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## What Is a Giant Field?

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### ABSTRACT

Study of giant oil and gas fields is useful not only to understand oil and gas habitat but also because statistical analysis of these data sheds light on future energy supplies. In such statistical studies, the definitions of both “giant” and “field” are important. The development of giant accumulations that are not fields increases the resource supply but can simultaneously decrease the accuracy of resource estimates and production forecasts unless care is taken with definitional issues.

### BACKGROUND

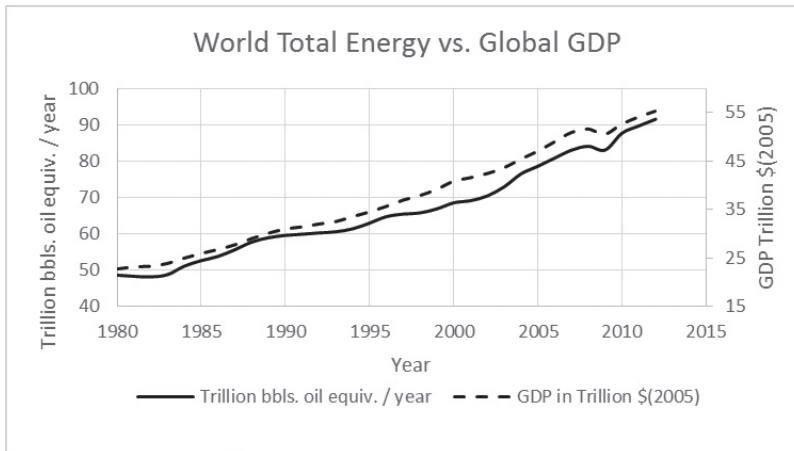
This volume is the fifth in a series of AAPG Memoirs that focus on the giant oil and gas fields.<sup>1</sup> As Michel Halbouty correctly observed in his introduction to the first volume in 1970, the giants play a disproportionate role with respect to both hydrocarbon reserves and hydrocarbon production. And as Grunau (1983) observed, the giant fields frequently provide the best data available on what has been discovered. Because oil plus natural gas account for over half of the global energy supply (IEA, 2014), their contribution to the global economy is a subject of interest and commentary far beyond the science of geology. Inclusion of the unconventional reserves and production from Canadian oil sands, and the continuous Bakken oil play and Marcellus gas play, have been cited for a range of opinions far removed from the science of geology.

<sup>1</sup>The AAPG Memoirs are Memoir 14 (Halbouty, ed., 1970); Memoir 30 (Halbouty, ed., 1980); Memoir 54 (Halbouty, ed., 1992); Memoir 78 (Halbouty, ed., 2003); and this volume.

Over the past two centuries, fossil fuels have become critical to the functioning of the economy. Oil’s role has been particularly important, with much of the world’s economic progress over the past century being ascribed to readily available oil (e.g., Hall and Klitgaard, 2012). The economic well-being of society is closely aligned with its energy supply (e.g., Tverberg, 2011), as shown in Figure 1.

Particularly when oil prices are high, discussion turns to how much oil resource remains on this finite planet. Such a peaking of interest occurred in the 1970s (e.g., Haun, 1975), and there has been renewed interest in the subject over the past decade of high prices. The issue of remaining resources is complex, involving not only raw material availability, but also questions of economics, technology, population, and ecology, to name but some areas of interaction. Political policy decisions are inevitably made and as scientists we can only strive to make our inputs into such discussions as objective as possible.

The giant oil and gas fields are especially important because of their disproportionate contribution to the total oil and natural gas resource. Different



**Figure 1.** Relationship between global GDP and world energy (sources: BP, 2014; World Bank, 2015).

approaches to using the data that the giant fields provide can result in different outlooks on the question of the remaining resource. But unless the definition of a giant field is explicit, each contribution is unique and cannot be compared with other studies. They thus fall short of the objective standard to which we aspire.

For example, Horn (2007) uses the giant field data to predict that giant fields eventually will account for only about 40% of the total amount of oil and gas recovered, whereas Nehring (2010) argues that reserve growth from existing giants will make them a more, rather than a less, important source of oil over coming decades. Deffeyes (2001) suggests that a major increase in reserves will require discovery of at least one field larger than Ghawar. Despite the current importance of oil sand deposits and the continuous deposits such as the Bakken and Marcellus in production statistics, the objective question is whether these should be included in the statistical data for giant fields or whether they represent fundamentally different types of hydrocarbon accumulation. Distinguishing between such different types of deposit is common in studies of other economic resources<sup>2</sup>; for example, hydrothermal gold veins are clearly different from placer gold deposits.

## CURRENT GIANT FIELD DEFINITION

The more recent compilations of giant fields by Horn (2003; this volume) include a definition for a giant field from Carmalt and St. John (1986): "...a giant oil or gas field is considered to be one for which the estimate of ultimately recoverable oil is 500 million bbl of oil or gas equivalent. Gas is converted to oil at a ratio of 6,000 cu ft/bbl.

Some fields are, therefore, giants only because their combined amounts of oil- and gas-equivalent total at least 500 million bbl, and not because either resource is that great by itself." Carmalt and St. John were aware of the more precise definitions suggested by Halbouty et al. (1970) and Nehring (1978) but faced the problem that detailed information is not always known about reservoir characteristics. Thus it is difficult to write a precise and consistent definition to indicate when separate subsurface pools can be combined into a single field and when they cannot. Instead, while Carmalt and St. John were precise about the giant part of the definition—equal to or greater than 500 million barrels (or oil equivalent) of ultimately recoverable oil and natural gas—they left the field part of the definition to common understanding. To paraphrase Stewart (1964), "...it is difficult to define, but I know one when I see one." And it was left at that. Statistical use of giant field data coupled with the significant technical advances that allow for exploitation of oil sands and continuous resources requires that the field part of the definition be made more precise. We suggest that compilations including both field and nonfield hydrocarbon resources be relabeled giant accumulations to indicate that some entries are not fields and that individual entries include an appropriate indication of the type of accumulation.

In Halbouty's introduction to Memoir 14, there is an explanation for using a compromise size for the giant part of the definition. Suggestions that the size be variable depending on access to markets, or other economic or operational details, were considered. But in the final paper of the volume, which established the public inventory of giants, the 500 million barrel figure was used, with a 3.5 trillion cubic feet cutoff for gas fields, which were listed separately. All subsequent compilations have used the 500 million barrel figure. However, the 3.5 trillion cubic feet of gas was changed to 3.0 trillion cubic feet (Nehring, 1978), presumably to allow a single

<sup>2</sup>The analogy between types of hydrocarbon deposits and types of ore deposits was suggested by Professor Stephen Kesler of the University of Michigan (2015, personal communication).

listing of giant hydrocarbon fields. Having a single list allows for combination giants of both oil and gas.

The second part of the definition of a giant field, namely what constitutes a field, was discussed in Memoir 14's final paper, which contained the listing of giants. The basic concept of a field was, and remains, a volume of the subsurface into which a hydrocarbon fluid has flowed. The devil is in the three-dimensional details of this subsurface volume. The original definition includes phrases such as "uninterrupted by permeability barriers" and "separate structural closures [with] a single, or common oil/water contact" and concludes with "There are other factors which also may be used to define an area as a single field." But then exceptions were allowed for geographically close groups of small fields with the same geologic setting. These were distinguished by names that included words such as complex, group, trend, or greater. Sometimes, the names of several smaller fields are simply combined in the list with hyphens, e.g., the Kelly-Snyder-Diamond M field. In short, an oil geologist's concept of a field was already proving difficult in definition, if not in concept.

Nehring (1978) made an attempt to make the Halbouty (1970) definition more exact. Nehring's specification started with the single accumulation—noting that a single accumulation "is synonymous with a pool or reservoir"—but then narrowly expanded this definition to include "a set of closely related accumulations." The expansion had to meet one of two standards: "multiple pools trapped by a common geologic feature" or "laterally distinct pools within a common formation and trapped by the same type of geologic feature where the lateral separation...does not exceed one-half mile" (0.8 km). In practice, both Halbouty (1970) and Nehring (1978) tended to group accumulations of pools into a single field rather than to use their definitions to separate a single field into two or more smaller fields on grounds of a precise definition. In arriving at a field definition, the model in people's minds was the exploration trilogy of source + reservoir + trap, a schema that implies fluid movement or migration in the subsurface. The overall consensus was that a field should be contiguous (or nearly so) on a map; that it should relate to a common source + reservoir + trap habitat; and furthermore should, if possible, not be dependent on nongeological factors such as political or operational criteria.

## PROBLEMS WITH THE CURRENT DEFINITION

Following the comprehensive lists Halbouty (1970) and Nehring (1978) provided, additional compilations were published by St. John (1980), Carmalt and St. John (1986), and Horn (2003). The Bakken and

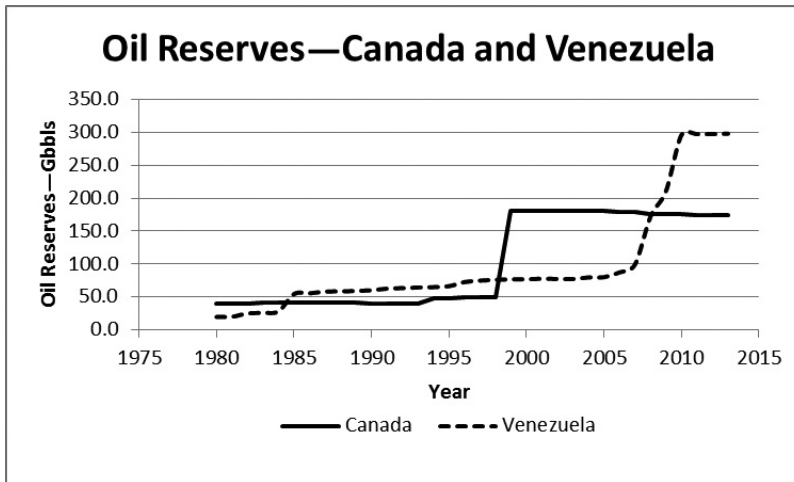
Marcellus plays, which are discussed in this volume, do not fit the traditional concept of field and should therefore not be included in statistical compilations of field data. We are not suggesting that these important accumulations not be discussed and understood; indeed, some argue that they represent the future of our industry. It is only that we should not include them in field statistics; they deserve their own compiled list.

The importance of what should be considered a giant field is underscored by Nehring's (2010) observation that recovery growth from already discovered giant fields over the coming decades will double the contribution of unconventional oil to the oil and gas resource base. In using this language, Nehring is clearly distinguishing giant fields from continuous accumulations. That this is a reasonable prediction is underscored by Klett and Schmoker (2003), who show that between 1981 and 1996, the existing giant fields accounted for an increase of 160 billion barrels of new reserves. While some of these may have been reserves reported for political reasons (Alekkett, 2012), reserve increases are also documented over this period in the United States where political factors were not an issue.

An illustration of the confusion that can result from inconsistent definitions can be seen in the reserve figures for Canada and Venezuela, which clearly show the addition of extra-heavy oil and bitumen-derived oil to the oil reserve statistics. The reserves themselves were not discovered in the years of increase; rather, people have known about them for decades, which makes this statistical reporting difficult to interpret. When making statistical projections, it is more useful to be able to identify both reserve and production contributions from fields, especially giant fields, as opposed to the contributions made by other types of accumulations. At present, more and more unconventional reserves are being added to the resource base, again raising the question of whether these resources are found in oil fields.

On the other hand, the unconventional resources of Arctic areas and deep-water marine areas currently being explored will, in all likelihood, result in the discovery of fields as we intuitively think of them. To justify the high operational costs, the drilling targets almost certainly are what we geologists normally consider giant fields.

We avoid the term unconventional to describe hydrocarbon accumulations. The term's current use indicates that it has significantly different meanings to different people. These meanings vary, but as Berman (2015) has pointed out, they basically translate to mean "expensive." While the term unconventional may therefore contribute to economics, we don't think it contributes to geologic understanding. Furthermore, some unconventional accumulations fit the intuitive sense of a field, whereas others do not.



**Figure 2.** Oil reserves of Canada and Venezuela, showing an increase based on changed definitions (source: BP Statistical Review, 2014)

### A REVISED GIANT FIELD DEFINITION

So what should the definition of giant field be? The giant part of the definition is sufficiently precise with respect to quantity: 500 million barrels of oil equivalent. Indeed, giant can refer to both fields and other types of accumulations. Natural gas is converted to oil equivalent at the ratio of 6000 cubic feet of gas equaling one barrel of oil. Using a single recognizably approximate conversion is preferable to a more accurate figure that might vary from field to field. But referring to the amount as ultimate recoverable oil creates confusion with the “ultimately recoverable resources” (McGlade, 2012) terminology used in resource evaluations; the latter contains amounts that are both as yet undiscovered or that, while discovered, are contingent on a better economic or technologic environment. For fields, we believe a better description would be current estimate of final size” which can be shortened to size estimate, which is to say the sum of historic production and the 2P (proved plus probable) reserves as defined in the Petroleum Resources Management System (PRMS) (SPE, 2011). In practice, this is what prior compilations seem to have used and meant. The contingent and undiscovered sections of the PRMS approach should be added to the estimated size only when the resource can be considered a 2P reserve.

Our concept of field follows the pattern established by Halbouty and Nehring in the 1970s but is made more explicit with differentiations to distinguish fields from nonfield accumulations. Our field definition thus has three components: (1) fluid composition, (2) geologic setting, and (3) geographic proximity. Accumulations that don’t meet all criteria can be important parts of the hydrocarbon resource but should be distinguished as nonfield accumulations. Because the subsurface is heterogeneous, there will be some uncertainty on the precise limits in individual cases. Nevertheless, we believe

that the definition will, in most cases, unambiguously distinguish a specific accumulation as either a field or a different type of hydrocarbon accumulation. An accumulation that falls outside our definition but that has always been considered a single field should continue to be considered a single field. We stress that to the extent possible, the definitions should rely on physical parameters and not on economic or operational criteria.

### Fluid Composition

The complete gradation in nature from light oils to bitumen needs an arbitrary dividing line to separate fields from nonfield deposits. We take 10° API as the point at which the fluid is so viscous that it should be considered a nonfield accumulation rather than a field. This is a commonly used dividing line, with higher API gravities considered heavy oil and those with lower gravity being termed extra-heavy oil (Meyer and Attanasi, 2013; McGlade, 2012; SPE, 2011). The existing field compilations have frequently adopted an operational definition—if the oil is produced by techniques used in oil fields producing lighter API gravity, then the accumulation is a field; if not, it is not. For this reason, the exclusion of extra-heavy oil from giant field compilations is imperfect. From a statistical viewpoint, it is best to leave existing fields alone, but use the 10° API dividing line when considering whether to call a new giant extra-heavy oil addition a field.

### Geologic Setting

The geologic setting for oil and gas accumulations is the primary focus for most petroleum geologists. The oil or gas that constitutes a hydrocarbon accumulation occurs

within the pore spaces of a rock, which we call a reservoir. But a reservoir is not always a field. To be a field, the oil or gas also must be confined in the reservoir by one or more geologic features that are different from the reservoir itself. This is the aspect of our definition that distinguishes giant accumulations such as the Bakken area and the Marcellus formation from fields. The different geologic feature may be a structure such as an anticline, one or more faults, a stratigraphic change, or a hydrodynamic regime; the critical thing is that there is something more than only the geologic character of the reservoir rock itself that is creating the accumulation. The implication is that the oil or gas would flow out of the reservoir if not for this, or these, different geologic features. Frequently, there are several different geologic features that act in concert to create the field. The classic case is a structure such as an anticline with stratigraphy that has a very low permeability formation overlying the reservoir. Implicit in such a system is that over geologic time the oil or gas has flowed, which is part of the implicit understanding of a field.

### Geographic Proximity

Our final requirement for a field is that it be a contiguous (or nearly contiguous) geographic entity. There are at least two difficulties with this part of the concept. The first is how far apart the different segments can be when they are discrete segments. For example, a number of the North Sea oil fields are composed of fault blocks that have separated the subsurface pools from each other, a situation that also characterizes many Niger delta fields. The source, reservoir formation, and trapping mechanism is identical from fault block to fault block, so it is entirely the separation in plan view that determines whether the pools constitute one or more fields. An operational factor may intrude here, as we don't advocate having a single offshore platform producing from two separate fields simply because the map view of their separation is over some arbitrary line. Such separations can also result from differing depositional characteristics such as those found in reservoirs deposited in deltaic and fluvial environments. But the greater the geographic distance separating two pools, the more justification there needs to be for considering the accumulation as a single field. We believe that one kilometer is a reasonable distance beyond which significant justification is required to consider separate pools as a single field.

A second problem with lateral separations is that of two separate accumulations that overlap in plan view. Aquino et al. (2003) suggest this for the Sihil Field in the Cantarell area; Campbell (2013) describes two vertically superimposed hydrocarbon systems in Saudi

Arabia, with gas accumulations that are below the known oil accumulations and which are generated by different source rocks. We suggest that in these cases, the likely congruence of trapping structures leads to accumulations being considered a single field, at least intuitively. So while two giants being superimposed in plan view is not impossible, we suggest that an overlap creates the very strong preference for considering all horizons as a single field.

### CONCLUSION

Following these ideas, we propose that the definition for a giant field in Carmalt and St. John (1986) be modified to read, "A giant oil or gas field is an accumulation of oil, natural gas, or a combination of these that has an estimated final recovery of 500 million barrels of oil and/or natural gas hydrocarbons of no less than 10° API gravity and that are trapped in the subsurface in a single or similar geological manner and that are a contiguous (or nearly contiguous) feature in map view, with gas being converted to oil equivalent at a ratio of 1 barrel = 6000 cubic feet."

The inevitable rough edges to this definition are not important; rather, for resource estimations and resulting policy decisions, what is important is recognizing the giant fields as a specific subset of giant hydrocarbon accumulations. At present, nonfield types of giant accumulation are playing a major role in changing the oil and gas industry.

As we have already noted, unconventional Arctic and deep-water marine exploration programs are searching for structures that, when discovered, probably will fit our definition of field. On the other hand, we do not consider as fields the accumulations of extra-heavy oil or bitumen. What such accumulations should be called is open for discussion. At present, there are not so many non-field giant accumulations that it is a major issue. Our preferred terms are continuous accumulation for the Bakken and the Marcellus types where the extraction is directly from an impermeable source rock; degraded accumulations for the oil sands; and potential resources for oil shales. At least some of these are already being exploited and are making important contributions to the economy. They are giant accumulations, just not giant fields.

We are mindful of comments by McGlade (2013) about uncertainty in resource evaluations. The new types of hydrocarbon resources presently and potentially being developed are certainly giant in their potential. But not distinguishing them from fields runs the risk of devaluing the resource projections upon which policy decisions are made.

## ACKNOWLEDGMENTS

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