Assessment Measures: Describing Uncertainty Accurately, Clearly and Unambiguously*

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Abstract

The history of the petroleum industry has clearly and repeatedly demonstrated that geologists and engineers cannot precisely predict or calculate hydrocarbon volumes potentially contained in a prospect or actually contained in a discovered field. The only moment at which this value is precisely known is the day after the final day of production. However, to optimize exploration strategy in a basin, or to manage development and production of a field, useful estimations of hydrocarbon volumes are essential. This must involve estimates, not only of the best estimate hydrocarbon volume, but also an appropriately characterized range of uncertainty. This uncertainty can then be tracked, managed, and used to optimize decision-making as the asset progresses through its lifecycle from prospect to producing field.

Several issues hamper this process. Firstly, terms used to describe uncertainty in the petroleum industry such as "mean", "most likely", "maximum", etc., are in common use in the English language, and their dictionary definition and vernacular meanings are not the same as their intended meaning when describing hydrocarbon volumes. This necessitates that both scientists and decision-makers understand the common lexicon of these terms to avoid confusion and to facilitate a rapid, effective and accurate transfer of information between these two groups.

Secondly, graphical renditions of hydrocarbon volume assessment results are often times interpreted in different ways by different people. These interpretations often conflict, causing confusion during technical discussions. This can complicate and retard an effective decision-making process based on these results.

A common schema of "Assessment Measures" is here proposed to clearly and simply ensure that all petroleum industry personnel carry consistent definitions of each volumetric term, and that visual inspection of, and conclusions drawn from, graphical representation of hydrocarbon volumes and their uncertainty is consistent within the same group of scientists and executives.

When scientists and managers share a common understanding of these definitions, decision-making processes are accelerated and optimized. Assets can now be evaluated and discussed without encumbering the process with misunderstandings regarding terminology and descriptors.

Introduction

The purpose of the Assessment Measures scheme is to standardize petroleum volume evaluation terminology and definitions. These labels are used in the description of many asset types, including plays, leads, prospects, new discoveries, producing fields, and production wells. Many Assessment Measure terms are inter-related. Groups of terms describe the relative magnitude of volumes within a common class of volume measure, e.g. “Lowside” and “Median” Geologic Success-case volumes. Others describe the same relative magnitude of volume across assessment classes, e.g. “Lowside Geologic Success-case” and “Lowside Geologic Risked” volumes. It is of prime importance to ensure, when dealing with an array of such similar and inter-related terms, that all stakeholders have a clear and specific understanding of each term. If this is not the case, discussions of these numbers, and conclusions drawn there from, will be easily derailed.

Some Assessment Measures are restricted to describing results from probabilistic (stochastic) assessments, usually conducted via a Monte Carlo simulation of component volumetric parameters. Other Assessment Measures are uniquely applied to describing only deterministic assessment results. Finally, some have utility in both realms, either because they can be used interchangeably, or because they describe very similar or identical circumstances within each assessment class.

Geologic Measures

The fundamental output of a probabilistic hydrocarbon assessment is the Geologic Success-case volumes. Geologic “success” is defined as encountering or potentially encountering hydrocarbon volumes exceeding a success threshold termed the Geologic Minimum volume. Volumes smaller than this value are considered failures. Therefore, the smallest possible value in the Geologic Success-case is the Geologic Minimum. Non-zero outcomes that are smaller than the Geologic Minimum are classed as failures along with zero outcomes.

The Geologic Minimum is a “volume of interest” and represents the smallest accumulation size that will be of interest to petroleum exploitation companies in a particular area or geographic setting. The Geologic Minimum must fulfill the following criteria. It must be a volume that:

1. Will be of potential interest to petroleum companies either presently or in the future.
2. Can be both detected by our technology and quantified.
3. Is large enough for us to be able to compile a meaningful census of similarly sized accumulations or features from our mapping efforts.

The Geologic Chance of Success (GCOS) is the probability of an accumulation exceeding the specified Geologic Minimum. Geologic Success-case volumes are therefore inextricably tied to the Geologic Minimum. If the Geologic Minimum increases, then the Geologic Success-case Assessment Measures volumes will inexorably increase. This occurs because as a number of outcomes between the original Geologic Minimum and the revised value will be excluded from the success-case, thus increasing the average Success-case volume and all the other Geologic Success-case Assessment Measures.

Geologic Success-case volumes are usually represented in graphical form as an exceedance probability (EP) curve (Figure 1). The curve displays all the successful outcomes modeled for a geologic feature. Along this curve lie specific standard volumetric markers, which are often quoted during the discussion of assessment results and are often used to judge the relative technical and investment merits of competing opportunities.

The Geologic Success-case curve does not feature failure outcomes. The curve therefore spans the full range of exceedance probability space, from zero to one, regardless of the total number of trials performed during the simulation or indeed the number of failure trials accompanying the successes.

Useful Assessment Measures on the Geologic Success-case curve include the Minimum (smallest successful outcome), 90th percentile - P90 (lowside), 50th percentile - P50 (median), Average of all possible outcomes - Mean, 10th percentile - P10 (highside), and Maximum (largest possible outcome). All these values are prefixed in the Assessment Measures scheme by the term “Geologic Success-case”.

The Geologic Success-case curve displays only the outcomes that exceed the Geologic Minimum volume. There is no reference to the number of failure outcomes associated with the displayed success-case outcomes. The failure trials are only revealed on the Geologic Risked curve, displayed in green on Figure 2. This curve features all the outcomes of the simulation; success or failure. It also reveals the relative abundance of successful to failure outcomes. The failure outcomes may result from an incurrence of geologic risk, i.e.

zero-volume trials, or the realization of marginal volumes below the Geologic Minimum, i.e. non-zero failure trials. Note that the non-zero failure trials are set to zero volume for displaying the Geologic Risked curve and it's associated Assessment Measures. The relative abundance of failed to successful outcomes is evident by observing the point at which the Geologic Risked curve intersects the y- (EP-) axis of the chart. This point of intersection is numerically equivalent to the GCOS.

Naturally, the volume ranges expressed by the Geologic Success-case and Geologic Risked curves are identical. The Geologic Risked curve is merely comprised of the same outcomes as the Geologic Success-case curve, only including the contributions of the failed outcomes, which are rated at zero, thus reducing the average and all other measures. The Geologic Risked curve effectively represents a proportionate re-scaling of the Geologic Success-case curve. A consequence of this relationship is that Geologic Risked volumes, at an equivalent EP value, are always less than the corresponding Geologic Success-case volumes. Volumes representing specific EP values simply transpose horizontally from the Geologic Success-Case curve to the Geologic Risked curve. The exception to this rule is the Risked mean. This value is not derived by horizontally projecting the Geologic Success-case mean. This is because the geologic Mean incorporates into its mathematical average the zero-value failure outcomes in addition to the success-case outcomes. The Risked mean therefore moves isotonically down the EP axis in proportion to the GCOS of the asset. The Risked Mean can easily be calculated from these curves by multiplying the Geologic Success-case Mean volume by the GCOS.

Economic Measures

When evaluating a prospective geologic feature, it is usually more important to know whether volumes potentially contained therein are currently economic, rather than just greater than the Geologic Minimum volume. By analogy with the Geologic Minimum, the smallest volume that is economic under current conditions is termed the Economic Minimum. It is a function of many factors, including resource density, hydrocarbon commodity price, development costs and other financial considerations. Naturally, not all Geologic Success-case outcomes fulfill these economic criteria. Economic Success-case outcomes are only those that exceed the Economic Minimum volume, and are therefore represented only on the section of the Geologic Success-case curve that exceeds the Economic Minimum.

Economic Success-case volumes are calculated using only those outcomes, which exceed the Economic Minimum volume, i.e. by truncating the Geologic Success-case curve at the Economic Minimum (Figure 3). The Economic Success-case curve is, like the Geologic Success-case curve, scaled to an EP range of zero to one and is hence a de facto expansion of the economic portion of the Geologic Success-case curve. This re-scaling exercise eliminates the uneconomic trials in exactly the same fashion that the Geologic Success-case curve eliminates trials that fall below the Geologic Minimum.

Economic Success-case volumes can now be easily determined from the re-scaled curve in exactly the same manner that the Geologic Success-case volumes can be determined from the Geologic Success-case curve. An identical suite of Assessment Measures is relevant to the Economic Success-case curve as to the Geologic Success-case curve (Figure 3).

In similar fashion to the GCOS representing the probability that the hydrocarbon volumes will exceed the Geologic Minimum, the Economic Chance of Success (ECOS) is the probability of encountering a hydrocarbon accumulation exceeding the Economic Minimum. It can be determined by two methods. First, by projecting the Economic Minimum volume onto the Geologic Risked curve and then reading across onto the EP axis. The EP value at the point of intersection numerically equals the ECOS. Secondly, by projecting the Economic Minimum volume onto the Geologic Success-case curve, across to the EP axis, and then multiplying this intersection EP value by the GCOS.

Inevitably, the ECOS of any asset can change frequently as economic conditions shift. If hydrocarbon price, or facilities fabrication costs change significantly, for example, the Economic Minimum for a prospect in a given geographic area will likely change, and with it the ECOS of all associated geologic features in that area.

In reality, of course, the economic attractiveness of geologic features is not characterized by volume alone. Other factors such as resource density, proximity to existing facilities, initial or sustained production rate, plateau duration, well costs, development costs, government financial reward systems, etc. will also impact the economic viability of a project. It is quite conceivable for a larger volume geologic structure to be less economically attractive than a smaller volume structure, depending on the relative circumstances of the two accumulations with respect to these multiple factors. Therefore, reading the ECOS and Economic Success-case and other Assessment Measure volumes off a curve should only be regarded as a screening evaluation. A more comprehensive and site-specific economic evaluation should be run on any prospect to specifically determine its economic attractiveness.

The Full Picture

A composite depiction of the Success-case, Risked, and Economic curves, annotated with their associated standard Assessment Measures, illustrates the full selection of terms available for the description of hydrocarbon volumes likely to be encountered in a particular geologic feature (Figure 4). The composite chart also clearly displays the graphical and mathematic relationships between pairs or groups of Assessment Measures. By referring to this chart, any volumetric description of an asset can be quantified and defined in a unique and unequivocal manner, greatly facilitating the comparison between competing investment opportunities.

Standard Volume Description

In the Assessment Measures scheme, any hydrocarbon volume can be correctly and uniquely described by selecting one term from each of five categories comprising a hierarchical sequence of descriptors, from top to bottom (Figure 5). The rows describe, successively, (1) the organizational/ company share, (2) the entity being described, (3) the assessment case, (4) the statistical measure, and (5) the hydrocarbon phase type. Each specific volume condition is thus described with a unique array of terms and vice versa.

One particularly acute and pernicious point of confusion, which can be easily avoided by adherence to this scheme of Assessment Measures, is the misuse of the term Unrisked volumes. This case assumes that all individual components of a geologic feature contribute to the overall volumes potentially within the reservoir, e.g. all fault blocks, all reservoirs, and all depositional facies extents, within a prospect. This is usually a highly unlikely outcome and frequently represents an anomalously large Geological Success-case. This is because a geologic success only requires at least one element of a geologic feature to contain more than the Geologic Minimum volume. All the others can fail and that outcome is still a success. For example, only one fault block can contain hydrocarbons, only one of many reservoir levels, or only one lithology within the trap.

Therefore, many geologic success-case outcomes do not receive a volume contribution from all their geologic components. The natural consequence of this is that outcomes that do receive volume contribution from all their geologic components, i.e. Unrisked cases, tend to be at the larger end of the Geologic Success-case spectrum. Therefore, using Unrisked volumes to describe a representative success-case outcome for a prospect is quite unreasonable and only serves to inflate the perception of the size of the feature.

Summary and Conclusions

We assert that the adoption of the standard scheme of Assessment Measures presented here offers many benefits. Primarily, it has the effect of institutionalizing the use of statistically correct terminology across an organization and the industry, something that has been sorely lacking over recent decades.

By using the correct terms to describe specific volumetric circumstances, geoscientists, engineers and managers are assured of using the same unique term to mean the same geologic condition. This has the desirable effect of avoiding confusion during discussions of hydrocarbon volume assessment results. This reduces frustration, and greatly facilitates an efficient and appropriate acreage acquisition, opportunity pursuit, maturation, and drilling decision-making process.

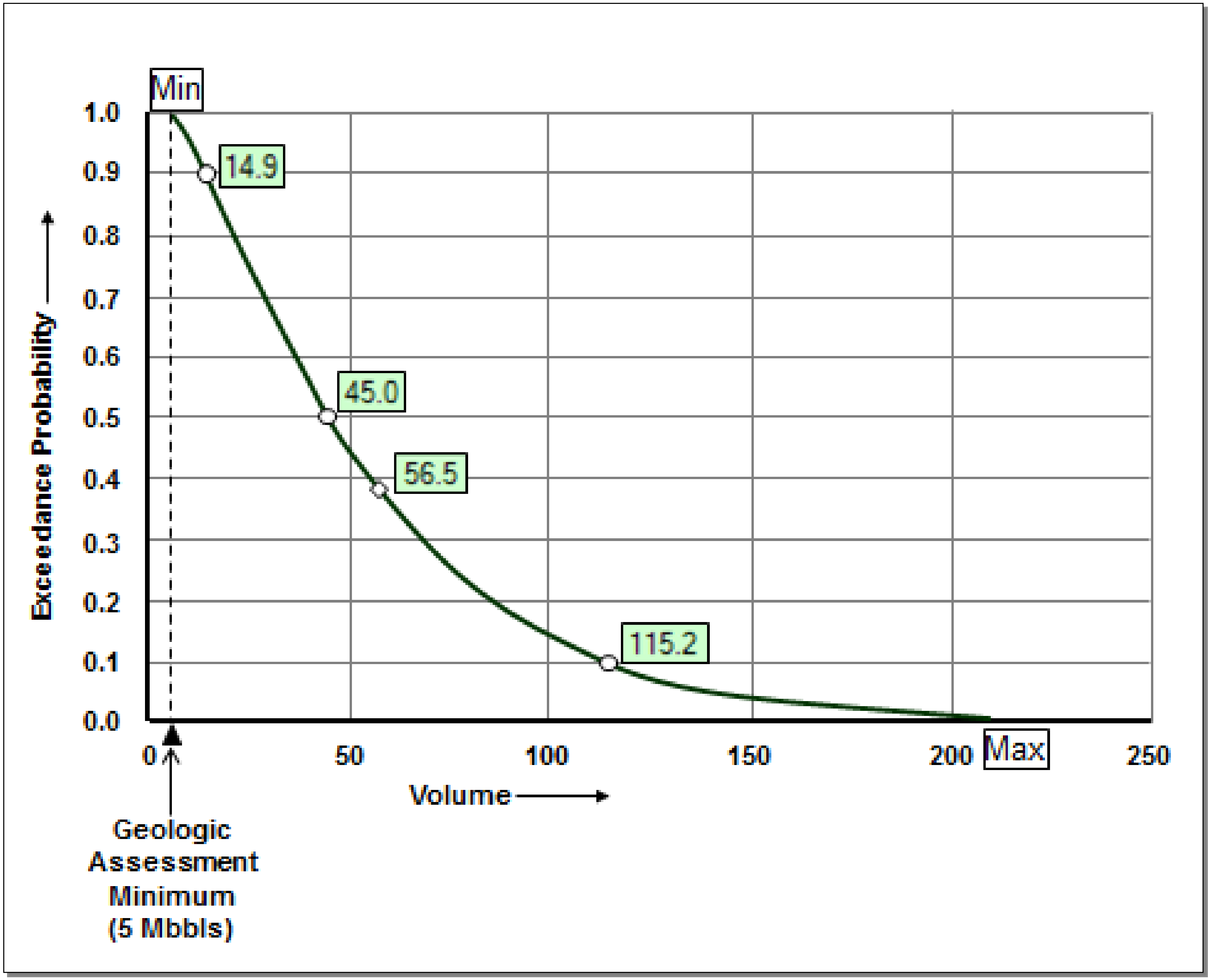

Figure 1. The Geologic Success-case curve.

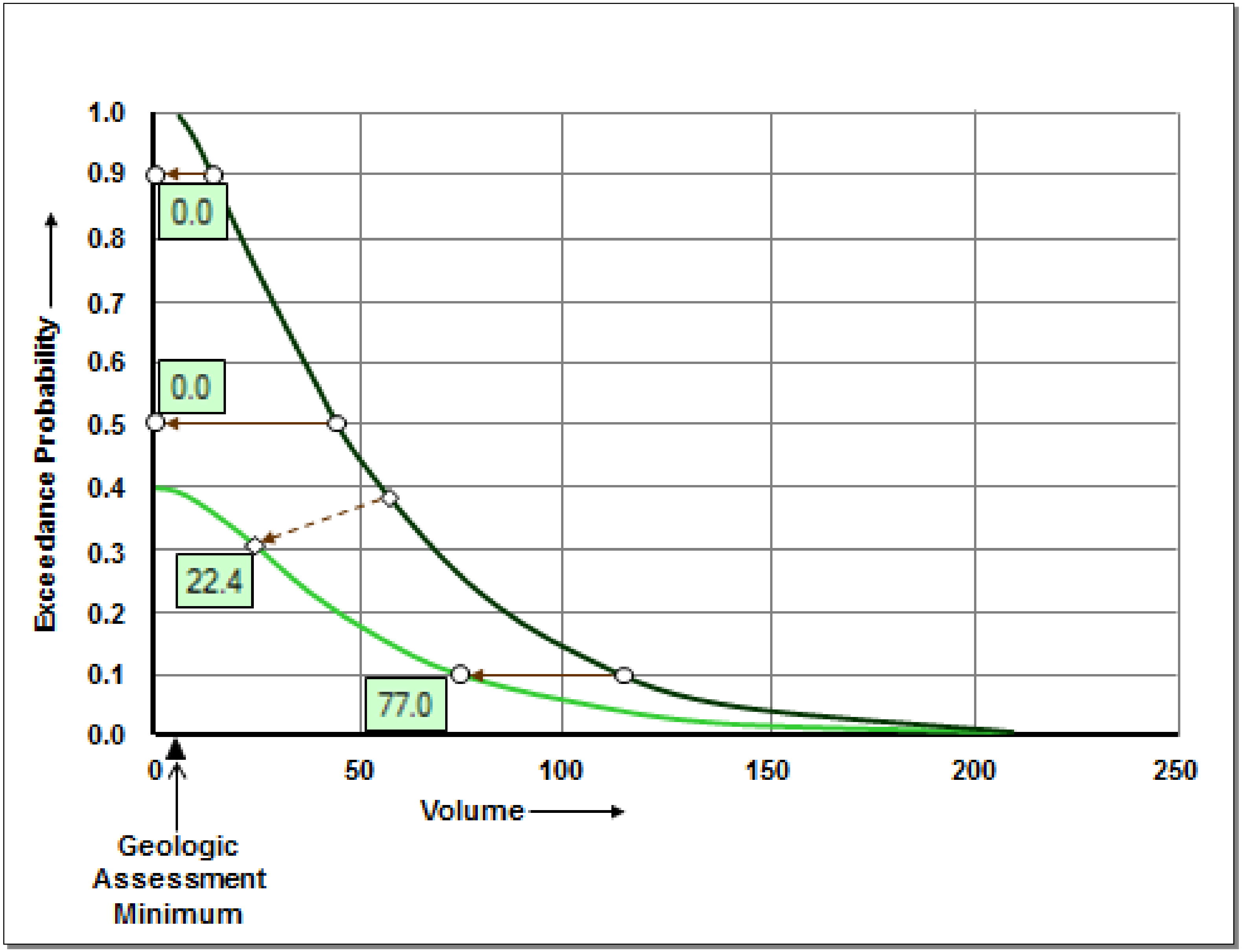

Figure 2. The Geologic Risked curve.

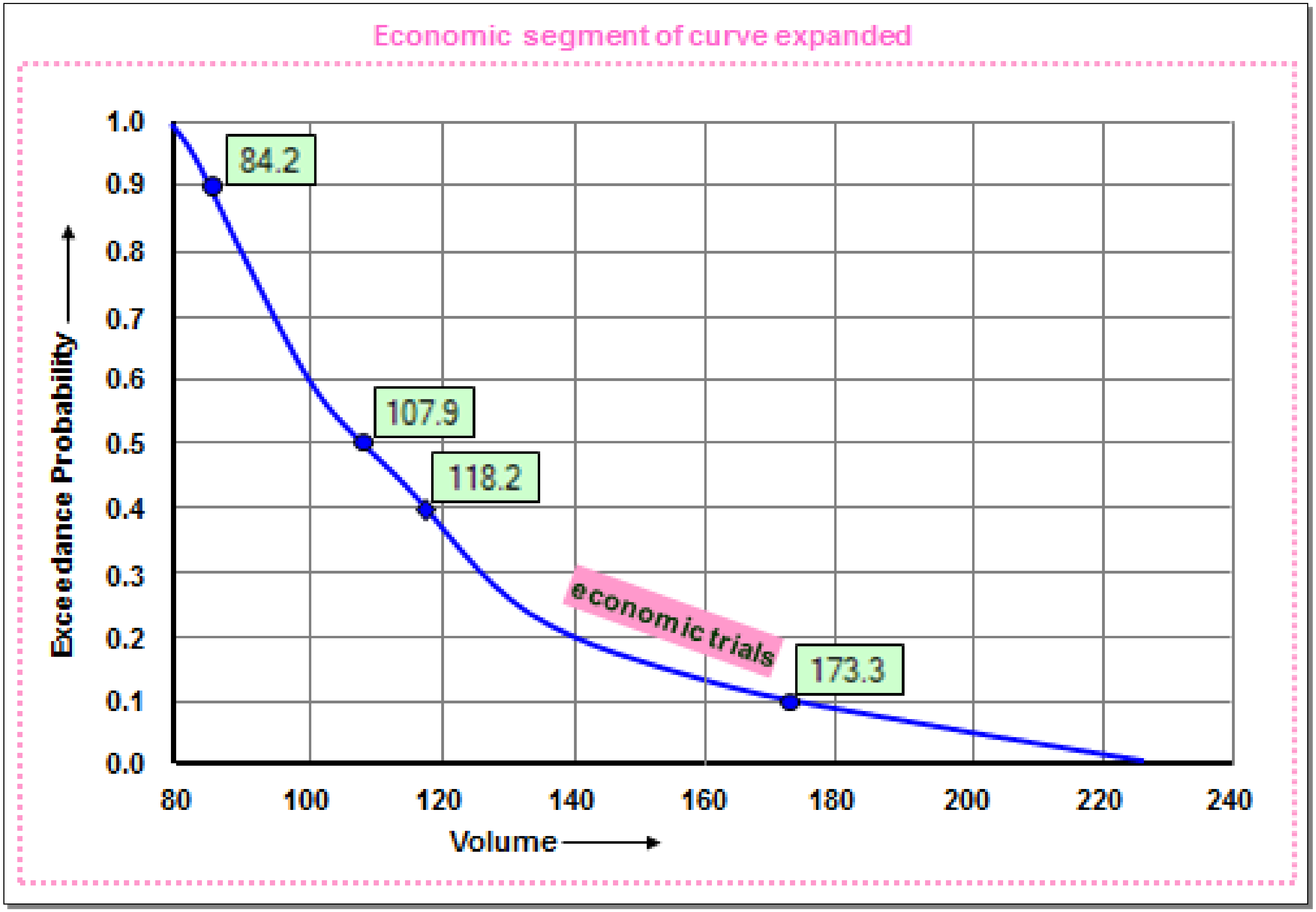

Figure 3. The Economic Success-case curve.

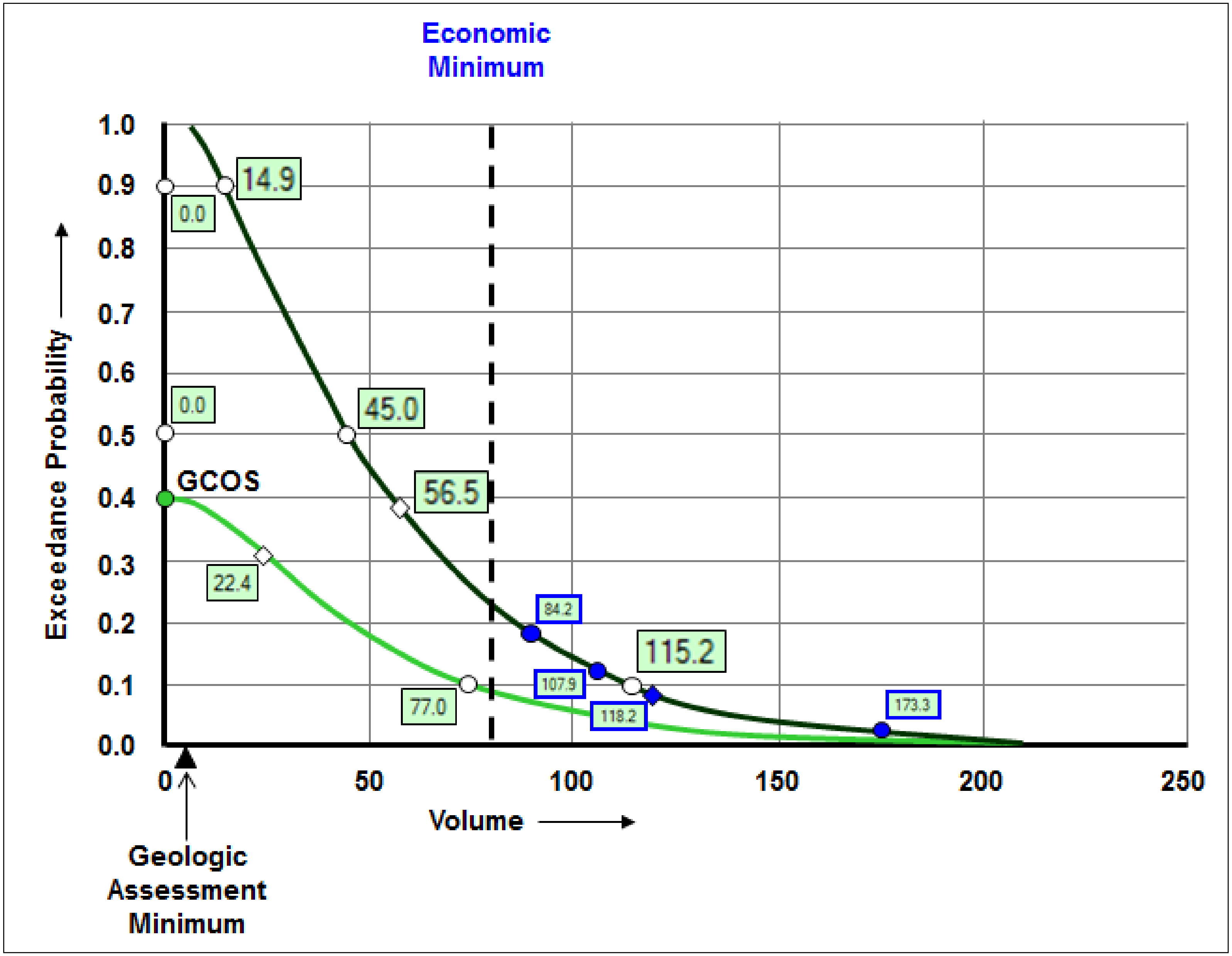

Figure 4. The full picture.

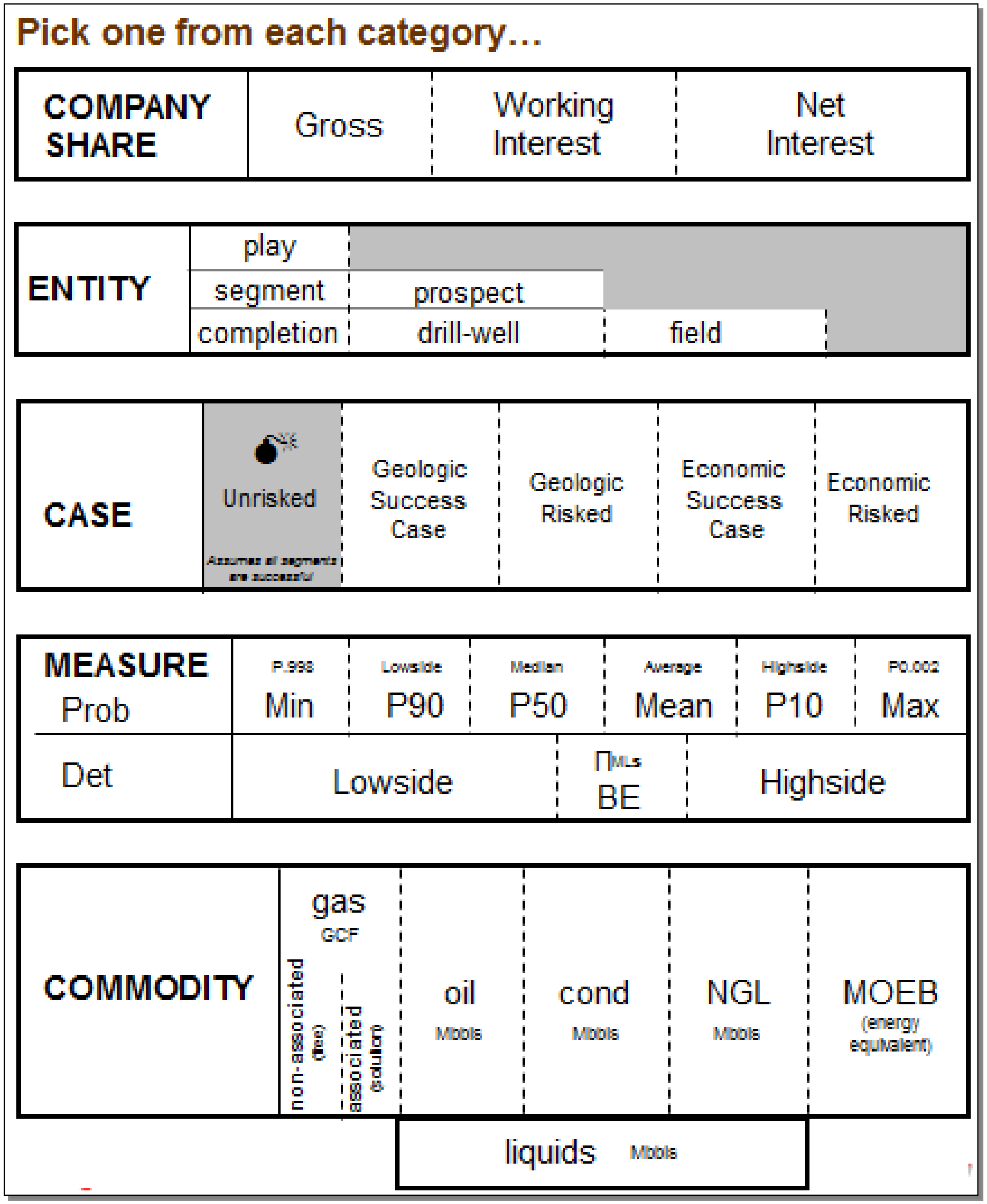

Figure 5. Volumes menu.