Basic Principles of Scientific Seismic Interpretation

These notes, based in K. Popper's and M. Ben-Ari's works, were prepared to Santos' explorationists.

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C. Cramez, April 2012

Science

VS

Pseudoscience

Naive Inductive Interpretation VS

Hypothetic-Deductive Interpretation

Wednesday, April 18, 2012



In this basin, there are not "structural traps".

Scientific sentence. It can be tested.

In this basin, there are structural traps, but their mapping is quite difficult.

Pseudoscientific sentence. Cannot be tested. Explorationist is always right.

Depending of the geological setting, this "flatspot" can correspond to an hydrocarbon accumulation or not.

Pseudoscientific sentence. Cannot be tested. The geoscientist is always right.





"I need a narrow grid and good seismic lines, may be a 3D, to evaluate the hydrocarbon potential of this offshore"

Pseudoscientific sentence. You need to know, *a priori*, what you want to evaluate.

Boss answering the geoscientist:

"Tell me what are your ideas, hypotheses or conjectures on this offshore, and then, may be, I'll give you some seismic data to test your ideas"

Scientific sentence. Explorationists can just recognize on seismic lines what they know. Naive inductive interpretations rarely lead to HC discoveries.



Serendipity can play a role in exploration, but:

"In observation fields chance helps those who are prepared" (Pasteur)

Sector Exploration Structures Structures

Observations do not create ideas. Ideas create observations.

"Observing details may be entertaining and fascinating, but we learn from generalities" Bak wrote.



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An evaluation of the importance of an observation can only be made within a framework.

If you don't have the framework, you are liable to make mistakes.

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Naive Interpretation (Naive Inductive Interpretation)



This naive and inductive seismic interpretation can be easily refuted (falsified). Indeed, taking into account the 2nd law of Thermodynamics (Goguel's law, in Geology), it is evident that it poses a significant volume problem. In addition, any geologic interpretation is proposed. The interpreter seems to be completely out of the geological context of Tunisia onshore.

Naive Interpretation (Naive Inductive Interpretation)





A volume of some 16 km³ for each kilometer perpendicular to the cross-section have disappeared at depth.

The hypothesis advanced by the interpreter (drilling proposal), using a naive inductive interpretation, is completely refuted even by a roughly palinspathic reconstitution (critical discussion). Indeed, knowing that in the area there is any significant horizontal displacement, such a reconstitution indicates that the proposed interpretation creates an enormous volume problem.

Observations

Contrariwise to naive seismic interpretations, in scientific seismic interpretations, observations are theoryladen.

The theoretical framework within which interpreters works is critical to observations themselves.

Hypothetico-Deductive Interpretation



On this interpretation, the interpreter knew, a priori, (i) the basin characteristics, (ii) the stratigraphic signature, (iii) the locations of the more likely potential source rocks, (iv) the more likely potential reservoirs, as well as (v) the type of trapping that one can expected on this deep offshore.

"Observations"

When an interpreter looks at a seismic line, there are no legends telling her what she sees, as, for instance:

"This is the sequence boundary SB. 10 Ma"

To identify seismic markers and geometric relationships between markers, interpreters must to know what they are looking for.

If this sounds somewhat circular, it is, and it can help to explain why scientific advance is difficult.

"Observations"



This geologic hypothetico-deductive tentative interpretation was performed using the global stratigraphic signature proposed by Vail, et al., in 1993. Detailed well results and synthetic are not available. Therefore, the proposed ages are highly speculative and so they must be highly criticized.

Observations are Theory-laden

Who are the potential Source Rocks?

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	14		

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"Observations"

Clearly, exploration must start with observations.

But once some initial observations have been made a circular process takes place.

Observation lead to hypotheses, which guide further observations, which influence the hypotheses.

Predictions & Retrodictions

Hypothetic-deductive tentative interpretations allow predictions and retrodictions.

Predictions are specifications of what will happen.

Retrodictions are a specification of what did happen.

Interpretations in Geology are quite specific in their retrodictions. If evidence is found that something occurred that contradicts an interpretation, it will have to be modified or rejected.

Any statement inferred within the deductive system is a logical consequence of its premises. If the premisses a true, so is the conclusion.

Predictions & Retrodictions



Interpretation Before Drilling

Predictions & Retrodictions



Interpretation After Drilling

Confirmation & Falsification

There is an inherent asymmetry between confirmation and falsification.

An interpreter can never truly confirm an interpretation because even if he runs a million successful tests, he can never be sure that the next one will be also succeed.

For this reason, interpreters tend to avoid phrases like: "Drilling proves the interpretation"

and prefer to speak in tones that seem to demonstrate a lake of confidence using wimpy phrases like:

"I'm led to believed that..."

Confirmation & Falsification

Interpreters need an appropriated theoretical background in order to observe what your eyes see.

Clearly, when dealing with the unknown you are likely to be misled by illusions.

The word belief is roughly synonymous with the words hypothesis and conjecture, which are to be preferred.

Theoretical Framework



Interpretation without or with a bad theoretical framework

Theoretical Framework



Azores

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Faeroes

Model

Surtsey

Theoretical Framework



Interpretation with a theoretical framework

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Hypotheses & Conjectures

Hypothesis is used for a claim that is assumed for the purpose of investigating its consequences, without any real evidence from truth.

Conjecture is used when there is evidence for a claim, but the evidence is not sufficient to justify the claim.

Very often, a geoscientist claims progresses from hypothesis to conjecture to fact.

Hypothesis & Conjecture



An interpreter can advance the hypothesis that the generating petroleum subsystem is within the blue interval. He has not a really evidence, but he can investigate the consequences. Conversely, he has evidence enough to conjecture that the fault bounding the rift-type basin (hypothesis) is a reactivated fracture zone, but the evidence is not enough to justify the claim. 25

K. Popper took the concept of falsification beyond a principle to demarcate science from pseudoscience.

So, the progress in seismic interpretation science is a never-ending cycle in which an interpretation is proposed, then falsified, and then another interpretation is offered in place, the new interpretation itself becomes a candidate for falsification.

Confirming an existing interpretation is like trading water. It gets nowhere.



So far, the only dry well, in a block of northern Angola offshore, was drilled to test the hydrocarbon potential of "basin floor fan reservoirs deformed by salt withdrawal on a four way dip trap". The trap was interpreted, as a turtle back and considered an analog of Andromeda (Congo) and Girassol fields. Such interpretation was often justified but never criticized, that is to say, falsified. The disappointing results of the well, once again, show that naive inductive interpretations are rarely criticized. Interpreters take them as their own babies and so, they systematically try to justify them and they forget to criticize them. As we'll see next a simple structural critic completely falsify then propose interpretation



A turtle back is an extensional inverted structure, therefore the absence of stretching faults on the top of the antiform is critical, as well as the absence of rim synclinals and associated depocenters. Similarly, the presence of channel anomalies, the absence of geometrical relationships (onlap) associated with BBF, and the internal configuration above and below the drape shale do not fits with potential basin floor fans reservoirs.



This hypothesis, proposed before drilling as an alternative to the turtle back and basins floor fans reservoir interpretation, is more difficult to falsified. The turtle back structure is replaced by drape and overbank shales, slightly deformed by salt flowage, and the basinal environments are replaced by slope environments with frequent channel-levee complexes ("gull wings").

Seismic interpreters propose interpretations. Then, they perform experiments, as wildcats, to check predictions.

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If an experiment refutes the predictions of the interpretation, the interpretation is falsified, and interpreters must search for a new interpretation not refuted by the experience.



This naive inductive seismic interpretation was criticized using the geological setting of the area, that is to say, a relative young convergent margin rather than a divergent Atlantic-type margin, and the basic principles of salt tectonics. A new interpretation satisfying the majority of critics is proposed on the next slide. However, it be also criticized in order to progress progress.



This hypothetico-deductive interpretation is must more difficult to refute than the previous one. Indeed, it satisfies, the
actual geologic setting, basic geologic principles salt tectonics, the Goguel's Law (2nd law of Thermodynamics) and actual
seismic activity. Nevertheless, as any interpretations it must be criticized by new data in order to approach the more likely
interpretation.32

Methodology

As a methodology, falsification has certain advantages over naive induction interpretations.

Falsification, unlike induction, recognizes that observations are theory-laden, performed within a theoretical framework.

Further more, falsification avoids talking about the "truth" of an interpretation. Instead, one interpretation is simply "better" than another because it has survived more attempts of falsification.

Methodology

In Petroleum Geology, as in other sciences, it is easy to suggest an interpretation, but it is extremely difficult to construct a concise, coherent interpretation that can be used to explain and predict.

As in other sciences, a circularity exists; geoscientists need data to develop hypotheses and conversely they need hypotheses to guide observations.