Depths, Times, and Velocities – Facts or Opinions?

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Paradigm, circa 1993

Peter on left
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It’s TIME to think in DEPTH.

PARADIGM GEOPHYSICAL

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Two truths, linked by an opinion…

• Wells are drilled in depth - truth
• Seismic data is a function of two-way travel time – truth
• Velocity in a highly complex earth – opinion
• Consequences
• Four major challenges
Consequences

- Offshore
  - Gross rock volumes incorrect
  - Incorrectly sized facilities
  - Wrong X-Y location
  - Wrong casing program
  - Miss small discrete targets

- Onshore
  - “Porpoising” of horizontal well
Challenge #1 – **many** types of velocity data

1-D Vertical Velocity Functions, Well logs, checkshots

Stacking, RMS, Interval, Gradient, Average, T vs D, DTC, DTS

Vertical axis T or D
Challenge #1 – many types of velocity data

Velocity Maps, Velocity Slices (horizontal or horizon-following)

V0, K, Average, RMS

Maps are indexed to horizons

Slices are indexed to times, depths, time maps, or depth maps
Challenge #1 – many types of velocity data

Velocity Cubes in the form of seismic

Interval, Instantaneous, Average, RMS, Thomsen’s Delta or Epsilon…

Vertical axis T or D
Challenge #1 – many types of velocity data

Crossplot, interval velocity from markers vs. seismic interval velocity maps

Well markers with depths and times

Niger Delta velocity function:
\[ V(z) = 1656 + 0.44z \]


Mathematical relationships

- \( V_{\text{water}} = 1500 \text{ m/s} \)
- \( V_{\text{sed}} = 3500 \text{ m/s} \)
- \( V_{\text{salt}} = 5000 \text{ m/s} \)

Constants
Challenge #2 – managing velocity data
Challenge #2 – managing velocity data

• Loose unmanaged pieces of data - “hoarder syndrome”
  – Random SEG-Y cubes
  – Excel spreadsheets
  – ASCII files

• Repurposing workstation data types wrongly
  – Velocity cubes loaded as seismic cubes
  – No tag which indicates velocity, what kind, what units. It matters!

• Who owns this piece of data? Version? Who has permissions to delete it? Time / date stamps?
Challenge #2 – managing velocity data

“Do you have sufficient control over your velocity data so that you could reliably reproduce your earth model in depth for your management, auditors or investors well after the fact?”
Challenge #3 – many velocity workflows

• Governed by
  – What kind of data you start with
  – Geology – sediments vs. hard rock

• What are you using the velocities for?
  – Time-depth conversion
  – Depth imaging starting model
  – Seismic inversion background model
  – Pore pressure prediction
Challenge #3 – many velocity workflows

- One size does not fit all
- You might not make use of all available information
- You might use the wrong algorithm for the geology
Challenge #3 – many velocity workflows

We accommodate:

• Fast-track, simplified, highly interactive
• Very geophysically rigorous with longer turn-around
• Everything in-between
Challenge #4 – workflows appropriate for your role

E&P generalists -

• Gather, store, manipulate, assemble, and use velocity data
• Not a producer, rely on others for velocity data
• Vast majority not seismic processors or depth imagers
• Don’t have nor want pre-stack
• Don’t have nor want LINUX cluster
• Want to stay in interpretation environment
Velocity challenges review

1. Many types of velocity data (types, sub-types, units)
2. Managing the data
3. Flexibility, because one workflow does not fit all
4. Workflows that interpreters can execute, without need of a depth imaging expert
   - No gathers
   - No cluster
   - Windows or Linux
Paradigm response to velocity challenges

- Handles the many types of velocity data
- Managed in Epos database
- Many possible workflows
- For E&P generalists
A detailed look

- High level description of the eight leaves on the left branch
- A software demo showing one possible velocity workflow
- Questions & Answers
All Paradigm velocity data types are managed

- Type, sub-type
- Units
- CRS
- Owned by a user
- Permissions
- Time, Date, Comments
- No loose files
- No re-purposed, mislabeled data types
Vertical Functions

What kinds

- Stacking velocity vs. time
- RMS velocity vs. time
- Average velocity vs. time or depth
- Interval velocity vs. time or depth
- Gradient vs. time or depth
- Time vs. depth

How created

- From sonic logs
- From checkshots
- By resampling a seismic cube of velocity values
- ASCII loader
Vertical Functions

Features

- Redatuming
- \( V_0-K \) calculation within individual layers
- \( V_0-K \) calculation for entire stack of layers using least-squares (best fit of model to actual)

How used

- Vertical function a way to store information
- An intermediate product, not an end-product
Volume Manipulations

What kinds
- Velocity volumes (various kinds)
- Residual volumes
- Formation volumes (strat column)
- Anisotropic attribute volumes
- Residual anisotropic volumes
- Q volumes

How created
- Maps
- Formation table
- Slice maps
- Another volume
- Crossplot relationship
- Vertical functions
- Well logs
- Global Velocity Model (GVM)
Volume Manipulations

Features

- Update – apply residual moveout or velocity to update velocity
- Edit – replace values with new $V_0 + K$ maps, scale factors, or fm. tables
- Transform – Resample – IL, XL, TWT or Z
- Smooth – Median, mean
- Extract – along TWT or Z maps

How used

- Use for domain conversion
- Use the volume for pore pressure analysis
- Use it as an initial depth imaging velocity model
- Use as inversion background model
How used

- In place of Dix
- Standard unbounded Dix equation may produce unstable, unrealistic interval velocities
- Exponential, asymptotically bounded functions
Seismic / Attribute Scaling

Features
- Converts seismic and attributes data between time and depth
- Option to scales in same domain
- Can use maps, fm. tables, slices, velocity volumes, crossplots, linear T-D models, constants, or Global Velocity Model
- Does not convert / scale interpretation

How used
- Domain conversion
- Same-domain scaling
Global Velocity Model

Features
• Single GUI with shortcuts
• Build and QC on-the-fly in 3D Canvas
• Domain converts seismic and attribute data, wells, interpretation
• Horizon-based, layer-cake (build downward) v0-K, or,
• Structure independent models
• Models managed in Epos database

Inputs
• Maps
• Relationships
• Advanced formulas
• Well markers
• Velocity volumes
• Velocity slices

How used
• Domain conversion
Well-Tie (Time-Preserving) Tomography

- Problem Statement – How can we resolve well-seismic misties in a way that obeys geophysics in the context of a three dimensional, anisotropic earth?

Delta Anisotropy Volume
Time-Preserving Tomography

- Global, simultaneous velocity, anisotropy, and structure updates
- Ray-tracing guarantees that laws of physics obeyed
- Imposes well information / geological constraints while remaining loyal to the structure and seismic in a flexible way
Time-Preserving Tomography

Features

- Tomographic inversion using ray-tracing
- Global best-fit velocity update
- Anisotropic velocity model
- Feasible for interpreters
  - No prestack gathers
  - No high-end cluster computer
  - Windows or Linux

Inputs

- Seismic depth map to well marker misties

How used

- Adjust seismic and interpretations to well depth
For more information on Time-Preserving Tomography please refer to www.pdgm.com, Resource Library, Paradigm TV Channel, 2016 Virtual Lecture Series – Season 1.
Background model for inversion

- Geostatistical Volume Creation
- Well-log Kriging within layers
- Simpler method
Background model for inversion

- Faults, stratigraphy honored when SKUA-GOCAD volume-based modeling used
- More complex than Geostatistical Volume Creation; it is modeling

Impedance model within simplified framework

Impedance model within SKUA grid
Volume Smoothing

- Redundant
- For the interpreter, same smoothing options as Volume Manipulations
1. Examine vertical functions, compute V0-K maps for layers
2. Condition using Constrained Velocity Inversion
3. Build a velocity volume in Volume Manipulations
4. Use a combo of volume, vertical sections, V0-K maps, and constants to build a Global Velocity Model; convert seismic and horizons to depth
5. Use conditioned vertical functions for inversion background model
Velocity challenges overcome

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Paradigm Online University

• [http://www.pdgm.com/online-university/](http://www.pdgm.com/online-university/)
THANK YOU!

Global Velocity Model

Vertical Functions

Seismic Attribute Scaling

Volume Manipulations

Background model for inversion

Constrained Velocity Inversion

Volume Smoothing

Well Tie Tomography

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Learn what you need, when you need it.