SEAM – THE CHALLENGE OF MODELING SEISMIC EXPLORATION AT FULL SCALE

Overview

SEAM—Modeling seismic exploration at full scale

Outline

- Introduction to SEAM
- Review of SEAM Phase I – Modeling modern 3D marine seismic acquisition
- Overview of SEAM Phase II – Modeling the future of land seismic acquisition
- Candidates for SEAM Phase III

What is SEAM?

SEG Advanced Modeling Corporation

The SEG Advanced Modeling Corporation

Society of Exploration Geophysicists
The international society of applied geophysics

SEAM
SEG Advanced Modeling Corporation

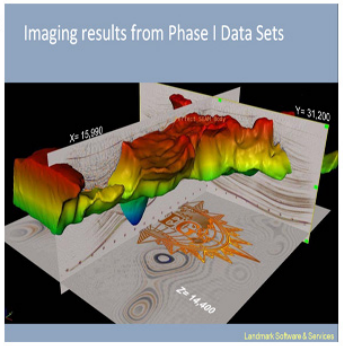
On 14 February 2007, the SEG Advanced Modeling (SEAM) Corporation was incorporated as a not-for-profit organization in the state of Oklahoma, with SEG as sole member, for the purpose of fiduciary, policy, and management oversight of the SEAM projects ("Phases"). SEAM is an industrial consortia dedicated to large-scale leading-edge geophysical numerical modeling.

The SEAM projects will provide the geophysical exploration community with geophysical model data for subsurface geological models at a level of complexity and size that cannot be practicably computed by any single company or small number of companies. A general introduction to the SEAM initiative can be found in TLE's June 2007 issue (44kb PDF).

The SEAM mission is to advance the science and technology of applied geophysics through a cooperative industry effort focused on subsurface model construction and generation of synthetic data sets for geophysical problems of importance to the resource extraction industry. Data sets, after an initial two years of confidentiality, will enter the public domain.

The primary goals of SEAM are to:

- design and generate synthetic model 3D and 2D seismic data
- share the high cost effort of substantial model design and generation
- provide a forum to discuss geophysical problems of interest
- advance the art of modeling and computation
- provide data sets for industry benchmarks and educational purposes



Now available:

- Imaging results using SEAM Phase I classic data sets
- Full Phase II Information Announcement

FROM THE BYLAWS:

To this end, the corporation shall advance the science and technology of applied geophysics by…

(1) designing and generating synthetic model 3D and 2D geophysical data that represent challenges to the geophysical community;

(2) providing a forum to discuss geophysical problems of interest;

(3) advancing the art of modeling and computation by testing and comparing modeling code for accuracy and efficiency;

(4) providing data sets for industry benchmarks and educational purposes; and

(5) furthering the science of seismology for the public benefit.

www.seg.org/resources/research/seam

Motivation for SEAM

- **Provide datasets to test algorithms for imaging and inversion** – i.e., datasets for models that represent realistic (complex) earth structures and physical parameters, *where the true inversion result is known*
- Better understand features and artifacts in real images
- Explore trade-offs in acquisition methodologies
- Train next generation of seismic processing and imaging experts

SEAM Corporation
Board of Directors

Management Committee
one representative from each participant

SEG Support Staff

Project Manager

Technical Committee 1

Technical Committee 2

Technical Committee 3

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Vendors

Two concurrent projects
SEAM Phase I – Marine seismic (2007)
SEAM Phase II – Land seismic (2011)

Projects have an initial 3-year lifetime
(with possible extensions)
Member fees are $60k/year
(with late fees)

SEAM Advanced Modeling Corporation
Board of Directors

Manik Talwani, Chair
Kevin Bishop, Vice Chair
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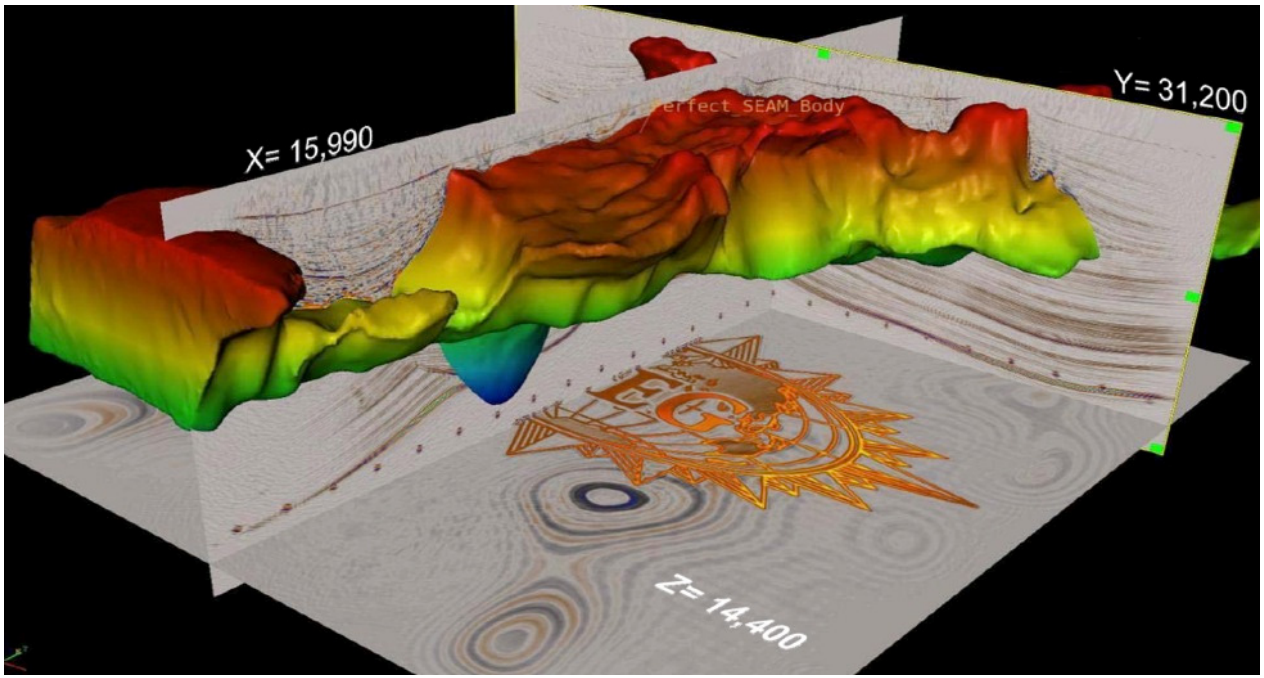
SEAM Phase I

Challenges of Sub-salt Imaging in Tertiary Basins,
with Emphasis on Deepwater Gulf of Mexico

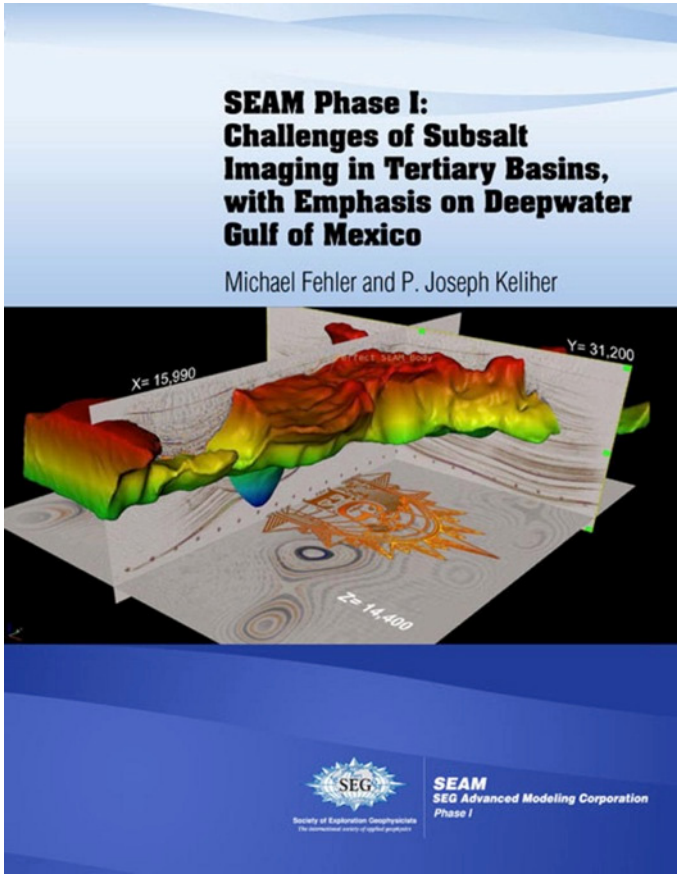


Anadarko · **BHP Billiton** · CGGVeritas · **Chevron** · **ConocoPhillips** · **Devon** · EMGS · **ExxonMobil** · Fusion · Geotrace · GX Technology
Hess · Landmark · **Maersk** · **Marathon Oil** · Nexen · **Petrobras** · PGS · **Repsol** · Rock Solid · **Statoil** · **Total** · WesternGeco

SEAM I Results

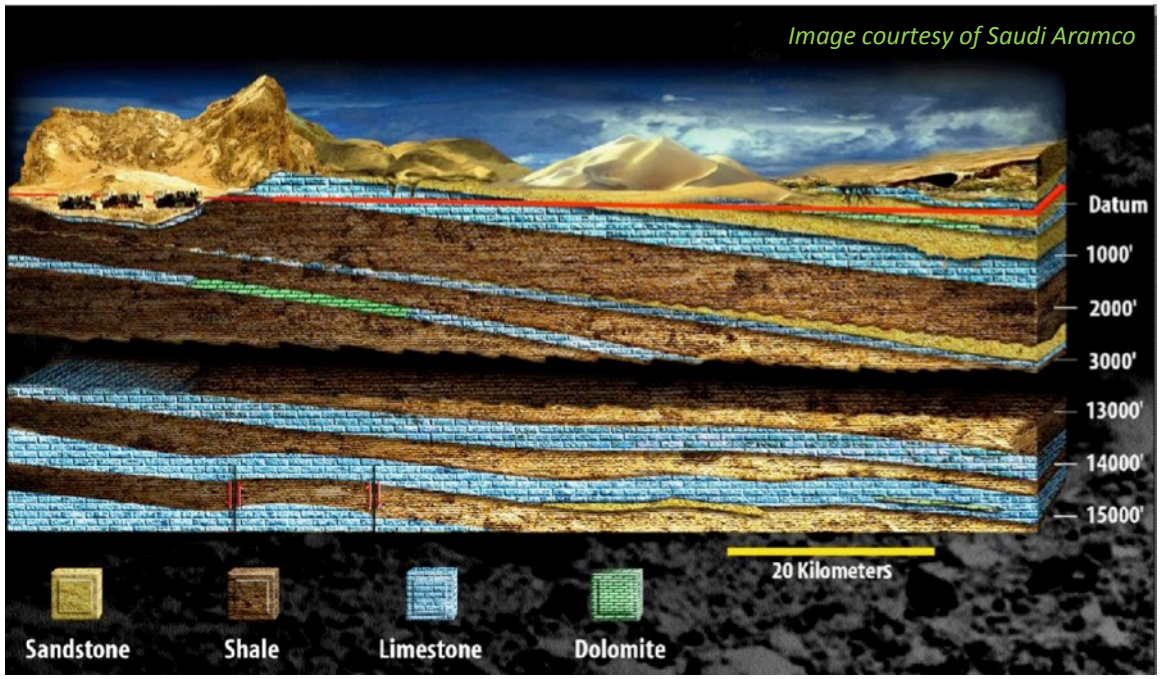
- Phase I finished acoustic simulations in 2011
  - 62 478 shots, 450 K traces/shot
  - Full data (220 TB) distributed to members
  - Classic data sets corresponding to conventional 2D and 3D acquisition geometries also available
- Phase I extension through a RPSEA proposal (www.rpsea.org)
  - Reduced set of pseudo-acoustic TTI and full isotropic elastic simulations
  - Simulations of non-seismic exploration methods: CSEM, MT, and gravity gradiometry
- Papers at SEG 2011 using Phase I results available at SEG SEAM web site

www.seg.org/resources/research/seam/seamsuccess011012



SEAM Phase II (launched March 2011)

Understanding the Challenges of Land Seismic through advanced 3D elastic modeling



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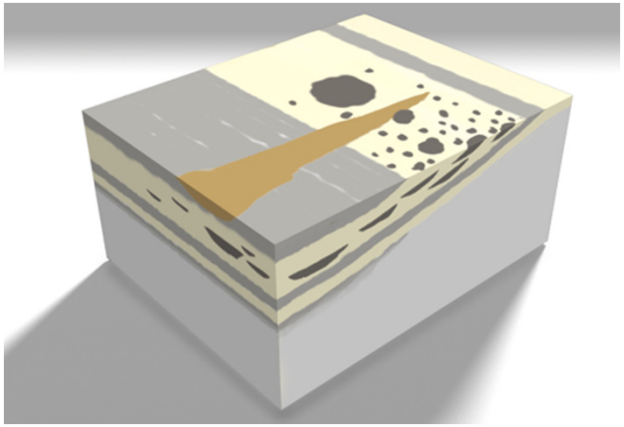
Hess · **Marathon Oil** · **Occidental** · **Repsol** · **SaudiAramco** · **Shell** · **Sinopec** · **Statoil** · **Total** · WesternGeco

Goals for SEAM Phase II – Land Seismic Challenges

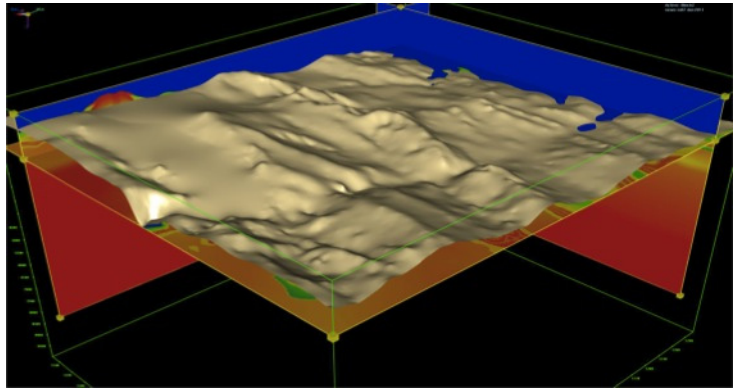
Use 3D elastic-wave modeling to better define

- **Trade-offs in next-generation land-seismic acquisition ("million-channel" systems)**
- **Challenges in land-seismic data-processing, imaging, and inversion**
  - Near-surface complexity: topography, strong velocity contrast, heterogeneity at all scales
  - Complex reservoirs: fractured, unconventional, complex structure
- **Modeling challenges**
  - Accurate representation of surface-wave scattering with extreme topography
  - Fully anisotropic modeling of fractured reservoirs: HTI, VTI, TTI, general anisotropy
  - Accurate modeling of Q (visco-elastic effects) to mimic the balance of surface and body-wave energy seen in real data

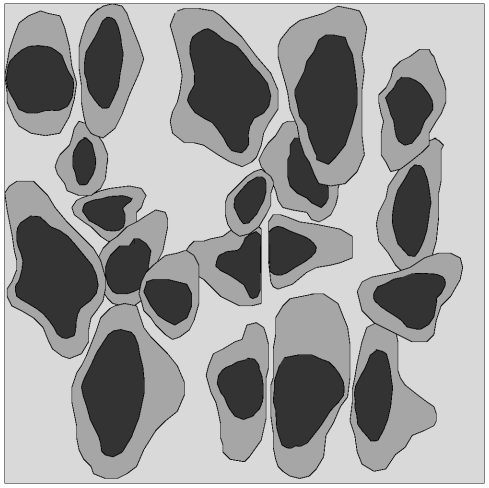
Arid near-surface model
(Saudi Aramco, Chevron, Sinopec)



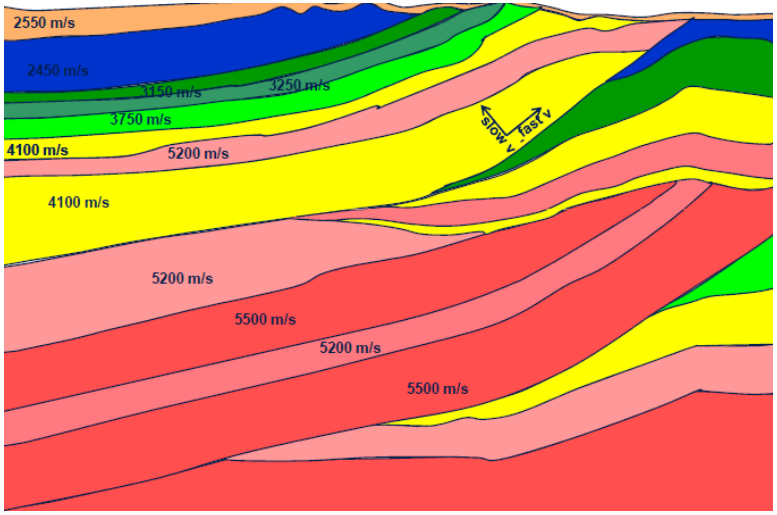
Foothills near-surface model (extreme topography)
(Total, Repsol, Shell)



Unconventional model
(fractured shale gas reservoirs + overburden)
(BP, Chevron)



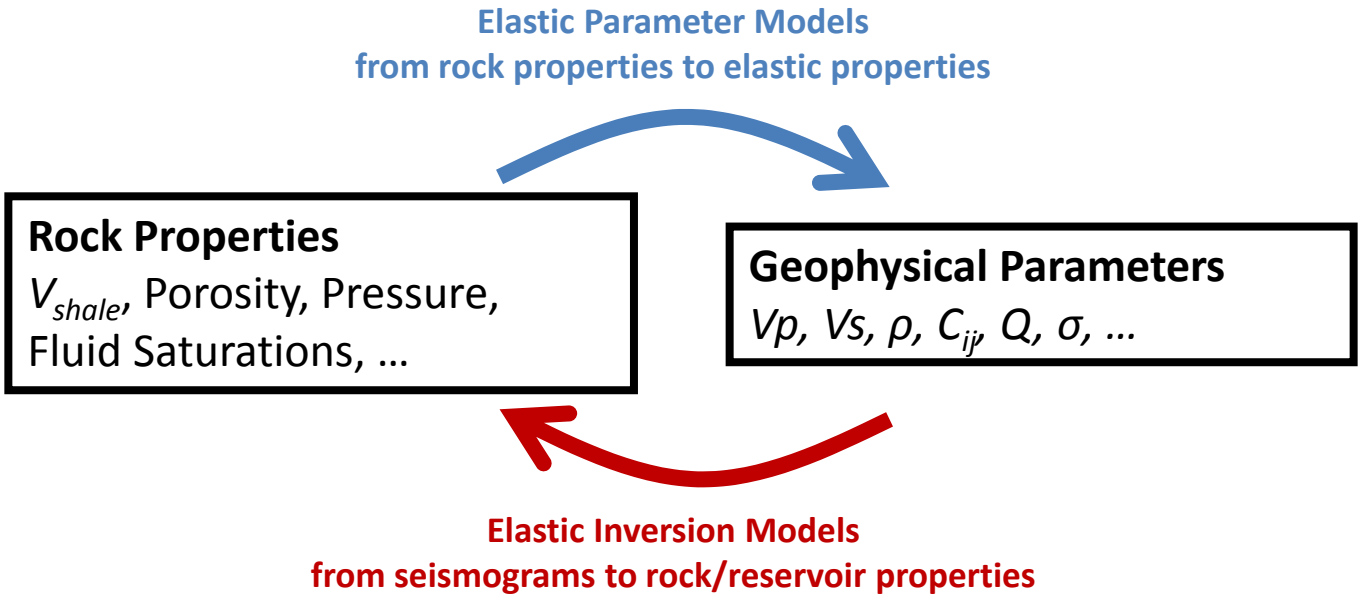
Thrust model (complex tectonic structure)
(Repsol, Total)



SEAM Approach to Model Building

Build generic structural models as much as possible from real geologic formations, including information, such as structure and reflectivity, from 3D seismic data

Populate the model with elastic properties derived from petrophysical models based on cores and well logs



Candidate for SEAM Phase III: One possibility

- **Mineral exploration ?**
- **Goal?**
  - Facilitate inversion and or interpretation?
  - Understanding data acquisition in mineral systems?
- **Data types?**
  - Electrical, induced polarization, and Electromagnetic
  - Potential field
  - 3D seismic
- **Geologic models?**
  - Deposit types?
  - Deposit systems/footprints?
- **Synergy with non-seismic in oil and gas exploration and production?**
- **Potential funding base?**

Possible opportunities

- Similar to SEAM Phase-I and II approach
  - Mineral related simulation program consisting of model building and simulation focused on EM
  - “Integrated” simulation focusing on 3D seismic, potential-field, and EM in hard rock environment
  - General non-seismic (gravity, magnetic, and EM) covering needs in hydrocarbon and mineral industries
- A modular approach
  - Perform model building and simulation, then deliver the results in packages
- A broader approach to include a near-surface hazard in oil and gas and other similar fields

Example model types

- Deposit systems for understanding the response of entire footprint
- Porphyry systems with multiple alteration phases
- Deposits under cover and at depth

Purpose of simulation projects

- Trials of acquisition systems, and processing and interpretation methods
- Understanding geophysical signatures of deposit systems
- Verification of simulation/interpretation algorithms
- Education of next generation geophysicists

Deliverable/product (?)

- Models
- Simulated data
- Verification of simulation/interpretation algorithms

Expertise/vendors

- Enough vendors in industry and academia to construct models with sufficient complexity with relevant geological features
- Several groups with the expertise, codes, and facility to carry out simulations

For further discussion regarding SEAM Phase-III candidate, please contact

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SEAM II Management & Technical Committees

Management

Gladys Gonzalez, Repsol

One representative from each member company

Administrative support

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Jan Madole, SEG
Barbara Cartwright, SEG

Oversight

SEAM Board of Directors

Project Manager

Michael Oristaglio, Yale/SEG

Near-Surface Modeling

Tim Keho, *Saudi Aramco*

Shon Bourgeois, *Marathon*
Scott Burns, OXY
Maria Donati, *Repsol*
Constantin Gerea, *Total*
Stefan Kaculini, *CGGVeritas*

Chris Krohn, *ExxonMobil*
Pedro Munoz, *Repsol*
Carl Regone, *BP*
Joseph Stefani, *Chevron*

Subsurface Modeling

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Charles Sicking, *Global*

Scott Burns, *OXY*
Gladys Gonzalez, *Repsol*
Stefan Kaculini, *CGGVeritas*
Elizabeth L'Heureux, *BP*

Jimmy Muskaj, *Repsol*
David Stathopoulos, *Repsol*
Joseph Stefani, *Chevron*
Qunshan Zhang, *Repsol*

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Carl Regone, *BP*

Robert Bloor, *Ion*
Scott Burns, OXY
Tim Brice, *WesternGeco*
Maria Donati, *Repsol*

George El-Kaseeh, *WesternGeco*
Tom Fleure, *Global Geophysical*
Steve Knapp, *Hess*
Jimmy Muskaj, *Repsol*

Corey Morgan, *BHP Billiton*
Jean-Marc Mougenot, *Total*
Pedro Munoz, *Repsol*
Gerry Wilbourn, *Anadarko*

Numerical Design

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Mauricio Araya, *Repsol*
Gladys Gonzalez, *Repsol*
Scott Morton, *Hess*
Joseph Stefani, *Chevron*

Igor Terentyev, *Hess*
Tetyana Vdovina, *ExxonMobil*
Qunshan Zhang, *Repsol*

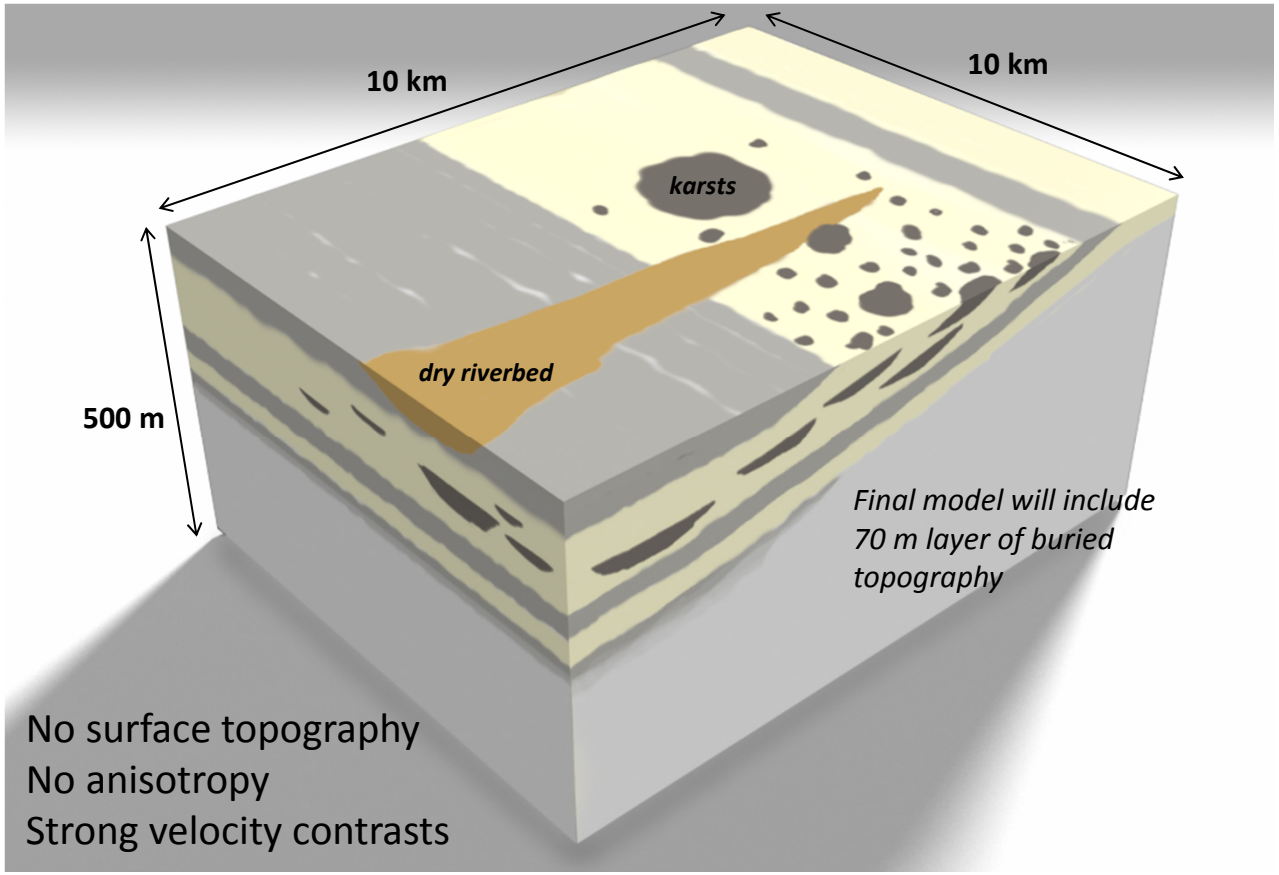
SEAM Phase II Summary [From 2012 briefing]

- SEAM Phase II started in March 2012, with 20 participants since June.
- Goal is to build **a suite of near-surface and subsurface models and perform full elastic-wave simulations to advance the state of the art in land-seismic** acquisition, processing and imaging, including studies of future high-channel land systems.
  - **Near-surface**: topography, strong scattering (karsts, voids), rapid velocity variations
  - **Subsurface**: subtle reservoir features (unconventional plays), fractures (anisotropy), complex structures
- Four models are under construction by technical committees.
  - **Arid model** (near-surface): strong velocity contrasts, dipping refractors, karsts, buried topography
  - **Unconventional model** (near-surface and subsurface): shale gas reservoirs
  - **Foothills model**: extreme topography and highly heterogeneous velocity
  - **Thrust-zone** reservoir model: complex structural geology
- **Several geologic models will be completed by the spring of 2012**, which will be followed by QC tests on the model and a series of benchmark numerical simulations.
- **Request for bid (RFB) for elastic simulations will be issued in summer 2012**.

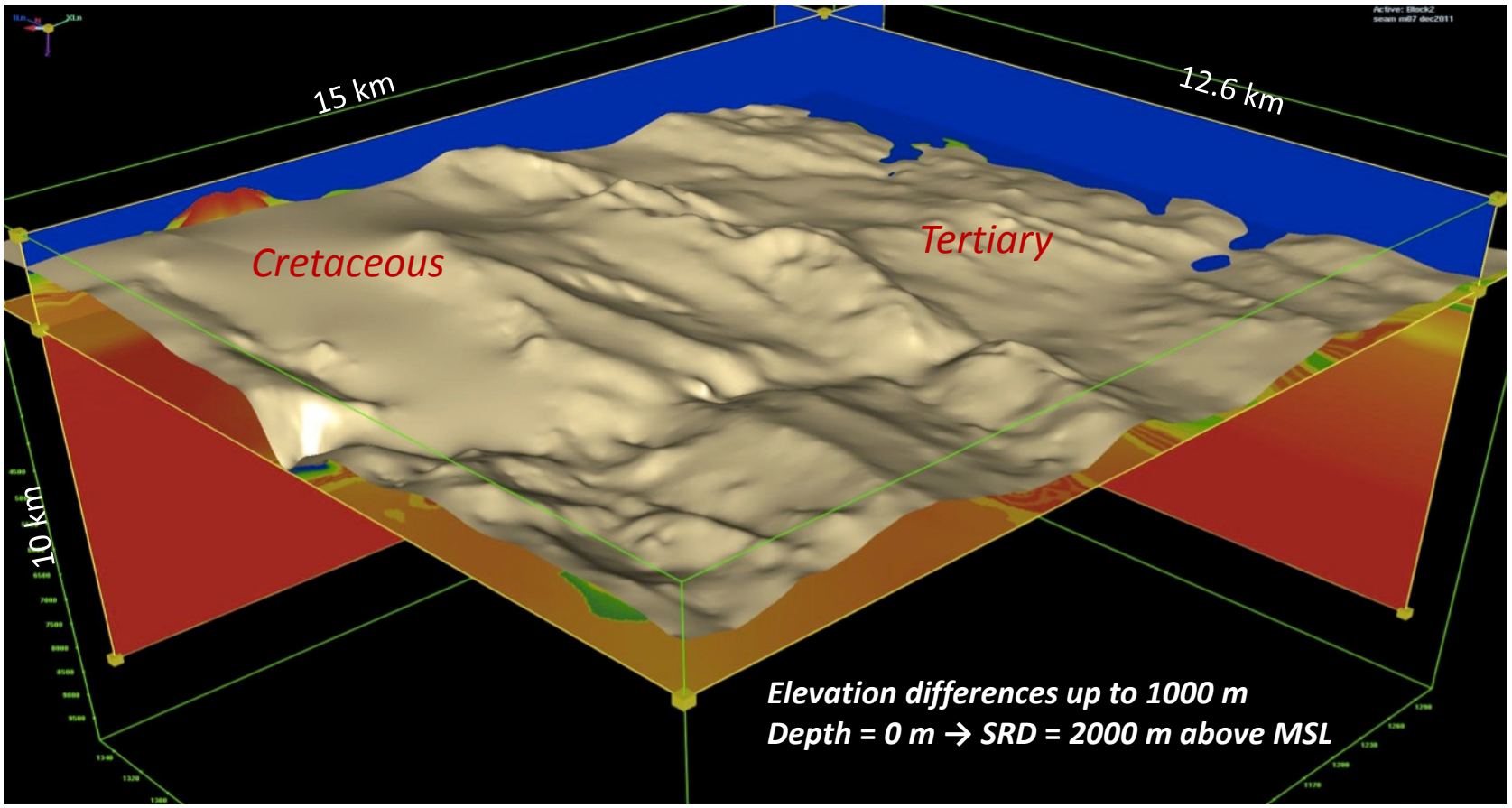
Arid Model

Expected final model parameters

- 10 km x 10 km x 2 km
- 500 m near-surface region
- *Vp* (min) = 1000 m/s (600 m/s)
- *Vs* (min) = 500 m/s (300 m/s)
- *fmax* = 60 Hz

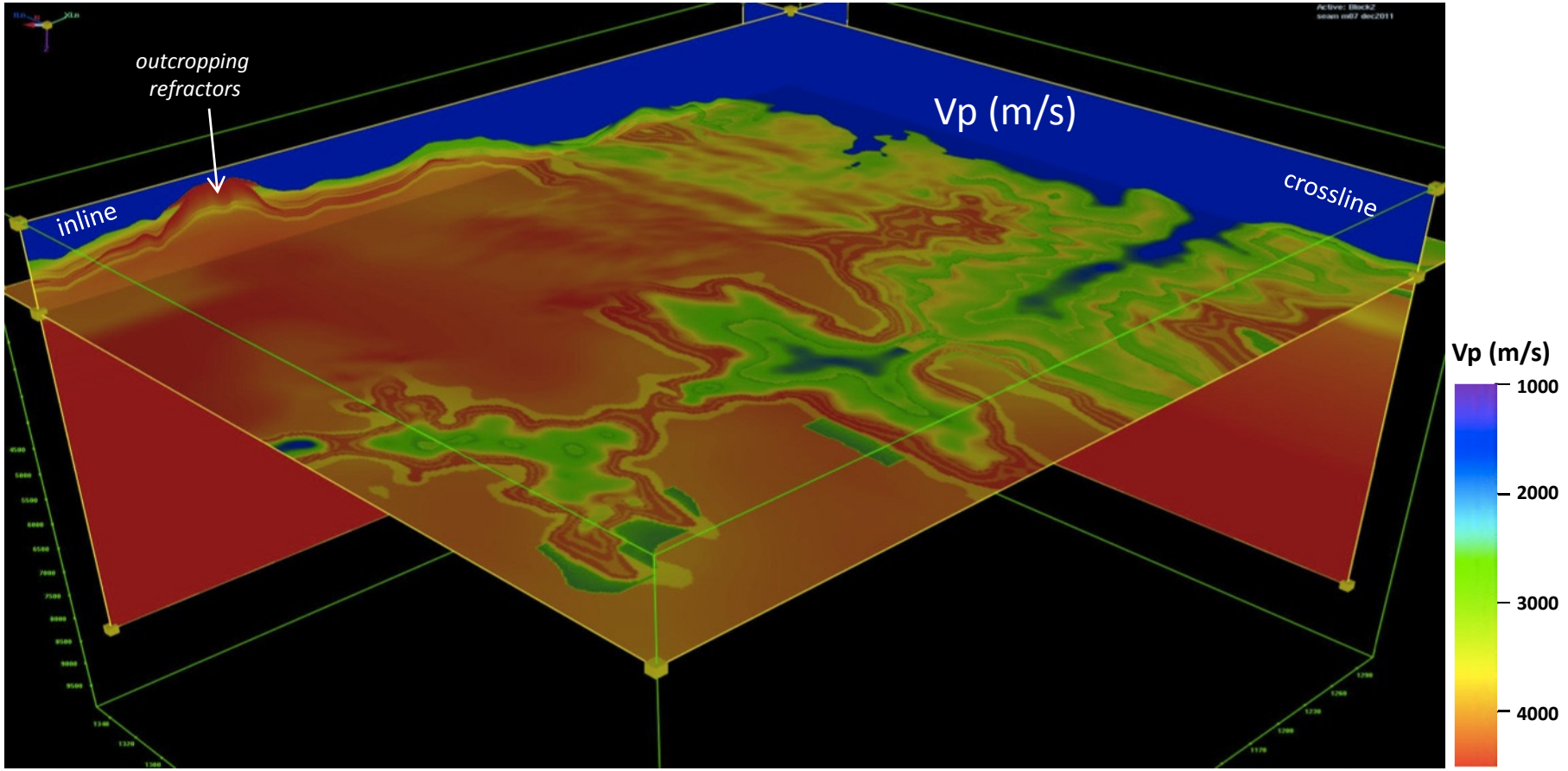


Foothills Model: Extreme topography



courtesy of Constantin Gerea, Total

Foothills Model: Strong near-surface heterogeneity



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Foothills Model: Strong near-surface heterogeneity