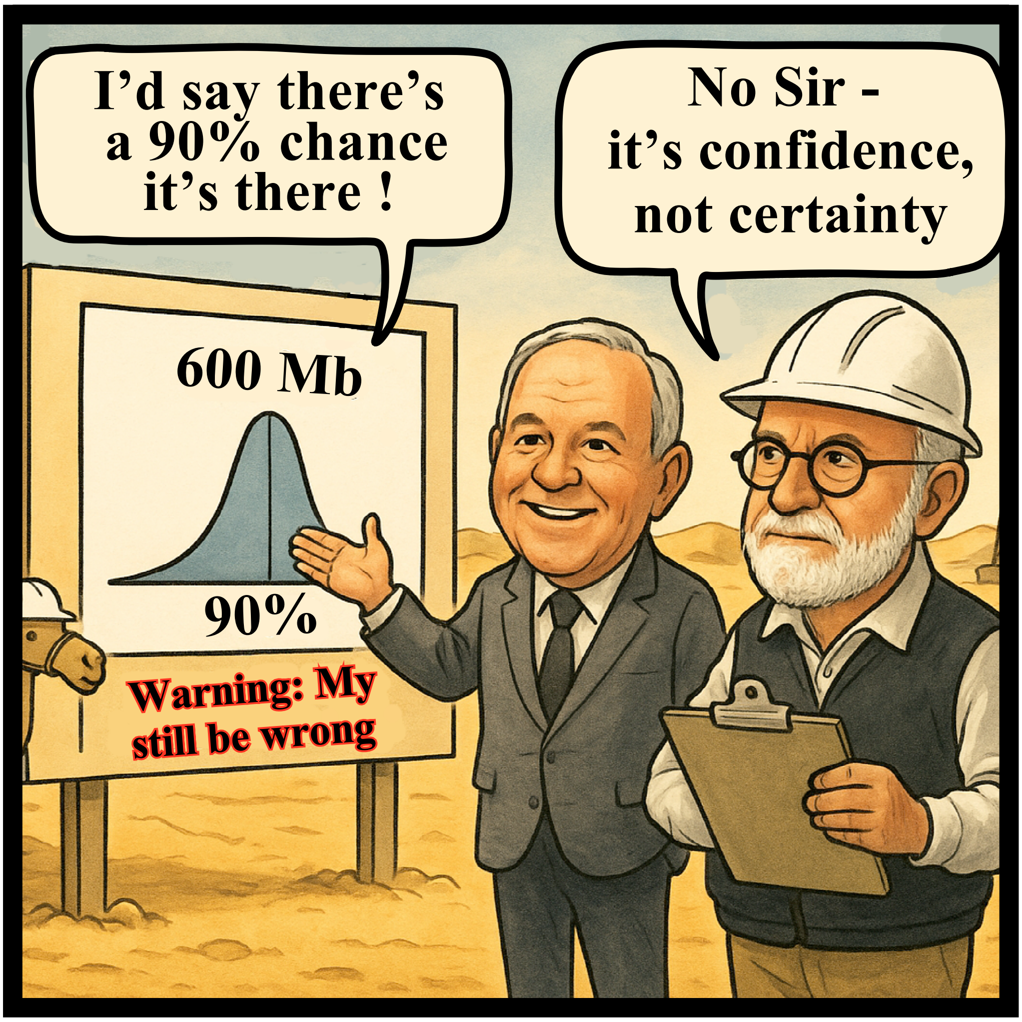
A Probabilistic Conjecture Can Never Be Proven

A Farmee–Geoscientist Exchange”



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Caption of the cover:

A Farmee–Geoscientist Exchange:

A familiar conversation in petroleum exploration, where the expectations of the investor (or *farmee*) meet the interpretive caution of the geoscientist. While the former seeks assurance, the latter must remind that probability reflects confidence, not certainty. The exchange illustrates the practical tension between financial commitment and scientific humility — a 90% chance is not a promise, but a model-bound expectation.

Résumé for Policymakers

This memorandum addresses a common type of statement in resource estimation, especially in petroleum exploration - for example:

"There is a 90% probability that this field contains at least 600 Mb (million barrels)."

Such statements are probabilistic conjectures. They do not describe what is known with certainty, but rather what is expected under uncertainty, based on models and assumptions. They help guide important decisions - whether to invest, drill, or wait - but they cannot be proven true, even if the outcome matches the prediction.

The key message is this:

✯ Probabilistic estimates are useful for managing risk, but they are not scientific facts.✯

Philosopher Karl Popper argued that a scientific claim must be open to falsification - that is, it must be possible to prove it wrong through observation. But probabilistic statements are not falsifiable, because any outcome (good or bad) can still be explained by the model.

As a result, they cannot be verified or disproven in the usual scientific sense. This does not mean probabilistic models are meaningless. On the contrary, they are essential for responsible decision-making under uncertainty. But they must be treated as tools, not as truths - and they require regular revision as new data becomes available.

Preface

This memorandum was prompted by recurring ambiguities in the way probabilistic language is used - and often misunderstood - in petroleum exploration. In particular, I aim to clarify the epistemological status of statements that assign likelihoods to future or unknown quantities, such as recoverable reserves.

While such statements are operationally necessary, especially for guiding decisions under uncertainty, they are often granted more authority than their logical structure permits. The purpose of this note is not to diminish the practical value of probabilistic models, but to make explicit their limitations - and to situate them within a philosophical framework that distinguishes between **utility**, **belief**, and **demonstrable knowledge**.

This analysis builds on the ideas of Karl Popper and others who emphasized the importance of falsifiability in science, and who cautioned against the illusion that probabilities can represent truth in the classical sense. The memorandum is intended as a contribution to a more disciplined and reflective use of probabilistic reasoning in the geosciences and in decision-making more broadly.

Caveat

This memorandum is intended as a complement to my earlier note, *"Probability and Verisimilitude,"* in which the central message may not have been presented with sufficient clarity. Here, with the assistance of AI, I aim to be more direct and objective by posing a focused question concerning a statement commonly used in petroleum exploration:

"There is a 90% probability that this field contains at least 600 million barrels."

Can such a probabilistic conjecture be proven?
This question will serve as the entry point to a broader reflection on the logical and epistemological status of probabilistic reasoning in the context of scientific and industrial decision-making.

Introduction

A *probabilistic conjecture* is a proposition that does not assert a definite fact, but rather assigns a degree of likelihood to a future or unknown state of the world. In petroleum exploration, such conjectures typically take the form of quantified statements under uncertainty - for example: *"There is a 90% probability that this field contains at least 600 Mb (million barrels)."* These are not deterministic claims;

they express expectations or beliefs about outcomes, often based on models, analogues, and incomplete data.

The question arises: **can such conjectures be proven?** The challenge is both philosophical and logical. Probabilistic statements, by their very nature, deal with uncertainty and cannot be confirmed or refuted by a single outcome - or even by several. If, after drilling multiple wells, **600 Mb are produced**, that does not prove the conjecture; it merely happens to be **consistent** with it. Conversely, if only **250 Mb are produced**, that does not disprove the conjecture either - the result may simply fall within the **10% tail** of the distribution. In this sense, probabilistic conjectures resist both **verification** and **falsification** in the traditional scientific sense.

A helpful analogy is the **weather forecast**. Suppose a forecast predicts a *90% chance of sunshine*. If it rains, that does not invalidate the forecast - it simply means the 10% possibility materialized. And if the sun does shine, that doesn't prove the forecast was correct — it merely aligns with it. In both cases, the truth of the probabilistic statement remains **untouchable** by any single outcome. It is this **resistance to definitive testing** that places probabilistic conjectures outside the bounds of what philosophers like **Karl Popper** would consider *provable*.

This issue was of central concern to Popper, who maintained that for a statement to be scientific, it must be **falsifiable** - that is, exposed to the risk of being refuted by observation. He was notably critical of probabilistic claims when they are used to assert knowledge. According to Popper, **no accumulation of favourable outcomes can ever confirm the truth** of a probabilistic hypothesis. At best, such hypotheses remain **conjectural** - useful for guiding decisions under uncertainty, but always **tentative**, **revisable**, and never logically demonstrable.

The Nature of Probabilistic Statements

Probabilistic statements, such as *"There is a 90% chance that this oil field contains at least 600 Mb recoverable,"* do not describe what **is**, but rather what **might be** under conditions of uncertainty. They are not factual claims about the actual state of the subsurface; instead, they express degrees of belief, informed by data, models, and geological reasoning.

Such statements emerge from a process that incorporates multiple sources of uncertainty: seismic interpretation, volumetric parameters, reservoir analogues, and statistical assumptions. The resulting estimate is often presented as a probability distribution - with values such as P90, P50, and P10 marking thresholds associated with confidence levels.

Crucially, the 90% figure does not refer to any physical or measurable frequency in nature. It does not mean that 90 out of 100 fields with similar data will contain at least 600 Mb. Instead, it means that - **given the assumptions of the model** - the estimate of 600 Mb lies at or below the 90th percentile of possible outcomes. In this sense, the statement reflects a structured form of **epistemic uncertainty**, not an ontological fact.

Therefore, probabilistic conjectures operate in a domain of **expectation**, not of verification. They help decision-makers manage risk and allocate resources, but they do not claim — nor can they — to describe reality with certainty.

Popper's Critique

At the heart of Karl Popper's philosophy of science is a fundamental rejection of **inductive reasoning** - the idea that we can infer general truths from repeated observations. For Popper, no number of consistent outcomes can ever confirm a universal claim. The classic example: observing a thousand white swans does not prove that *all* swans are white - a single black swan is enough to falsify the claim. Thus, **science advances not by confirmation, but by refutation**.

This leads directly to Popper's central criterion for scientific knowledge: **falsifiability**. A statement or hypothesis is scientific only if it can, in principle, be proven false by observation. If no possible observation could contradict it, then it lies outside the realm of science.

Probabilistic conjectures, however, do not meet this criterion. Take the example: *"There is a 90% probability that this field contains at least 600 Ma."* This statement is constructed in such a way that **any single outcome is compatible with it**. If the field yields 700Mb, the estimate appears vindicated — but not proven. If it yields only 250 Mb, one might simply say that the unlikely 10% scenario occurred. There is no outcome that *must* contradict the conjecture.

This is the crucial issue: **probabilistic statements are insulated from refutation by their own logic**. They preempt failure by admitting uncertainty from the outset. As a result, they **cannot be falsified**, and therefore, in Popper's framework, they **cannot be regarded as scientific assertions** in the strict sense. At best, they serve as tools for managing expectation and risk — useful, but epistemologically fragile.

The Illusion of Confirmation

A common misconception in both scientific and industrial contexts is that a correct prediction somehow *confirms* the underlying probabilistic conjecture. For instance, if a field is predicted to contain a 90% probability of holding at least 600 Mb, and subsequent development reveals precisely that amount - or more - it may be tempting to view this as a validation of the estimate.

But this is an illusion.

Probabilities cannot be confirmed by outcomes. The fact that a prediction coincides with a result does not demonstrate that the probability assigned was correct. By definition, a probabilistic conjecture allows for a range of outcomes, each with some degree of likelihood. If a highly probable outcome materializes, that is merely **consistent with** the model - not proof of its validity.

Inversely, if a low-probability event occurs - for example, the field turns out to hold only 250 Mb - the conjecture is still not falsified. The model *anticipated* that possibility, however unlikely, and thus protects itself from contradiction. In either case, **no amount of observed outcomes can verify the truth of the probability assigned**, because the statement is inherently **non-deterministic**.

Instead, probabilistic models are **revised**, not proven. As new data become available - from additional wells, better seismic imaging, or updated geological understanding -the input parameters are adjusted, and the probability distribution is recalculated. The process is iterative and adaptive, but it never leads to final confirmation. The model improves, but it does not *converge on truth* in the logical sense.

This is why Popper and others have insisted that **the apparent success of a probabilistic prediction must not be mistaken for evidence of its truth**. What it reflects is internal coherence and perhaps practical utility - but not logical or empirical demonstration.

The Role of Probabilistic Reasoning in Science and Industry

Despite their logical limitations, **probabilistic conjectures play an essential role in science and especially in industry**, where decisions must be made under uncertainty. In petroleum exploration, for example, assigning probabilities to volumetric estimates allows stakeholders to weigh risks, evaluate scenarios, and allocate capital - all before committing to expensive drilling operations. Probabilistic reasoning, while epistemologically weak, is **practically indispensable**.

In this context, the aim is not to *discover truth*, but to **manage uncertainty**. A volume estimate with 90% probability does not assert that the reservoir “truly” contains that amount; rather, it supports a risk-weighted decision: to drill, to farm out, to delay, or to exit. These decisions are inherently made under **conditions of**

partial ignorance, and probability offers a structured way to act without full knowledge.

This reflects a crucial distinction: the difference between **epistemic caution** and **operational necessity**. From a philosophical standpoint, we may acknowledge that no probabilistic conjecture can be verified or proven. But from an operational standpoint, acting as if some outcomes are more likely than others is both reasonable and necessary. In this sense, **decision-making tolerates uncertainty** in a way that scientific proof does not.

Hence, **usefulness and truth must be kept apart**. A probabilistic model may be immensely valuable in helping a company manage risk, communicate expectations, and guide technical strategy. But that same model remains, in Popperian terms, **a conjecture — not a confirmed fact**. It is useful, not proven. It facilitates action, not knowledge in the strict sense.

This duality is central to the modern use of probability in applied fields. The language of likelihood and confidence intervals allows uncertain knowledge to be quantified, shared, and acted upon. Yet, **the moment such language is mistaken for certainty**, or even for verifiable truth, the reasoning becomes epistemologically unsound.

Conclusion

A **probabilistic conjecture** may serve as a valuable guide for action, particularly in fields like petroleum exploration where uncertainty is inherent and decisions must be made with incomplete information. Statements such as *“There is a 90% probability that this field contains at least 600 Mb”* are not claims of fact, but expressions of belief grounded in models, assumptions, and prior data. They help quantify uncertainty and support risk-based decisions — but they **do not describe truth**, and they **cannot be proven** in either a logical or empirical sense.

No amount of confirming outcomes can establish the validity of such a conjecture, and no single observation can falsify it. This lack of falsifiability places probabilistic statements outside the bounds of what Karl Popper considered scientific. They are not wrong for being uncertain — only if they are mistaken for certainties.

The integrity of scientific reasoning lies in the **recognition of this limit**. It requires that we acknowledge the **provisional and revisable** nature of our models, especially when they involve probability. To act under uncertainty is necessary; to claim truth under uncertainty is not.

Ultimately, a probabilistic conjecture is not something to be proven. It is something to be **used with caution, revised with new evidence, and understood for what it is**: a rational response to uncertainty, not a statement of fact.

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