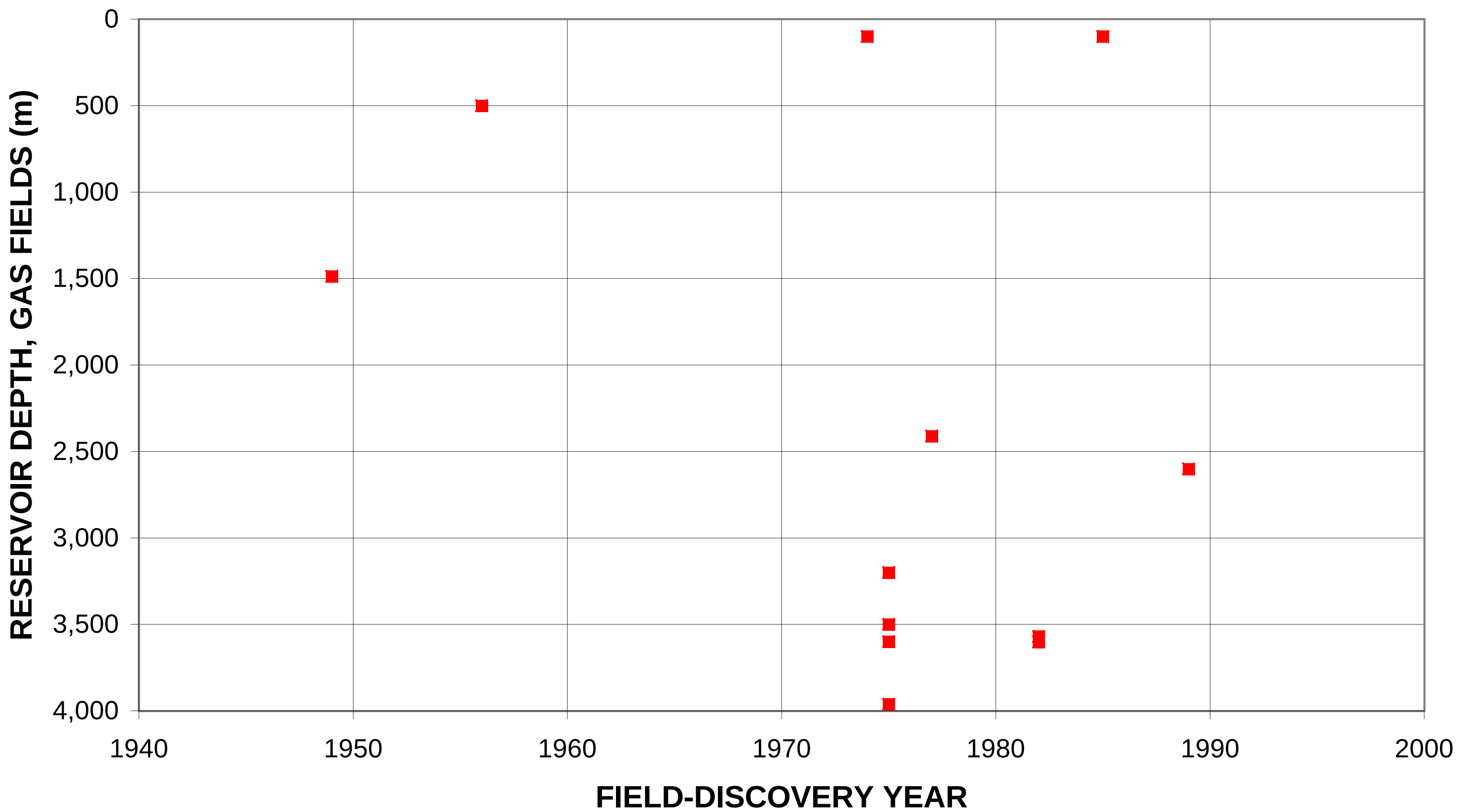
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



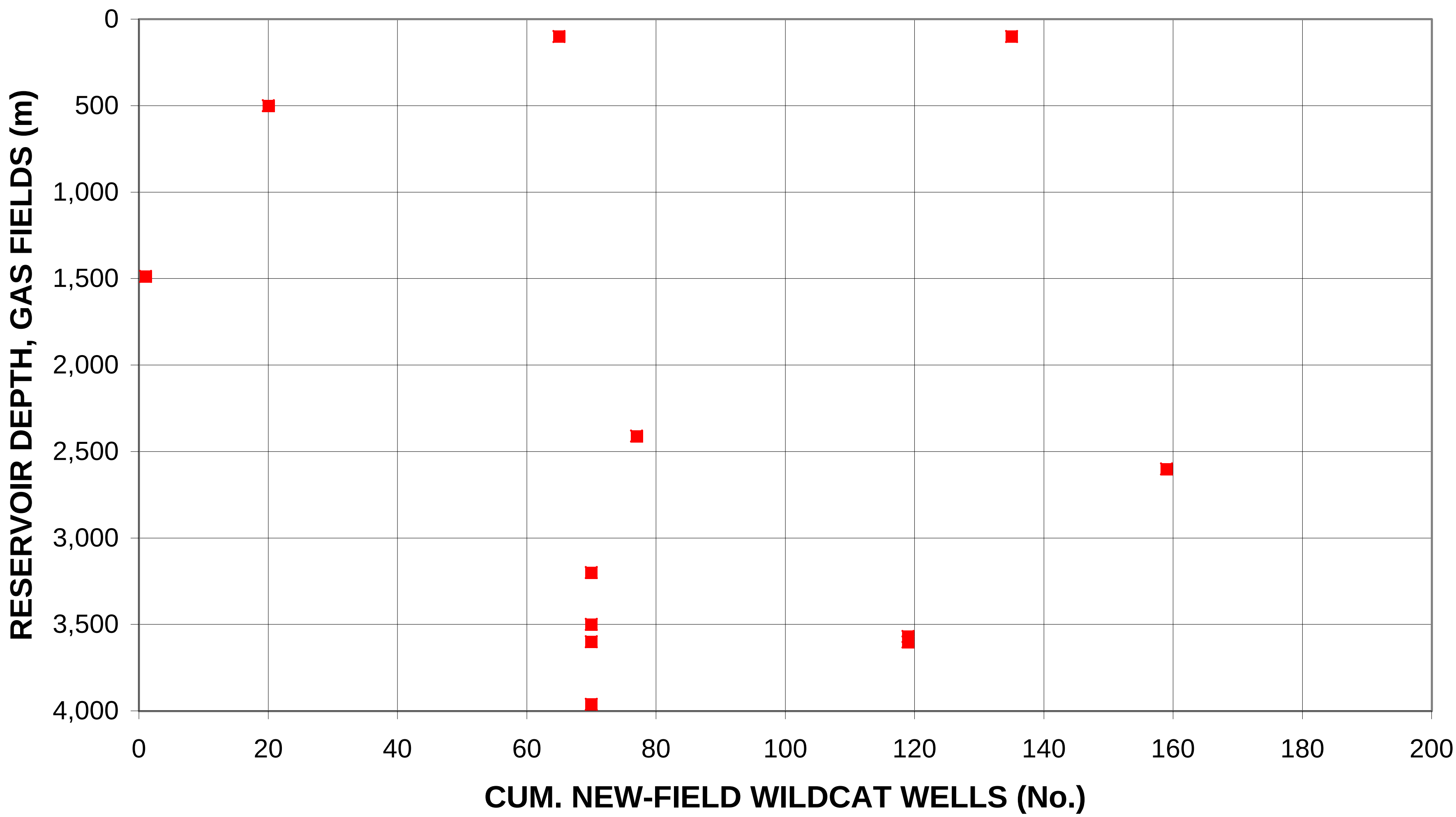
Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201



Jurassic-Cretaceous Structural/Stratigraphic, Assessment Unit 20480201