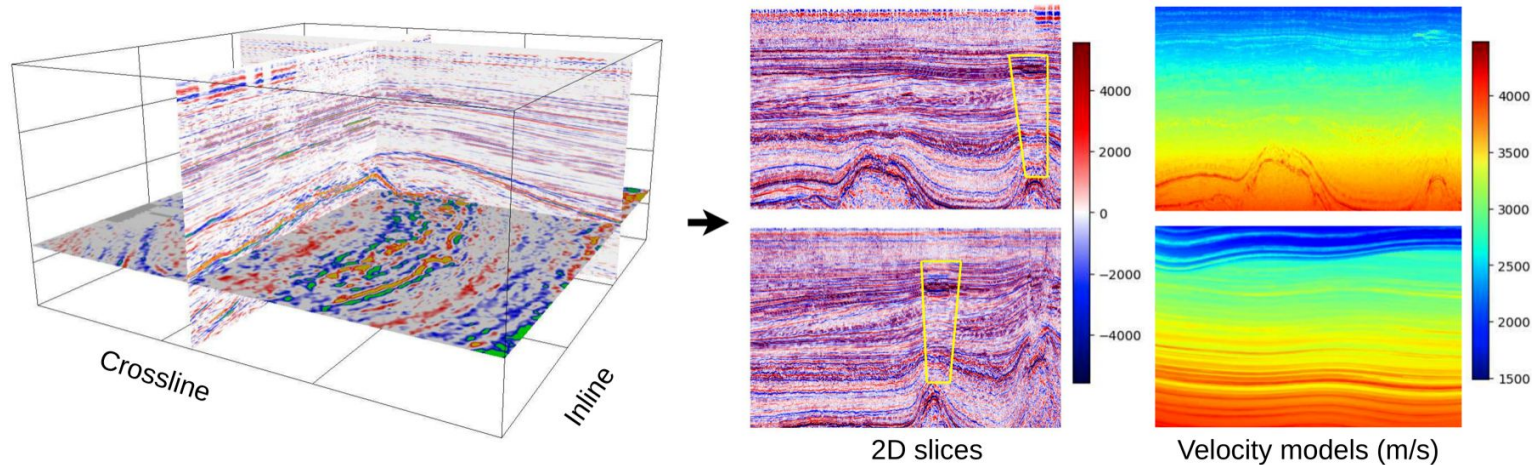


SIGMA: A Physics-Based Benchmark for Gas Chimney Understanding in Seismic Images

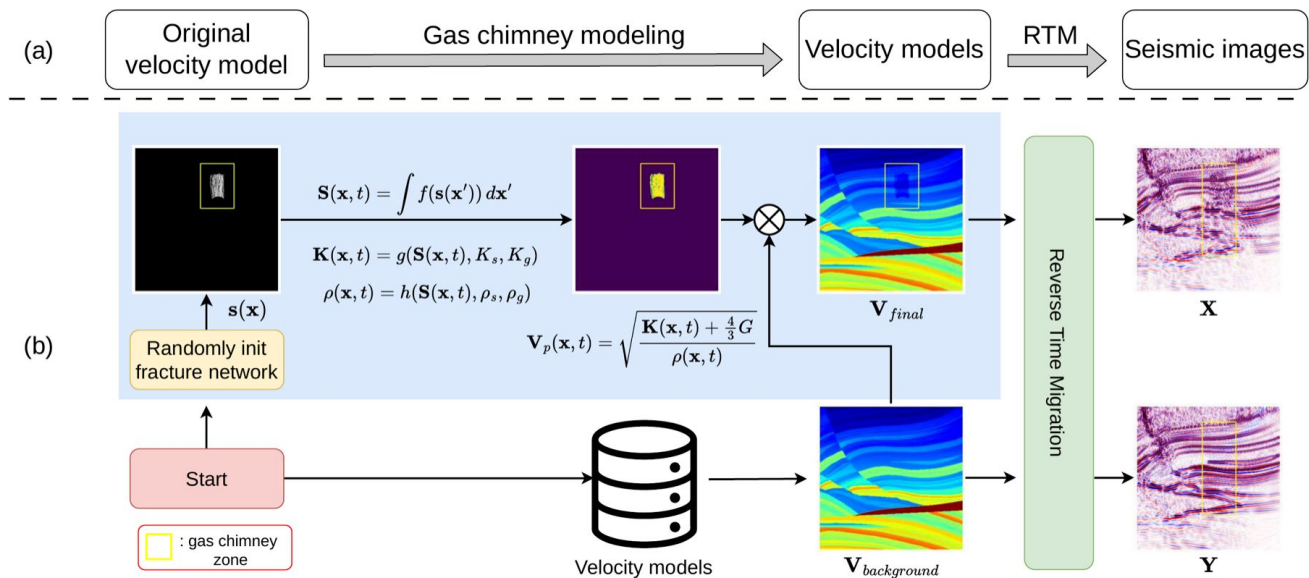
Bao Truong, Quang Nguyen, Baoru Huang, Jinpei Han, Van Nguyen, Ngan Le,
Minh-Tan Pham, Doan Huy Hien, Anh Nguyen

Introduction



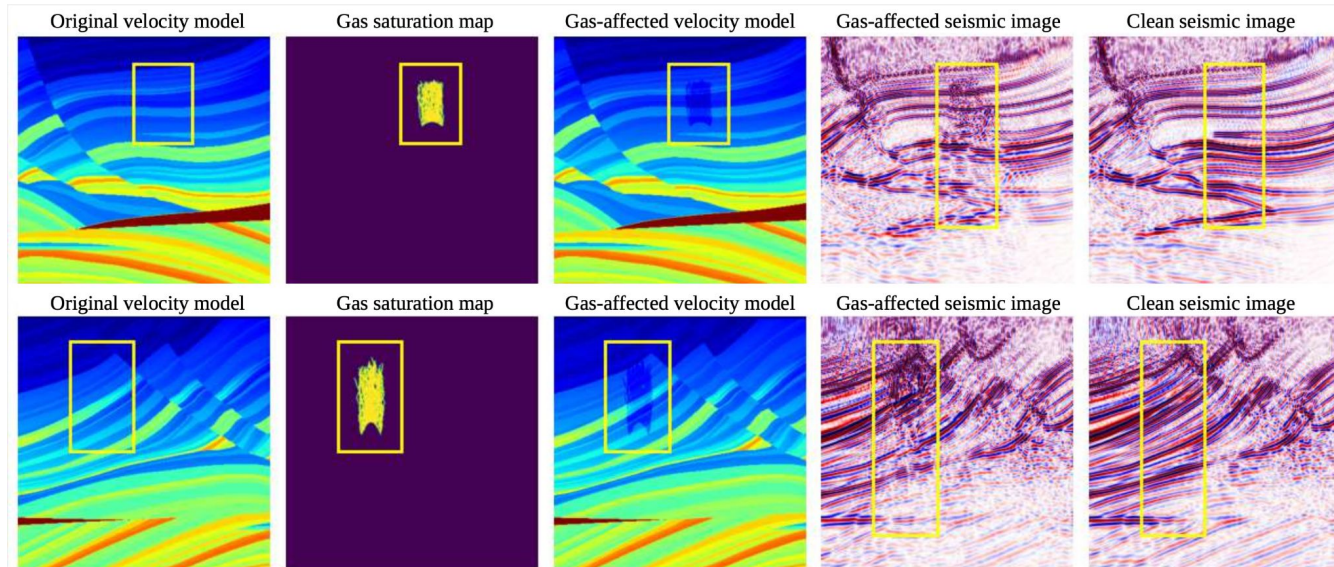
We introduce **SIGMA**, the first large-scale, physics-based synthetic dataset for gas chimney understanding, featuring pixel-level masks and paired ground-truth images.

Dataset Generation Pipeline



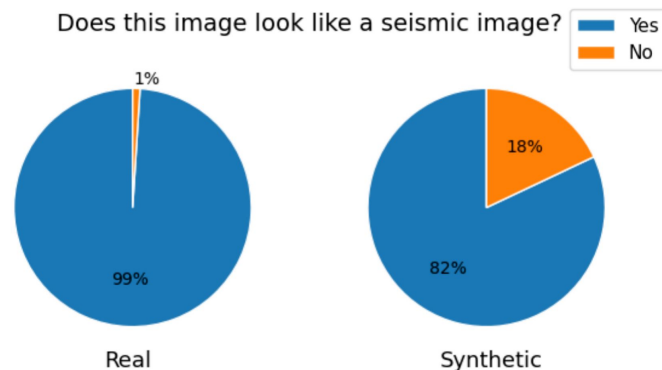
Our dataset creation pipeline is designed to be automated and scalable.

Data Samples



We present examples in our SIGMA dataset, including original velocity model, gas saturation map, gas-affected velocity model, gas-affected seismic image and clean seismic image.

- **Scale:** Includes **400** seismic image pairs covering a vast area of over 1,600 km².
- **Diversity:** Derived from 20 diverse real-world velocity models with varied geological structures.
- **Resolution:** Each sample is 512×512 pixels, representing a survey area of approximately 2.048×2.048 km².
- **Realism validation:** A user study confirmed that **82%** of synthetic samples were **perceived** as real seismic images.



Benchmarks

- We benchmark **SIGMA** dataset on two primary tasks:
 - localization of the gas chimney regions.
 - enhancement of seismic features in the gas chimney area.

| Model | Year | IoU \uparrow | Dice \uparrow |
|------------------|------|----------------|-----------------|
| FaultSeg [87] | 2019 | 0.76 | 0.86 |
| DualUnet [83] | 2023 | 0.84 | 0.91 |
| FaultFormer [77] | 2025 | 0.80 | 0.87 |
| FaultViT [44] | 2025 | 0.75 | 0.86 |

GAS CHIMNEY DETECTION RESULTS

| Model | Year | SSIM \uparrow | PSNR \uparrow | Corr \uparrow | SNR \uparrow |
|-------------------|------|-----------------|-----------------|-----------------|----------------|
| ConditionGAN [94] | 2022 | 0.52 | 20.02 | 0.81 | 3.33 |
| SeisDDPM [23] | 2023 | 0.41 | 16.14 | 0.61 | 0.68 |
| SeisGAN [50] | 2023 | 0.30 | 15.66 | 0.46 | 2.08 |
| SeisResoDiff [95] | 2024 | 0.30 | 16.05 | 0.70 | 0.59 |
| SIST [22] | 2024 | 0.65 | 19.00 | 0.77 | 3.51 |

GAS CHIMNEY ENHANCEMENT RESULTS

Conclusion



SIGMA is serving as the first benchmark for gas chimney understanding in seismic imaging. We believe that the release of this dataset will promote further research in automated seismic interpretation and subsurface anomaly detection related to gas chimney occurrences.



THANK YOU!