

## Summary

### The Challenge

Seismic interpretation remains a critical bottleneck in subsurface analysis—time-intensive, subjective, and prone to interpreter bias. While deep learning offers automation potential, traditional models are highly task-specific and require extensive labeled datasets that are scarce in geophysics.

### Our Solution: Domain-Aware SAM Adaptation

We adapted Meta AI's Segment Anything Model (SAM) for seismic facies segmentation by integrating **geophysical domain knowledge** through multi-attribute seismic inputs and custom visualization techniques. This approach leverages SAM's foundation model capabilities while addressing the unique challenges of geological feature recognition.

### Key Innovation: Multi-attribute enhancement to SAM

We developed a domain-aware workflow combining seismic amplitude, coherence, and curvature attributes with weighted color blending to improve feature discrimination without sacrificing SAM's broad generalizability.

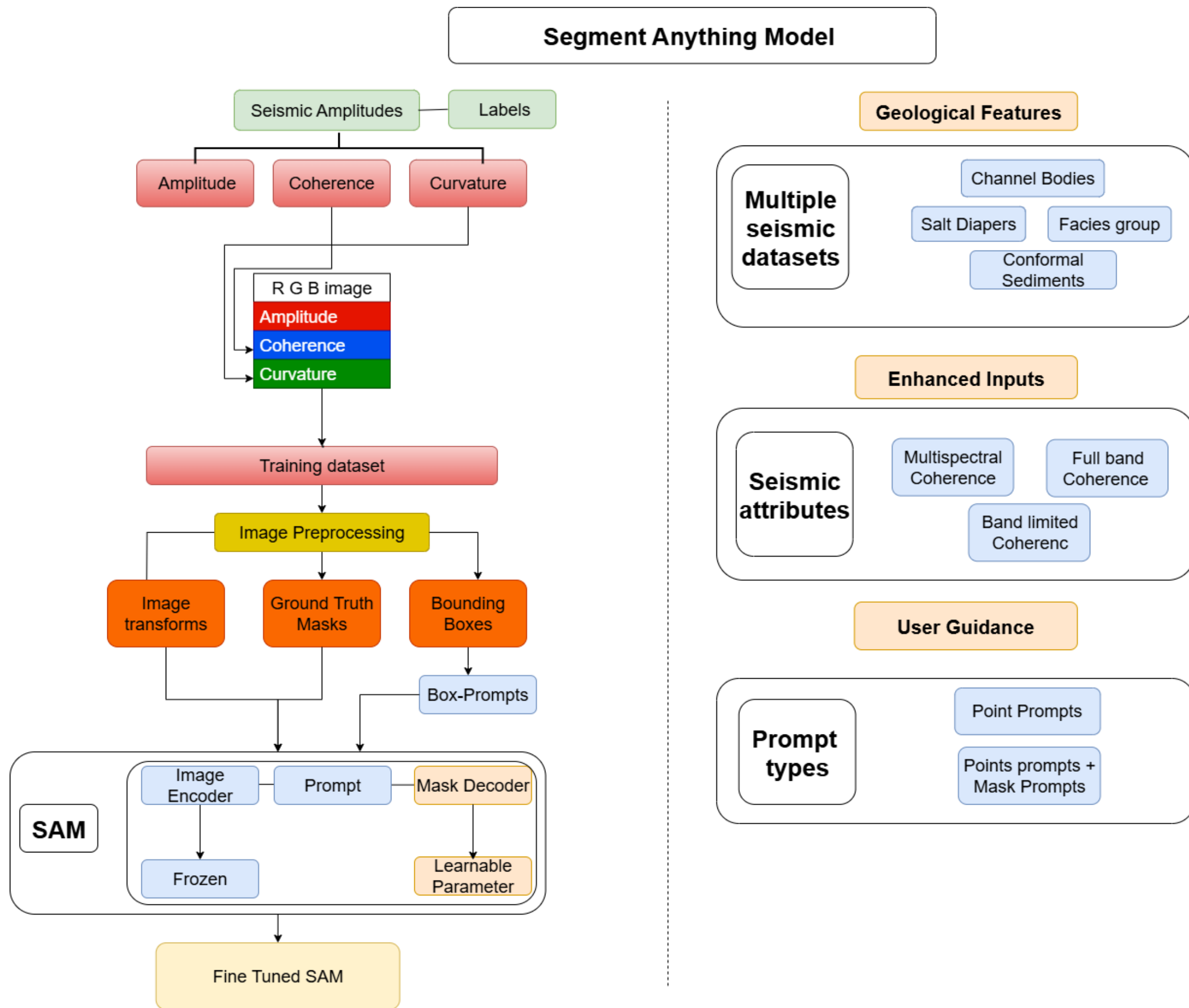
### Results That Matter

- **Successful segmentation** of diverse geological features: karst, salt domes, channels, and conformal sediments
- **Maintained generalization** across feature types without requiring feature-specific training
- **Optimal prompt strategies identified:** Complex features benefit from mask + point combinations while simple structures require minimal interaction
- **Fine-tuning trade-off quantified:** High accuracy for specific features vs. maintained flexibility across all geological structures

### Impact

This work demonstrates how foundation AI models can be effectively adapted for specialized geophysical applications, positioning SAM as an **intelligent assistant** that accelerates interpretation workflows while preserving essential human expertise and geological insight.

## Methodology



## Results and discussion

### Improvement of SAM by fine tuning

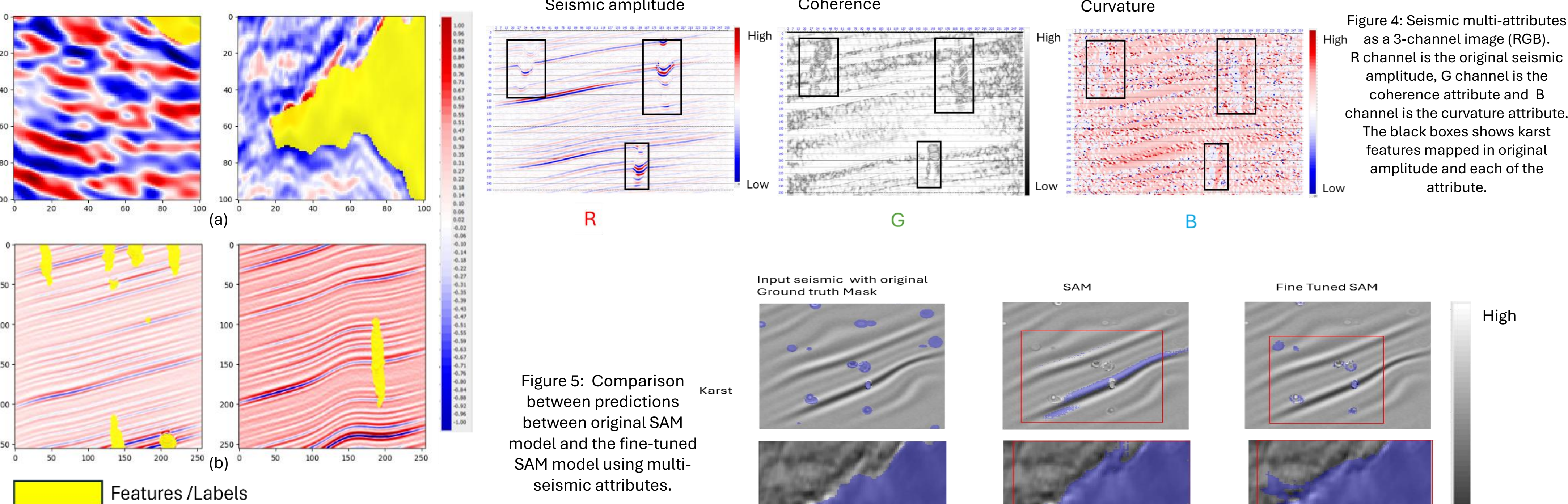


Figure 2: Seismic Images and labels, (a) shows the salt labels on seismic, (b) shows the karst labels on seismic on inline section.

### Improvement of SAM using enhanced inputs

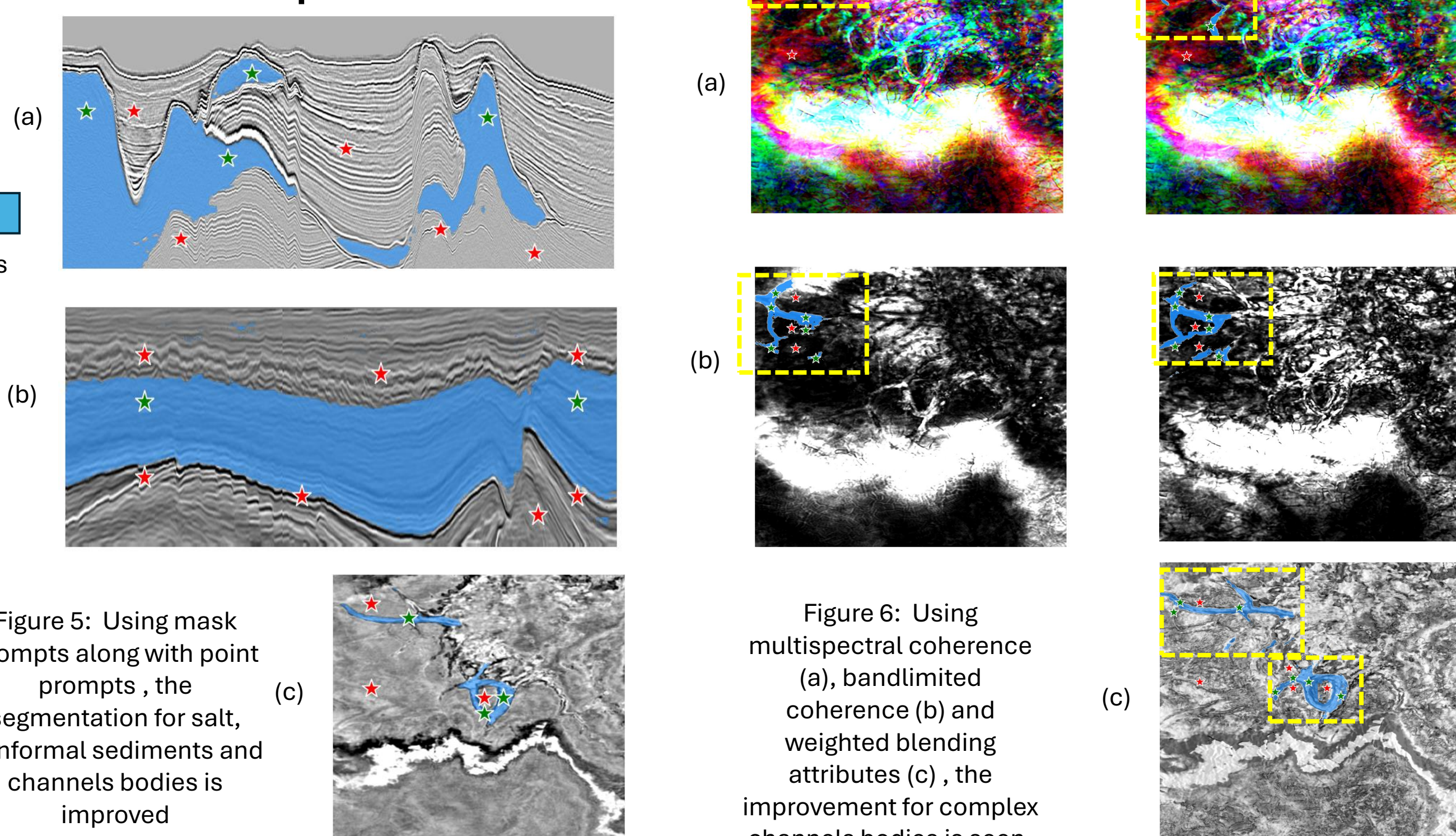


Figure 6: Using mask prompts along with point prompts, the segmentation for salt, conformal sediments and channels bodies is improved

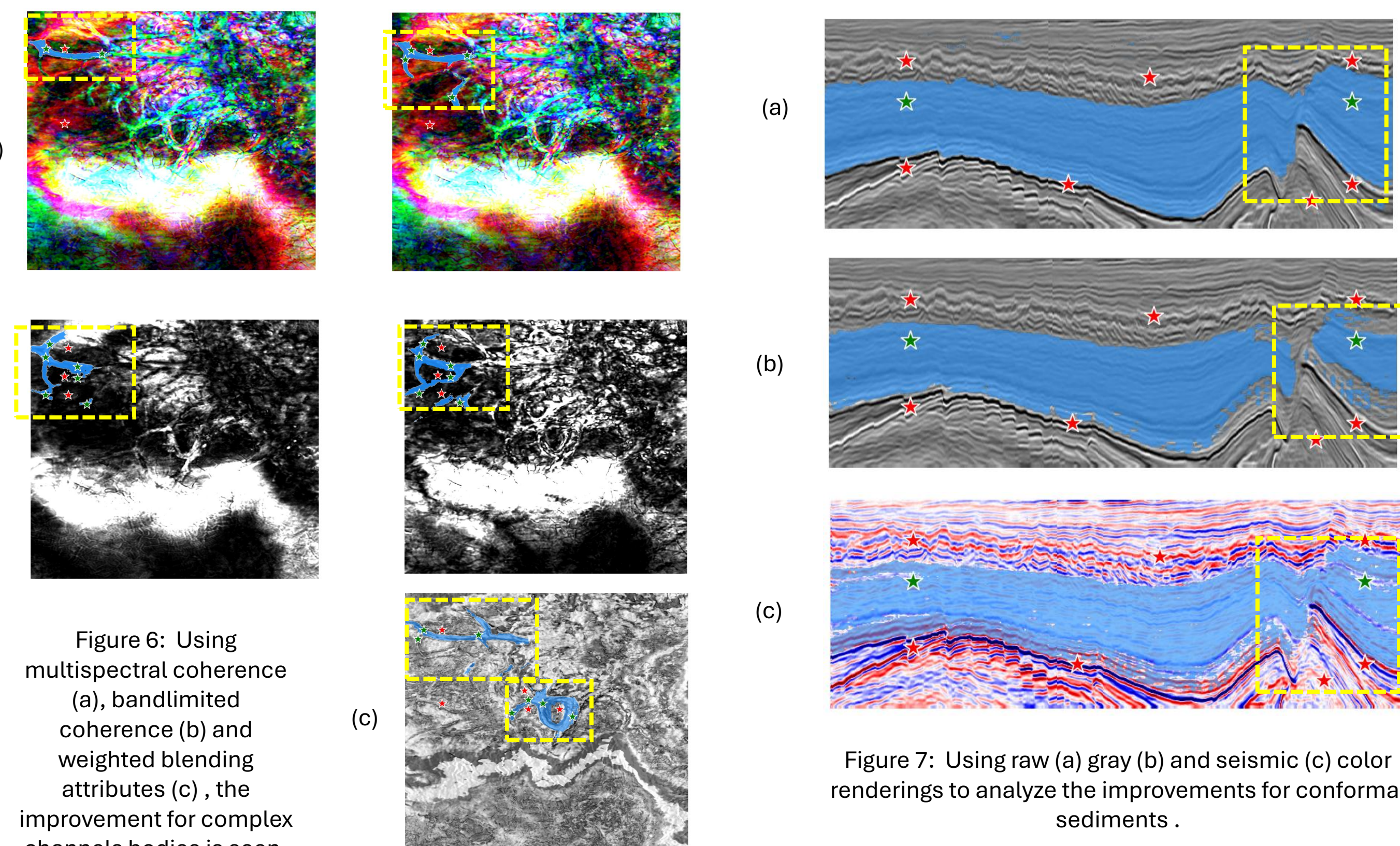


Figure 7: Using raw (a) gray (b) and seismic (c) color renderings to analyze the improvements for conformal sediments.

Observations		
Aspect	Approach	Observations
Seismic Features Tested	Karst, salt, channels, conformal sediments, various facies	Reduced manual interpretation time and improved objectivity. SAM's generalization capabilities segmented all tested features.
Geophysical Domain-Aware Adaptation	Integrated seismic attributes (Full-band, multi-band, multispectral coherence)	Attributes highlighted target features, aiding model discrimination. Good segmentation, but complex features required more prompts.
Fine-Tuning	Applied for specific features	High accuracy for targeted features but limited generalization beyond the fine-tuned class.
Prompt Types	Point, box, and mask prompts	Points alone were insufficient for complex facies; combining masks with points improved results.
Color Rendering	Weighted blending & multi-attribute color mapping	Enhanced boundary clarity and feature separation; complex structures still required more prompts.
Role of SAM	Assistant to interpreters, not a replacement	Supported interactive workflows aligned with interpreter expertise.

## Conclusion

**Multi-attribute seismic inputs (coherence, curvature, amplitude) combined with custom color rendering enable SAM to segment complex geological features without fine-tuning, maintaining broad generalizability across diverse seismic facies.**

### Key Take-Away Points:

- **Enhanced Segmentation Performance:** Multi-attribute inputs dramatically improved feature discrimination for complex structures like channels that would otherwise require task-specific fine-tuning.
  - **Optimal Prompt Strategy:** Complex geological features require combined mask+point prompts (4-5 prompts) while simple structures like salt domes achieve accurate segmentation with minimal interaction (1-2 prompts).
  - **Fine-tuning Trade-off Confirmed:** While fine-tuning delivers high accuracy for specific target features, it significantly reduces model generalization—the use of mask prompts and multi-attribute approach maintains flexibility across all tested geological structures.
- Overall, SAM functions as an **intelligent assistant** that amplifies interpreter expertise rather than replacing it. The interactive workflow preserves expert geological knowledge while dramatically reducing manual interpretation time and improving result consistency and objectivity.

## Acknowledgments

We gratefully acknowledge Afonso, Basso, Kuroda, Vidal, and Papa (2018) and SEG SEAM AI for developing synthetic seismic data that supported parts of this research. We sincerely appreciate the researchers who made their valuable data publicly available on GitHub. We extend our heartfelt thanks Dr. David Lubo-Robles and AASPI consortium for their continued support.

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## Overview

### The Challenge

Seismic interpretation remains a critical bottleneck in subsurface analysis—time-intensive, subjective, and prone to interpreter bias. While deep learning offers automation potential, traditional models are highly task-specific and require extensive labeled datasets that are scarce in geophysics.

### Our Solution: Domain-Aware SAM Adaptation

We adapted Meta AI's Segment Anything Model (SAM) for seismic facies segmentation by integrating **geophysical domain knowledge** through multi-attribute seismic inputs and custom visualization techniques and different prompting techniques.

This approach leverages SAM's foundation model capabilities while addressing the unique challenges of geological feature recognition.

### Key Innovation: Multi-attribute enhancement to SAM

We developed a domain-aware workflows: first, fine-tuning SAM with seismic amplitude, coherence, and curvature attributes; and second, leveraging attributes as RGB inputs with weighted blending and prompting techniques. Together, these approaches improve feature discrimination while maintaining SAM's broad generalizability.

### Results That Matter

•**Successful segmentation** of diverse geological features: karst, salt domes, channels, and conformal sediments

•**Maintained generalization** across feature types without requiring feature-specific training

•**Optimal prompt strategies identified:** Complex features benefit from mask+point combinations while simple structures require minimal interaction

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### Impact

This work demonstrates how foundation AI models can be effectively adapted for specialized geophysical applications, positioning SAM as an **intelligent assistant** that accelerates interpretation workflows while preserving essential human expertise and geological insight.

- **Seismic interpretation** is essential for identifying and mapping subsurface geological features, but it is often **time-consuming** and subject to **interpreter bias**.
- **Deep learning** and **computer vision** offer potential to automate and speed up this process but they have **limitations** due to **scarcity of datasets** and they work **for specific task** they are trained for.
- The **Segment Anything Model (SAM)**, developed by Meta AI, is a modern vision model capable of identifying objects in images with **user input**.
- It is an advanced computer vision models with **strong generalization and efficiency**.
- This study explores how SAM can be adapted for seismic data analysis and tested the model with and without fine tuning and showed the model improvements using seismic attributes, prompt types, color renderings.

- Applied a **domain-aware approach** by incorporating seismic attributes, multiple visualizations, and color renderings to enhance geological structure visibility.
- **Bridged the gap** between geophysical domain knowledge and foundation vision models by integrating interpreter priorities into the SAM workflow.
- Leveraged **multi-attribute seismic data**, weighted blending, and color blending techniques to improve feature differentiation.
- Positioned SAM as a **powerful assistant** for interpreters, enabling interactive segmentation while respecting expert judgment.
- Streamlined **detection and extraction** of geological features, reducing manual interpretation time, thus improving **efficiency** of geophysical workflows