
Concepts, Technology, Price, and Access Drive Giant Field Discoveries

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This Memoir continues the AAPG Giant Oil and Gas Fields of the Decade series (Figure 1) initiated by Michel Halbouty in 1970 with AAPG Memoir 14, *Geology of Giant Petroleum Fields*. He continued the series in 1980 with Memoir 30, *Giant Oil and Gas Fields of the Decade, 1968–1978*; in 1992 with Memoir 54, *Giant Oil and Gas Fields of the Decade, 1978–1988*; and in 2003 with Memoir 78, *Giant Oil and Gas Fields of the Decade, 1990–1999*. A giant oil field is generally estimated to contain in excess of 500 million barrels of oil equivalent (MMBOE) estimated ultimate recovery. In this current volume, we are attempting to describe some of the more significant and representative fields discovered in the decade 2000 through 2010, all of which contain over 500 MMBOE estimated ultimate recovery (Figure 2). The decade of 2000 through 2010 is characterized by the rise of the “unconventional” plays. These are dominated by large regional accumulations in small microscopic pore throats. In addition to the unconventional accumulations, deep-water accumulations continue to have increasing importance in the global hydrocarbon budget.

This Memoir begins by looking at the global characteristics of the giant fields discovered in the decade 2000 through 2010. We then take a look at discovery trends and predictions from the current and previous decades and project those trends into the decade 2010 through 2020. In the field summaries, our objective is to document the type of trap for each field, followed by

a discussion of trap formation; the age of the reservoir rocks; and the source, generation, and migration of the hydrocarbons. Additionally, we look to the factor(s) that drove the final investment decision and how “Discovery Thinking” contributed to a field’s discovery. Finally, we look to understand why a field is important to oil and gas exploration; for instance, is a particular discovery the opening of a new play or a useful concept?

Looking at the discovery rate of giant fields since the late nineteenth century, at least four factors seem to control the frequency of discovery of giant oil and gas fields. These include concepts (e.g., geological models), technology, price, and access to drilling locations.

Many authors have discussed the importance of creativity in the exploration process. To paraphrase Halbouty (1970, p. 5) in Memoir 14, “Discovery Thinking” is a key to exploration that he succinctly described in the following language:

“As we make it a point to learn how these giant fields formed, we should study the modes of occurrence of the accumulations, the types of trap, how each trap formed and how it was found, the age of the reservoir and the age, or ages, of the sediments in which the petroleum generated and from which it was expelled and migrated to the trap. We should ask ourselves: first, what is usual about each

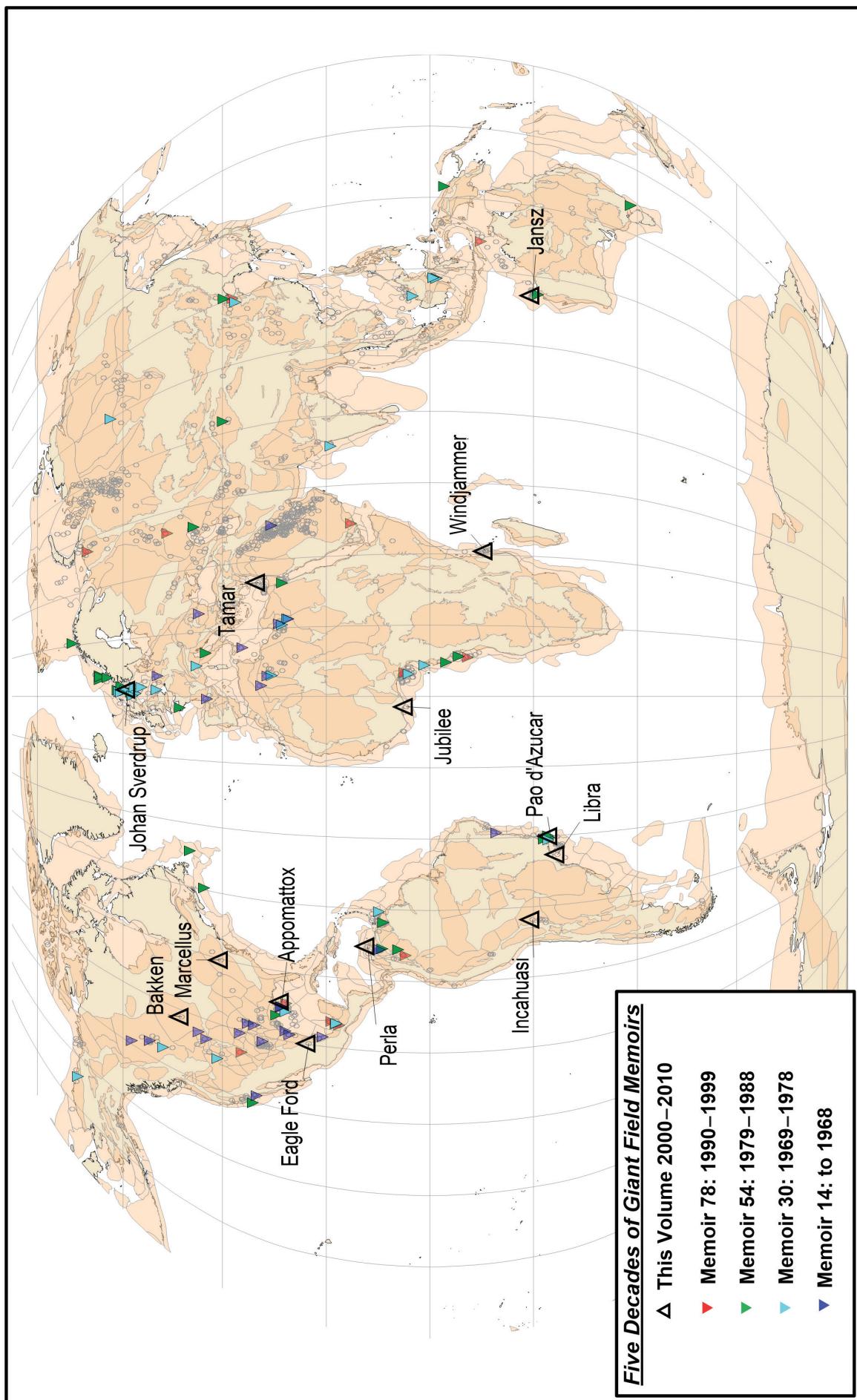


Figure 1. Five decades of Giant Field Memoirs. Open triangles indicating fields included in this volume.

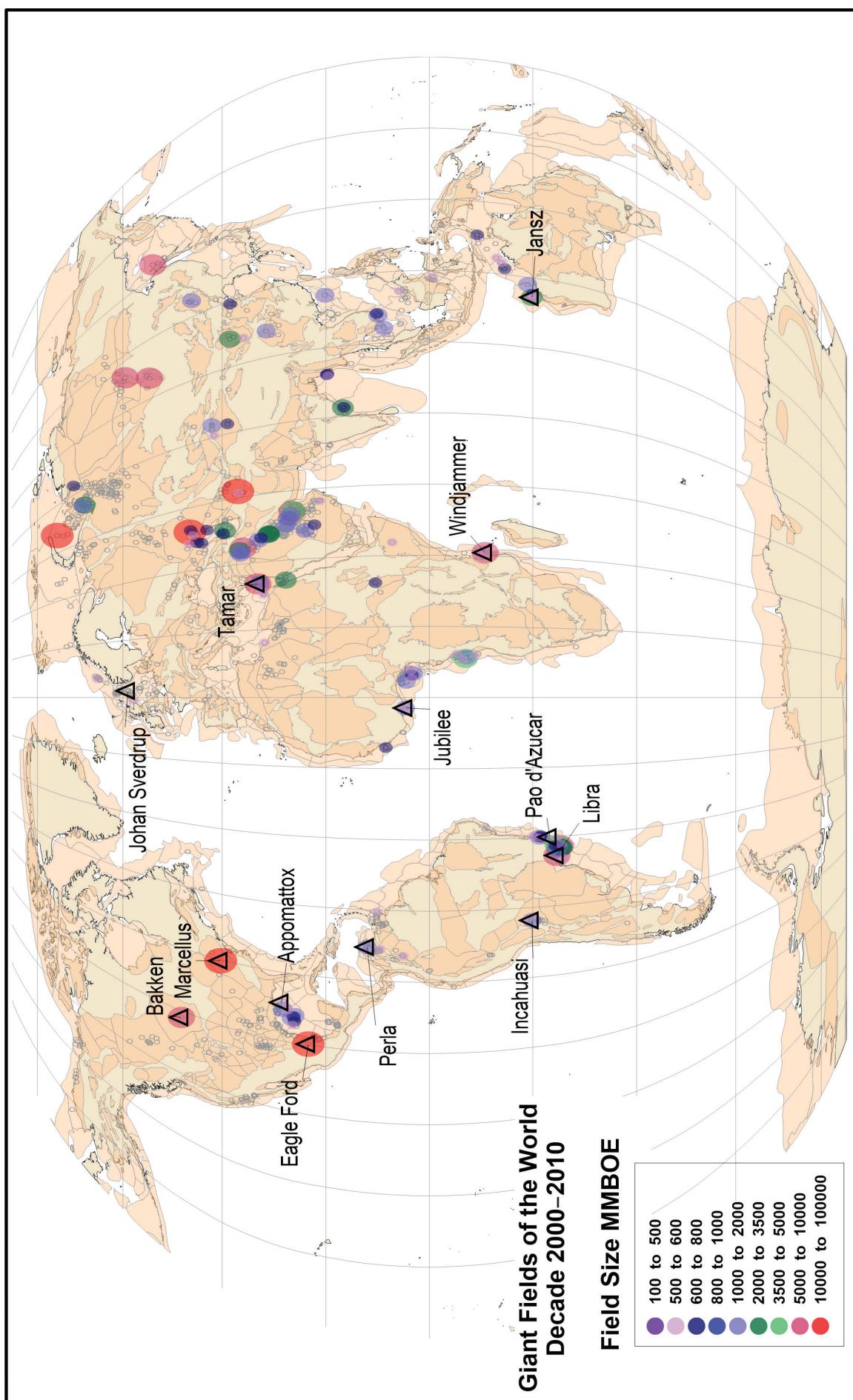


Figure 2. Giant Fields of the Decade discovered between 2000 and 2010 and currently estimated field size. Open triangles indicating fields included in this volume.

of these accumulations? And second, what is unusual? Then we must concentrate on the unusual, for commonly it is that unusual aspect which is the key to accumulation. Prejudiced ideas should be discarded, for it is these old, ingrained, hard-nosed prejudices which also stifle exploration; old prejudices must not be tolerated in our thinking of the future."

Figure 3 highlights the giant fields by the decade in which they were discovered. In general, the number of giant field discoveries was greatest in North and South America until about the middle of the twentieth century. Discoveries in the Middle East picked up in the 1920s with the discovery of Kirkuk. In the 1950s, the number of discoveries picked up in Russia and the Middle East, and the largest fields continued to be in the Middle East. In the decade 2000 through 2010, unconventional development in North America dominated the size of giant field discoveries. Other important discoveries in this decade included offshore subsalt development in Brazil and new gas fields in Tanzania and the eastern Mediterranean.

Figure 4 shows that the relationship between price and the number of giant field discoveries was not particularly correlated until the Organization of Petroleum Exporting Countries (OPEC) embargo in the 1970s. Following the price peak around 1981 and the following recession, the discovery rate declined by over 50% until early in the decade 2000 through 2010 when the price began to increase, leading to more discoveries. Interestingly, discovery volumes (Figure 5) decreased on a decade-by-decade basis between 1970 and 1990. The most dramatic increases were 1890 through 1900 with the discovery of Midway-Sunset and Kern River in California and 1920 through 1930 when Kirkuk (Iraq), Gachsaran (Iran), and Tia Juana (Venezuela) were discovered.

The evolution of geologic concepts that control the accumulation of oil and gas has evolved from the later decades of the nineteenth century when exploration was focused on oil seeps, beginning in 1868 with the discovery of La Brea Field in the Talara Basin, Peru, then Azerbaijan and the United States (i.e., California and Pennsylvania). Recognition of the importance of anticlines dominated the first half of the twentieth century, so surface mapping was recognized as a critical exploration tool.

Petrophysical tools began to be developed in 1927 with the first multielectrode electrical survey in a wellbore; shortly thereafter came the first resistivity log in 1929. Logging tools to detect hydrocarbons continued to develop until the decades 1940 through 1950 and 1950 through 1960 with the development of

the petrophysical tools commonly used today (sonic logs, density logs) and development of reservoir characterization beginning with Archie's law in 1941. Our understanding of reservoirs truly began to increase with magnetic tape recording and processing of logs from tape. The first digitized log tape was on location about 1965, but it took until 1977 for a logging truck to be equipped with a computer. The 1970s also saw the first desktop computer-aided log analysis system introduced and the beginning of remote sensing using space imagery.

The use of seismic as an exploration tool began in 1914 when seismic tomography was used to delineate salt domes in Germany, and the first reflection seismograph survey was shot 1921, near Ardmore, Oklahoma. Seismic sources and tools developed through the 1950s and 1960s, and digital seismic recording began around 1963. Processing advances followed in the 1970s when seismic data were presented in color, seismic attributes were introduced, seismic inversion was introduced, seismic stratigraphic interpretation was developed, and bright spot technology was developed at Shell. In the 1970s, color presentation of seismic data was implemented, and seismic stratigraphy together with seismic attributes became common tools. Seismic attribute analysis matured in the 1990s, and the implementation of pattern recognition and neural network analysis was introduced in the 1990s.

By the year 2000, geological tools were available, including the anticlinal theory of accumulation and fracture systems; geochemistry of source rocks; subsurface mapping; petrophysical tools; and seismic acquisition, processing, and interpretation. To complete the story, it is important to note that the first reservoir stimulation was done using gunpowder in 1865, and the first hydraulic fracturing technique was developed and patented in 1949. Drilling technology progressed from the twin-cone roller bit to the tri-cone bit in 1935. The diamond bit was introduced in 1941. Offshore production began in 1897 in Summerfield Field, California, followed by barge drilling in Louisiana in 1911 with the Gulf #1 Ferry Lake. In 1948, the Kermac #16 was drilled 10 miles offshore in Louisiana. Measurement-while-drilling was described around 1964 and was first used in an offshore well in 1980. Horizontal drilling began to be utilized extensively in the 1980s. Finally, coiled tubing drilling began around 1991, and the first hybrid coiled tubing drill rig was developed in 1997.

The decade 2000 through 2010 can be thought of as the beginning of the unconventional revolution. The integration of rock mechanics using geology, geophysics, and engineering in this decade led to new workflows for geologists, geophysicists, and engineers

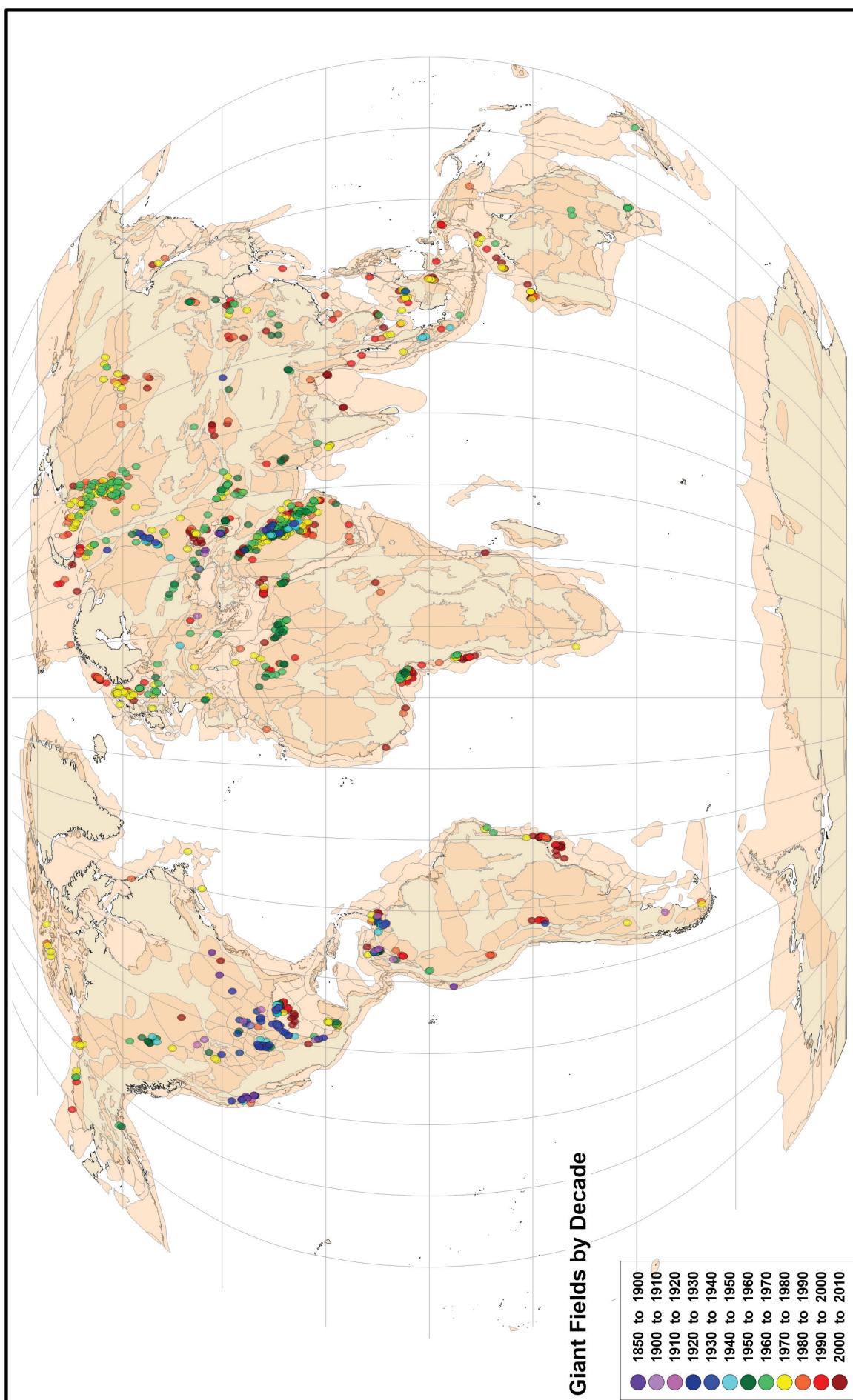


Figure 3. Giant Fields of the world by decade of discovery.

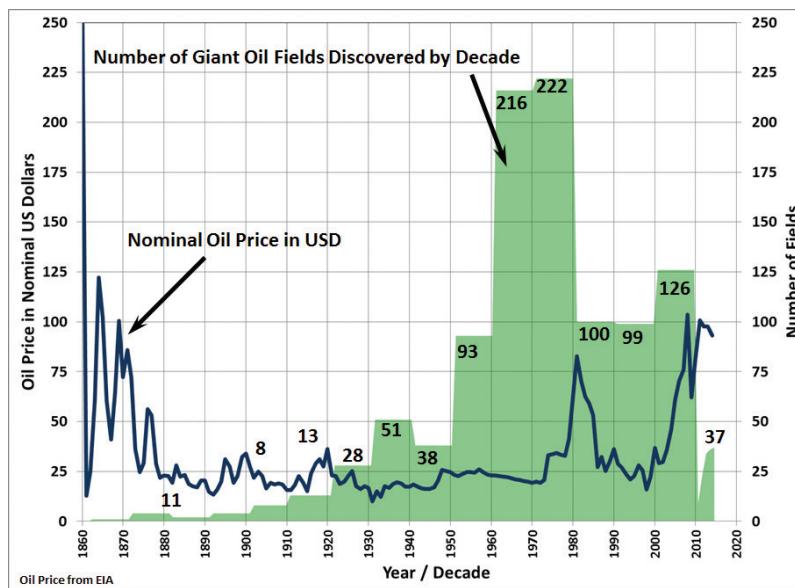


Figure 4. Number of giant oil fields discovered by decade and nominal oil price in US dollars.

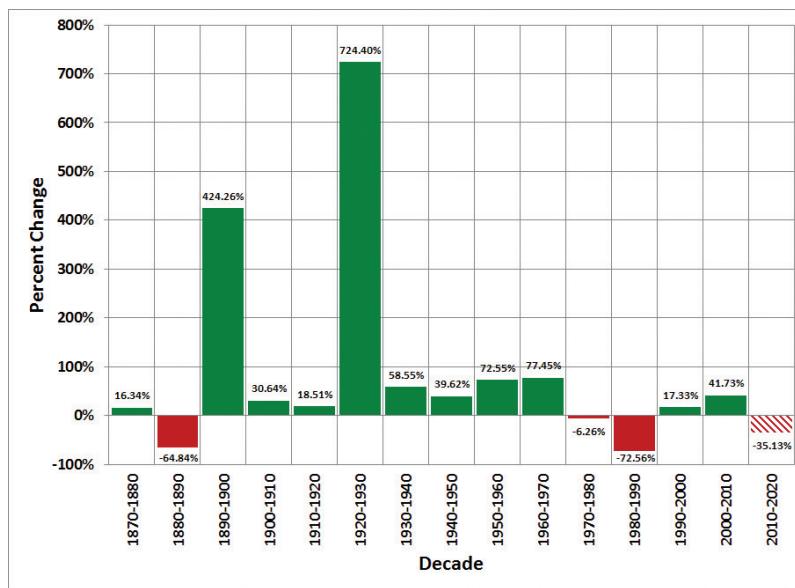


Figure 5. Percent change by decade of giant fields discovery.

to complete wells in reservoirs previously considered too tight for economic production. This integration brought together intensive core analysis and new sample imaging techniques to characterize the pores in low-permeability rocks. As discussed by Carmalt and Moscariello in this volume, these basin-scale accumulations are recognized as giant accumulations, but statistically, these accumulations are a separate population from conventional accumulations.

In summary, all giant accumulations have common attributes of a petroleum system, including reservoir,

trap, seal, source rock, and generation and migration of hydrocarbons. Reservoir porosity and permeability extend from systems that will give up hydrocarbons without stimulation to those requiring significant hydraulic fracture stimulation. Traps and seals can be regional in the case of continuous hydrocarbon deposits (unconventional), or they can be confined to smaller areas by structural and stratigraphic conditions (conventional). All petroleum systems require that an organic-rich source rock be mature, but in the case of unconventional accumulations, the hydrocarbons

have not migrated out of the source rock, so the source rock is also the reservoir.

Traditional roles in discovering giant fields over previous decades included the “rockers” (geologists well versed in reservoirs), the “trappers” (geophysicists mapping the geometry of accumulations), and the “sealers and the sourcers” (explorers following source rock and seals). More than ever, successful giant field discovery in the decade 2000 through 2010 was led by the “integrators.” “If you know how to hammer, every problem is a nail. Modern explorers need to diversify their tool kit” (Steven Getz, 2015, personal communication). Basin analysis, geochemistry, cutting-edge seismic imaging, and rock mechanics have become important additions to the explorer’s

skill set. The ingenuity of combined disciplines continues to meet the demands of an energy-hungry world.

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