The Use and Abuse of Geophysics in Oil and Gas Reserve and Resource Estimation*

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Abstract

Improvements in seismic technology have been one of the major technical advances in the industry over the last several decades. Progress has been rapid and multi-faceted, with significant improvements in acquisition, processing, and interpretation. These developments have provided increasingly robust images of the subsurface that have proven valuable in enabling enhanced reservoir definition relative to historical well control methods. In recognition of these advances and the widespread use of seismic data in reservoir description, 2009 SEC regulations permit the use of seismic as a "new technology" that is acceptable in providing support for the determination of proven reserves. While the use of seismic data can influence many factors in a reserves evaluation, we may categorize the myriad impacts of seismic data in terms of its role in each of the following areas: (1) mapping of the geologic structure, (2) mapping of the reservoir extent, (3) determination of reservoir thickness, (4) determination of fluid contacts, and (5) evaluation of reservoir net to gross. When viewed in the context of these five factors, the potential impact of adding seismic data to the list of SEC recognized technologies may be substantial. However, when viewed critically, and in light of a "reasonable certainty" standard, even modern seismic datasets can suffer from common limitations that degrade the quality of the data and can introduce considerable uncertainties in reservoir interpretation. Factors such as limited resolution (resulting from insufficient frequency content or narrow bandwidth), complex imaging problems (e.g., sub-salt, fault shadows, gas clouds, etc.), and heavy reliance on intrinsically non-unique and model-driven processing techniques (e.g., tomography, pre-stack depth migration) can each act to distort our image of the subsurface and result in substantive uncertainties in reservoir description. Overcoming these constraints is likely to involve a mix of both technology and the use of a standardized corporate process with the objective of maintaining a consistent vision toward the application of seismic data in resource and reserve estimation.

The Use and Abuse of Geophysics In Oil and Gas Reserve and Resource Estimation

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Modernization of Oil and Gas Reporting

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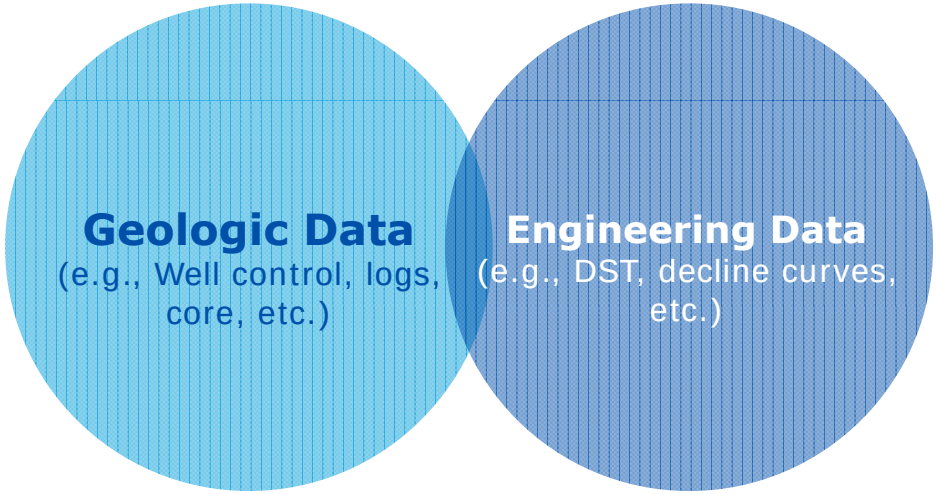
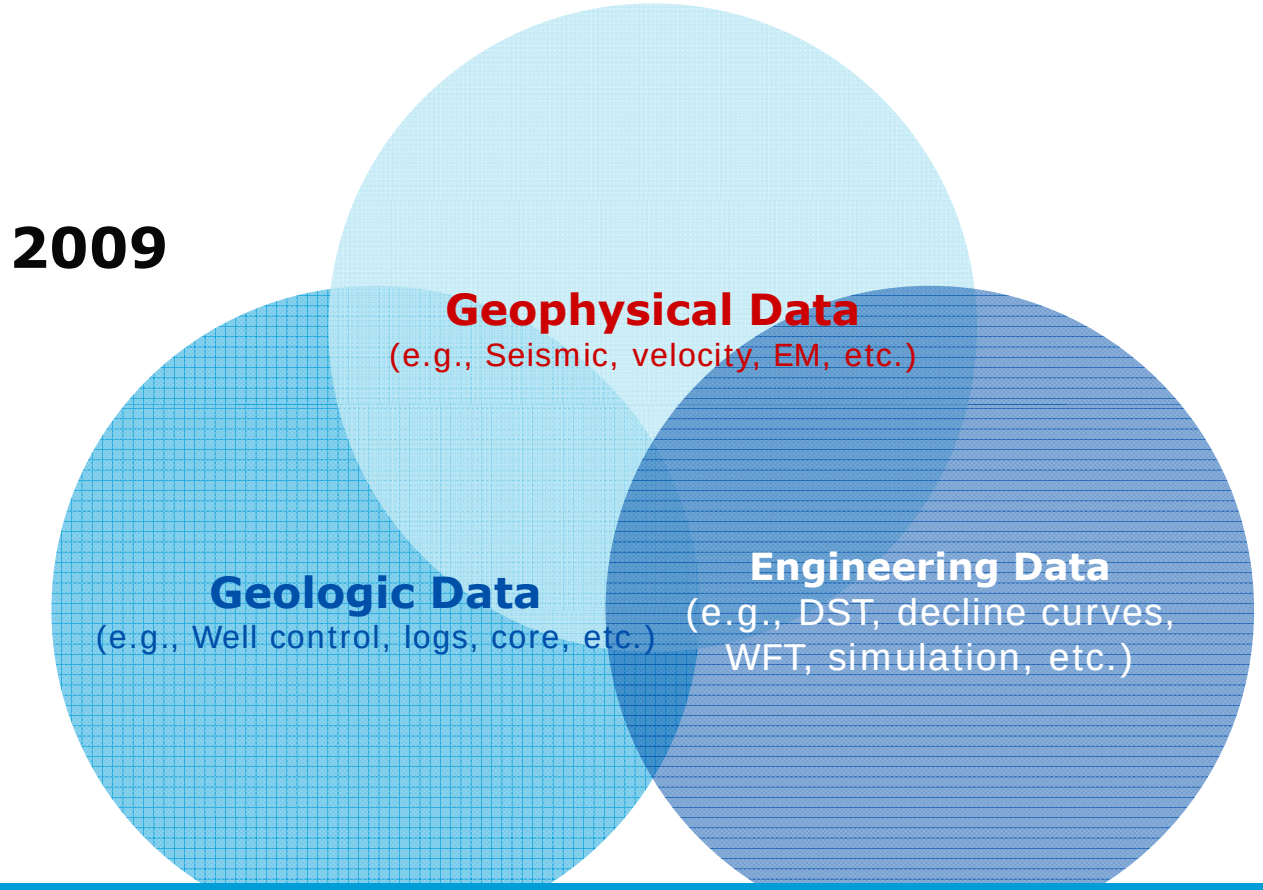
1978



Prior State

The technologies acceptable for use in the determination of proved reserves are defined within the constraints of a rule-based system. This approach provides a conservative reserve estimate, but excludes a wide array of technologies that could otherwise improve the assessment.

Modernization of Oil and Gas Reporting



Current State

The introduction of a principle-based reserve system and the removal of explicit technology exclusion allows for a wide variety of data to be utilized in reserve evaluations. This will require a much greater degree of integration than previous estimation techniques.

Modernization of Oil and Gas Reporting
"New" and "Reliable" Technology

SEC 1978

SEC staff only recognized

- Well logs
- Production or Flow tests
- Analogy
- Analytic methods (Craft and Hawkins)
  - Volumetric
  - DCA
  - Material Balance
- Simulation with history match

SEC 2009

"**reliable technology**" permits the use of technology (**including computational methods**) that has been **field tested** and has **demonstrated consistency and repeatability** in the formation being evaluated or in an **analogous formation**. This new standard will **permit** the use of a **new technology** or a **combination of technologies** once a company can establish and **document the reliability of that technology or combination of technologies**.

Definition:
New Technology is any technology or groups of technologies not previously recognized by the SEC staff

Requirement:
Document in field tests or analogous formations with reliable and repeatable results

Modernization of Oil and Gas Reporting
"Reliable" Technology and Geophysics

Regulations Now: Allow the use of "new technology" such as seismic in reserve evaluations. The use of seismic can influence:

1. Structure – **Previously Allowed**
2. Reservoir Extent/Continuity – **New for beyond offset**
3. Reservoir Thickness – **New for thickening**
4. Fluid Contacts – **New for LKO/HKO**

In light of *"reasonable certainty"* and *"reliable technology"* standards, the critical factors in geophysical data that limit its potential reliability include, but are not limited to:

- Finite resolution (e.g., Mis-identified barriers/discontinuities)
- Model-driven (e.g., Velocities, PSDM)
- Non-uniqueness (e.g., Time-depth conversion, lithology)
- Complex and interpretive processing (e.g., PSDM, inversion)
- Data quality (e.g., old acquisition, complex geology)

Use of Seismic in establishing Proved Reserves

- **Now:** Regulations allow the use of “new technology” such as seismic to:
- **Establish continuity of the productive reservoir**
- Establish a lower proved limit of a reservoir.
- Establish an upper proved limit of oil

Still Restrictions on unpenetrated Fault Blocks

The reliability of seismic techniques should be documented in field tests or analogous formations with reliable and repeatable results in the basin.

This example shows the same seismic data with two different velocity models. “Reliability” will be very data and model dependent.

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The reliability of seismic techniques should be documented in field tests or analogous formations with reliable and repeatable results in the basin.

Reservoir continuity cannot be reliably established from seismic amplitude alone. Additional data (e.g., 4D, production) required.

Continuity of Productive Reservoir
Pitfalls / Mitigation

- Seismic discontinuities cause greater compartmentalization than expected – Analogies required; default to old offset rule
- Reservoir limits or quality degradation is poorly resolved – Analogies required; default to old offset rule
- Time thickness to depth thickness is not well understood due to lack of sampling, change in reservoir quality, tuning… – Analogies required; default to no thickening

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Still Restrictions on unpenetrated Fault Blocks

The reliability of seismic techniques should be documented in field tests or analogous formations with reliable and repeatable results in the basin.

Seismic admissible as evidence of contact; excellent record of analogies, high quality seismic, simple sand/shale lithology.

Use of Seismic in establishing Proved Reserves

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- Establish continuity of the productive reservoir
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Still Restrictions on unpenetrated Fault Blocks

The reliability of seismic techniques should be documented in field tests or analogous formations with reliable and repeatable results in the basin.

Seismic not allowed as evidence of contact; poor record of analogies (<60% work) due to lithology complications and significant volume at risk.

Use of Seismic in establishing Proved Reserves Establishing Contacts

Various suggested QC products to establish reliability:

- Seismic proved reliable in the area for proving LKH and/or HKO
- Simple lithology: false anomalies at the reservoir level are not expected
- Demonstrate that the amplitudes defining pay are consistently distinguishable from regional background with high confidence.
- Depth structure conformance of anomalies
- Documentation of tuning thickness w/ hydrocarbons and brine
- Well ties show unambiguous correlation with seismic
- Sensitivities to thickness, porosity, anisotropy documented
- Documentation of full offset acoustic/elastic modeling in the reservoir
- No significant discontinuities between well control containing hydrocarbons and the area to be booked
- Clear modeled and observed AVA/AVO behavior (Class I/II/III/IV) between brine and hydrocarbon bearing cases.
- Basic fluid information (Oil / Gas gravity, GOR, water salinity)
- If significant transition zone is possible, “J” Function analysis must be incorporated

* Booking Proved Reserves in separate fault blocks, reservoirs, or adjacent structures not tested by wells, is not acceptable regardless of seismic indicators.

Use of Seismic in establishing Proved Reserves

Regulations Now: allow the use of "new technology" such as seismic to:

1. Structure – **Previously Allowed**
2. Reservoir Thickness – **New for thickening**
3. Reservoir Extent – **New for beyond offset**
4. Fluid Contacts - **New**

However, due to the inherent uncertainties in the acquisition, processing and interpretation of seismic:

- Localized analogies required to validate the interpretation
- Rigorous requirements for use of seismic as primary method
- Integration of all available data will be the key to establishing *reliability* and for the documentation of *reasonable certainty*.