4th European Meeting on 3D Geological Modelling
21/23 February 2018 – Orléans

Vel-IO 3D: a recipe for 3D management of velocity data and time-depth conversion

C. D'Ambrogi[1] & F.E. Maesano[2]

1 – Servizio Geologico d'Italia ISPRA chiara.dambrogi@isprambiente.it 2 – INGV francesco.maesano@ingv.it

Motivations

basin-scale

3D geological modeling of wide areas, characterized by lithological heterogeneities and variability of the unit thicknesses controlling strong lateral velocity variations

NEEDS

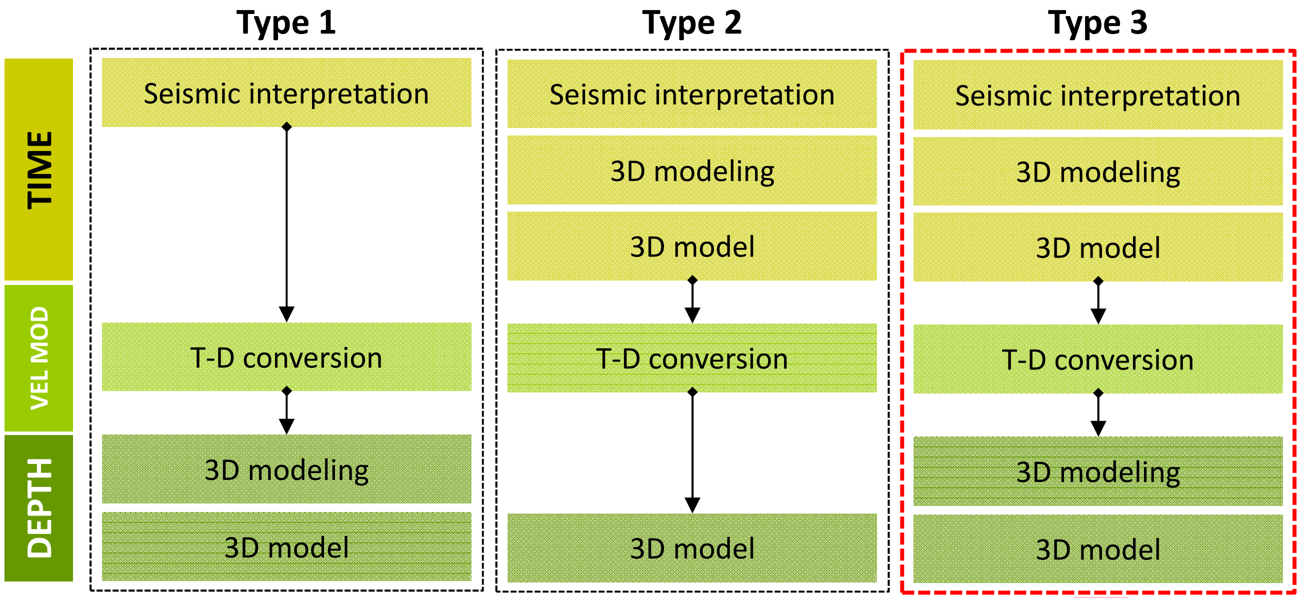
a 3D velocity model able to describe the variation of the velocity parameters

CRITICAL PHASES

How to manage 3D velocity variability?

What is the best strategy to perform time-depth conversion?

Workflow



Workflow types after GeoMol Project, 2012-2015

Our preferred recipe

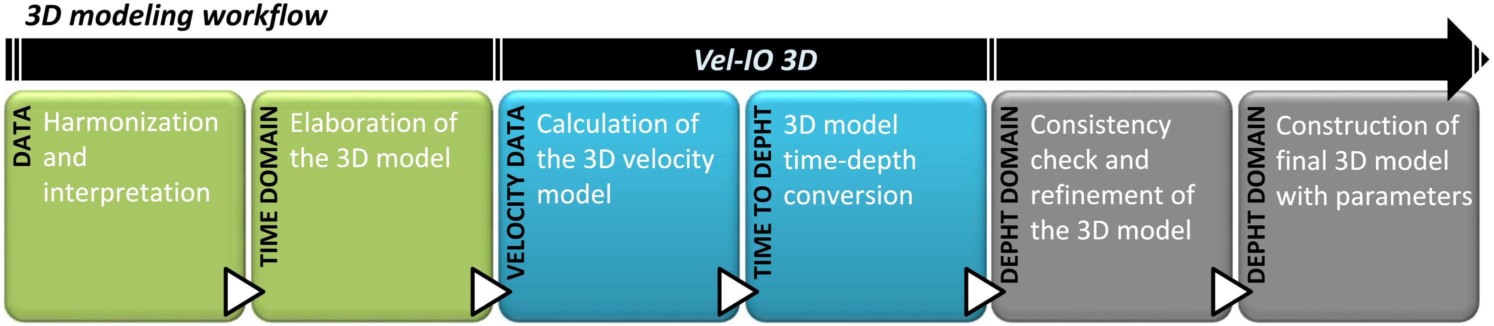
The double 3D modeling phase (in time and depth domain) allows the best use of all the available constraints and repeated check and refinement phases

Motivations
Workflow
Vel-IO 3D
Results

Workflow

To properly manage the most critical phase of the 3D model construction we developed the **Vel-IO 3D** tool as core part of the 3D modeling workflow

3D modeling workflow



Motivations
Workflow
Vel-IO 3D
Results

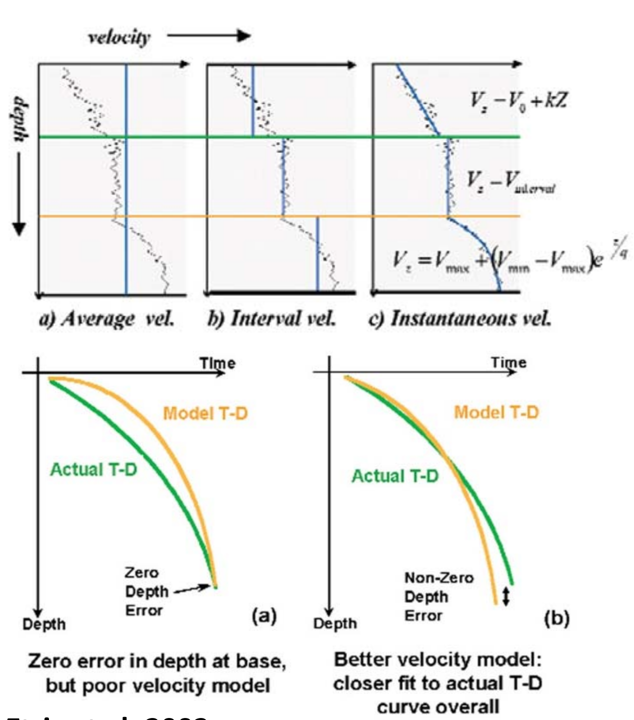
Vel-IO 3D is composed by three independent scripts, written in Python*, that automate:

1) the 3D instantaneous velocity model building
2) the velocity model optimization
3) the time-depth conversion

Vel-IO 3D is designed to build and manage 3D velocity layer-cake model

* Version 2.7.11

According to 3D model aims, and on the base of available data, different type of velocity can be used in **Vel-IO 3D**



Etris et al. 2002

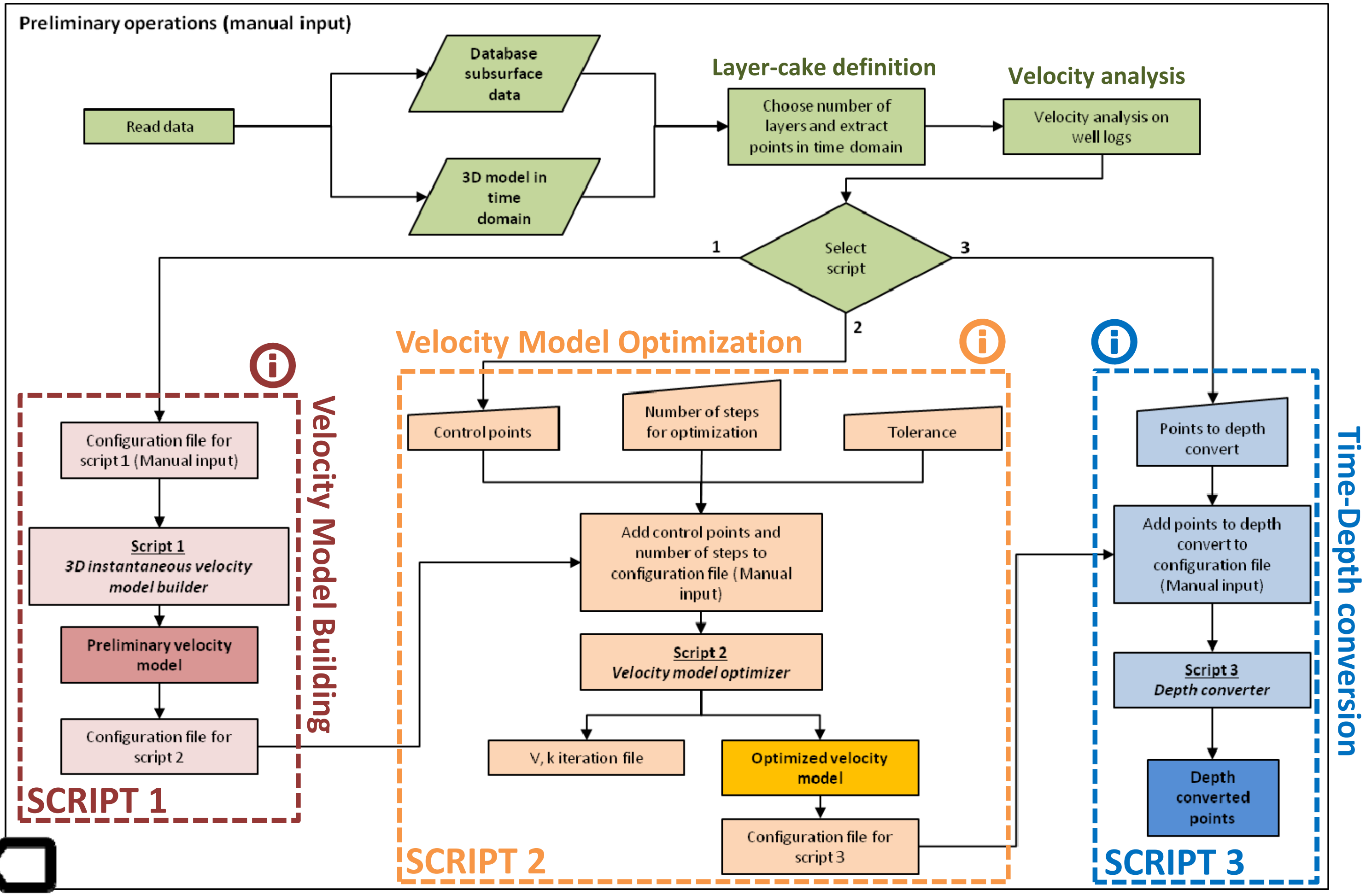
Average velocities give a first approximate time-depth conversion – can be used at regional scale. **Interval velocities** give a better local results after time-depth conversion - can be used in homogeneous areas and provides and exact match on well markers. **Instantaneous velocities** allow to consider the velocity variation with depth (including velocity inversion).

We adopted the function for time-depth conversion with instantaneous velocity model using a linear gradient (k) and an initial velocity for each layer (v_0)

$$v(z) = v_0 + kz$$
$$v(z) = dz / dt$$
$$Z_n = Z_{n-1} + v_{0n}(e^{k_n \Delta t} - 1)/k_n$$

Marsden, 1992

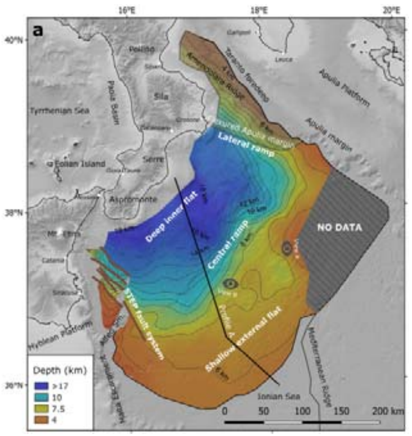
Motivations
Workflow
Vel-IO 3D
Results


Preliminary operations (manual input)
Read data
Database subsurface data
3D model in time domain
Layer-cake definition
Choose number of layers and extract points in time domain
Velocity analysis
Velocity analysis on well logs
Select script
1
2
3
Velocity Model Optimization
Control points
Number of steps for optimization
Tolerance
Add control points and number of steps to configuration file (Manual input)
Script 2
Velocity model optimizer
V, k iteration file
Optimized velocity model
Configuration file for script 3
SCRIPT 2
Velocity Model Building
Configuration file for script 1 (Manual input)
Script 1
3D instantaneous velocity model builder
Preliminary velocity model
Configuration file for script 2
SCRIPT 1
Time-Depth conversion
Points to depth convert
Add points to depth convert to configuration file (Manual input)
Script 3
Depth converter
Depth converted points
SCRIPT 3

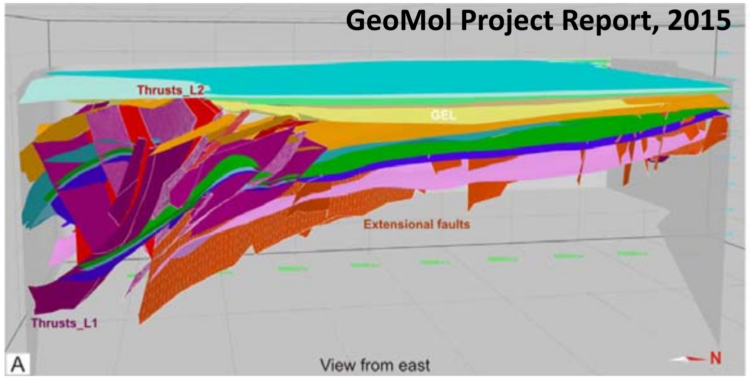
Vel-IO 3D tool has been implemented to be applied in wide areas characterized by great level of geological complexity

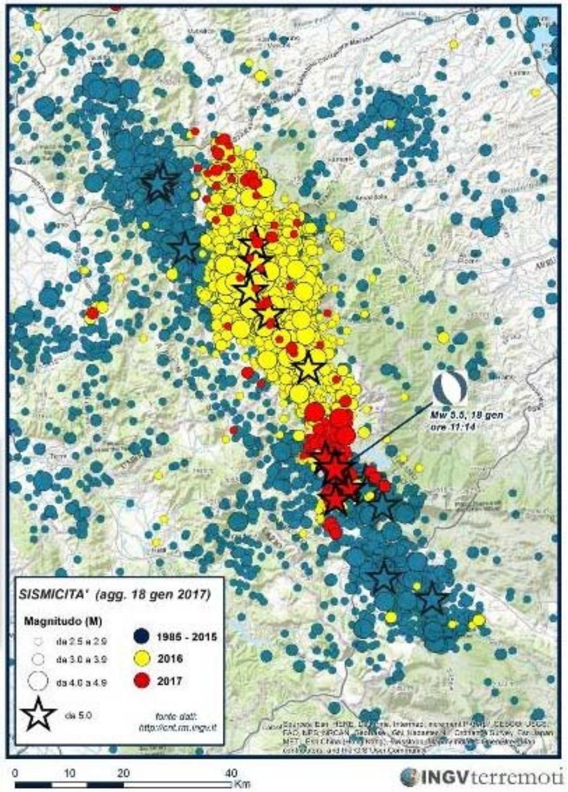
3D model	Area (km^2)	Depth (km)	Velocity model layers	Modeled horizons	Seismic lines (km)	Velocity data
Po Basin – GeoMol Project	5,700	13	4	15	12,000	Well log velocity + Stacking velocity
Calabrian Arc Subduction	10,000	20	4	1	8,600	Stacking velocity
Po Basin	43,000	8	2	6	8,000	Well log velocity
Central Italy – RETRACE-3D	4,500	> 20 km	n.d.	5/6	2,800	Well log velocity + Stacking velocity

Maesano et al., Sci. Rep., 2017



GeoMol Project Report, 2015

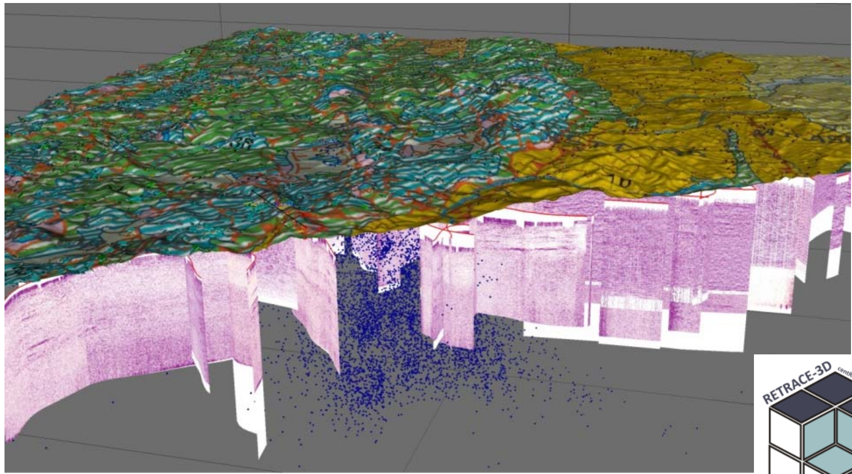




Central Italy seismic sequence 2016/2017

M 6.0 – 24/08/2016
M 5.9 – 26/10/2016
M 6.5 – 30/10/2016
M 5.5 – 18/01/2017

RETRACE-3D centRal italy EarThquakes integRAted Crustal modEl



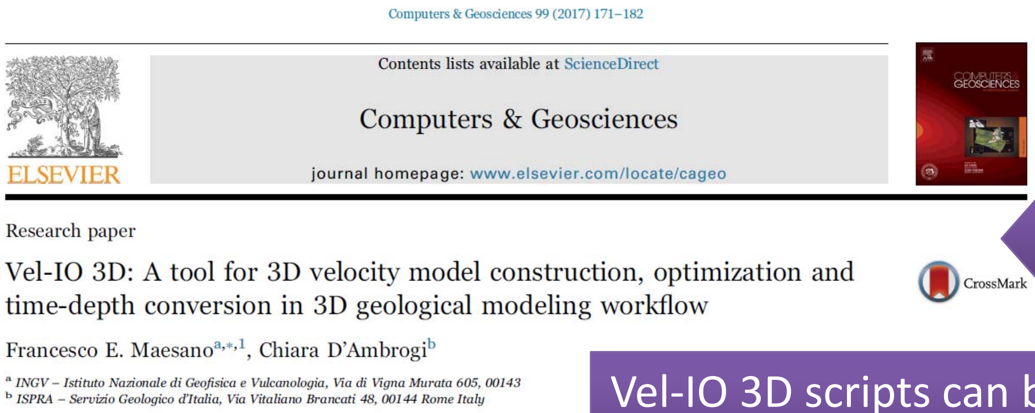
Vel-IO 3D will be used to build the velocity model and tested as possible input for a better relocation of earthquake position

Motivations
Workflow
Vel-IO 3D
Results

Vel-IO 3D is a flexible and easy to use tool.

Vel-IO 3D runs independently from the adopted 3D modeling software.

Vel-IO 3D scripts can be used for specific steps of the 3D velocity model creation and time-depth conversion.


Computers & Geosciences 99 (2017) 171–182

Contents lists available at ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

ELSEVIER

Research paper

Vel-IO 3D: A tool for 3D velocity model construction, optimization and time-depth conversion in 3D geological modeling workflow

CrossMark

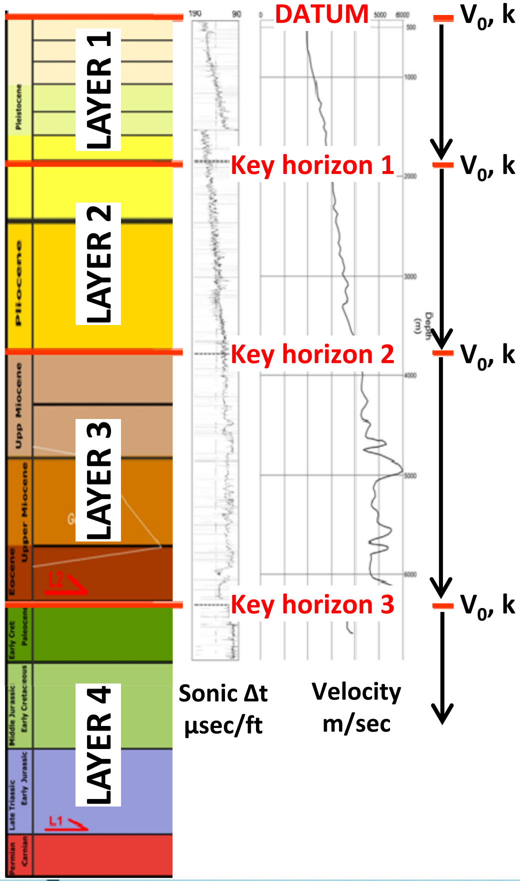
Francesco E. Maesano[a,*,1], Chiara D'Ambrogi[b]

[a] INGV – Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143
[b] ISPRA – Servizio Geologico d'Italia, Via Vitaliano Brancati 48, 00144 Rome Italy

For detailed description of **Vel-IO 3D**

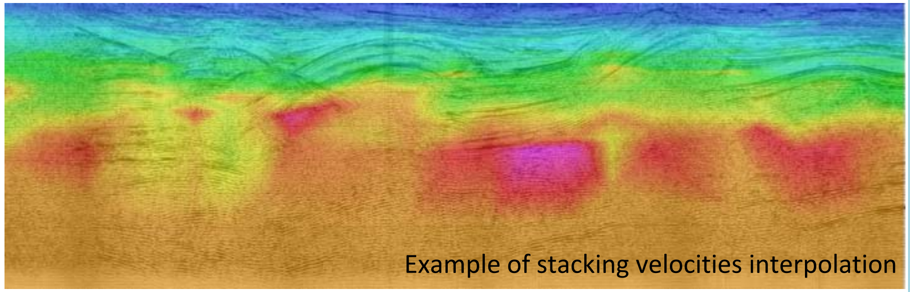
Vel-IO 3D scripts can be downloaded from: https://github.com/framae80/Vel-IO3D

Velocity-based layer-cake scheme



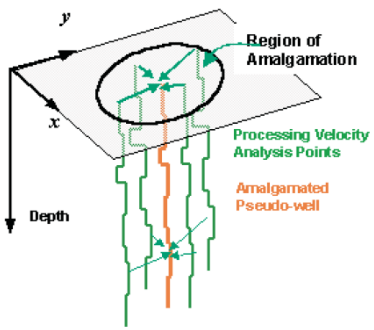
Velocity analysis

Velocity data are derived from sonic log slowness data inversion.



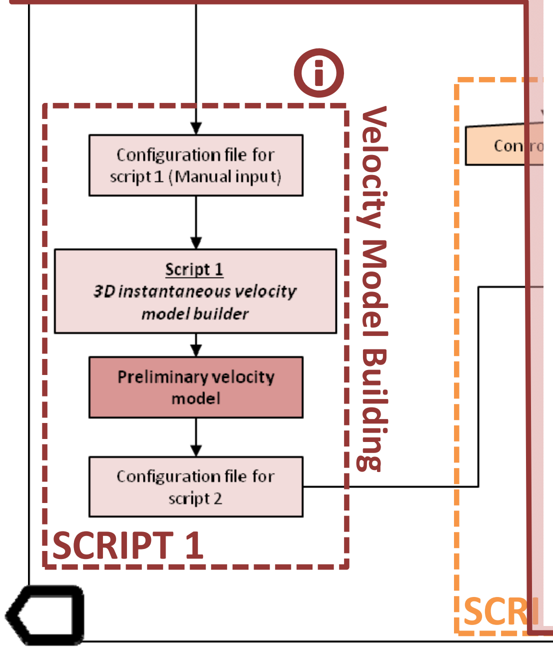
Example of stacking velocities interpolation

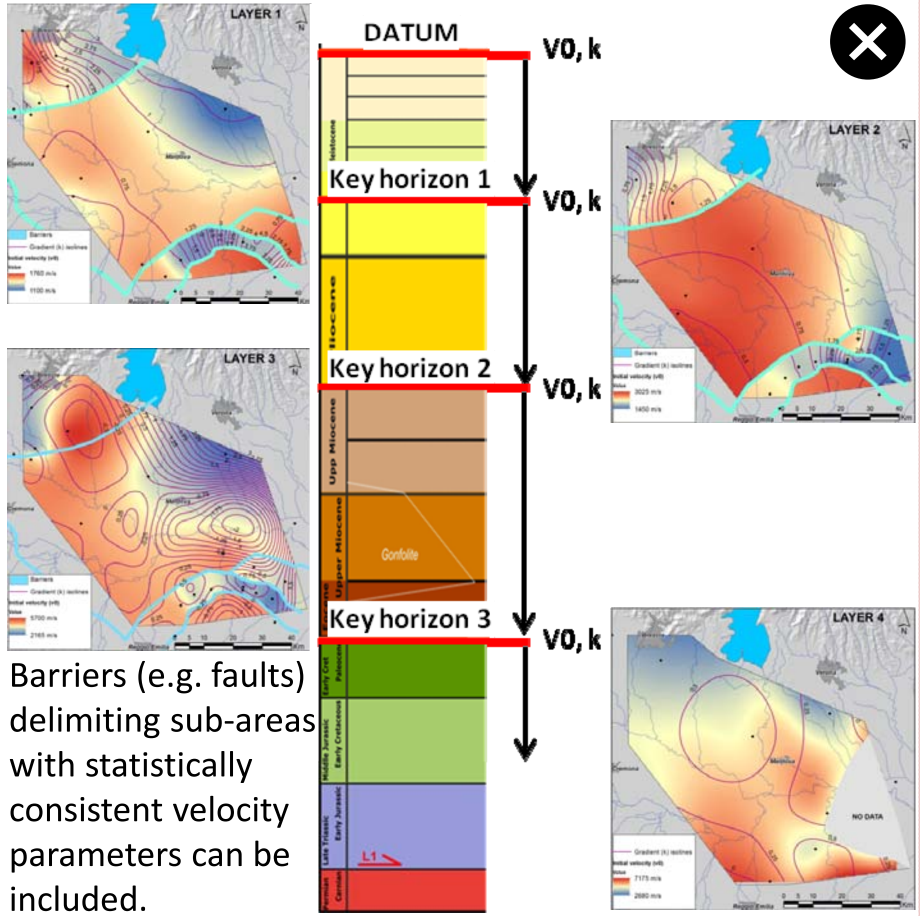
Where no sonic log data are available the stacking velocities obtained during the seismic processing can be used to build "pseudowells".
In this case it is appropriate to aggregate more than one track data to perform a more robust statistical analysis (region of amalgamation).



Etris et al., 2002

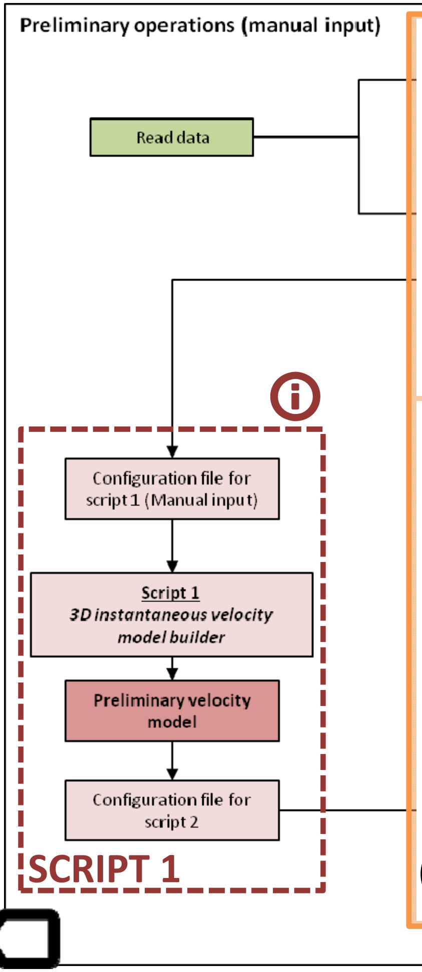
Script 1 produces the maps of initial velocity (v_0) and gradient (k) interpolated along the 3D geometry of each key horizon representing the top of the velocity layers.





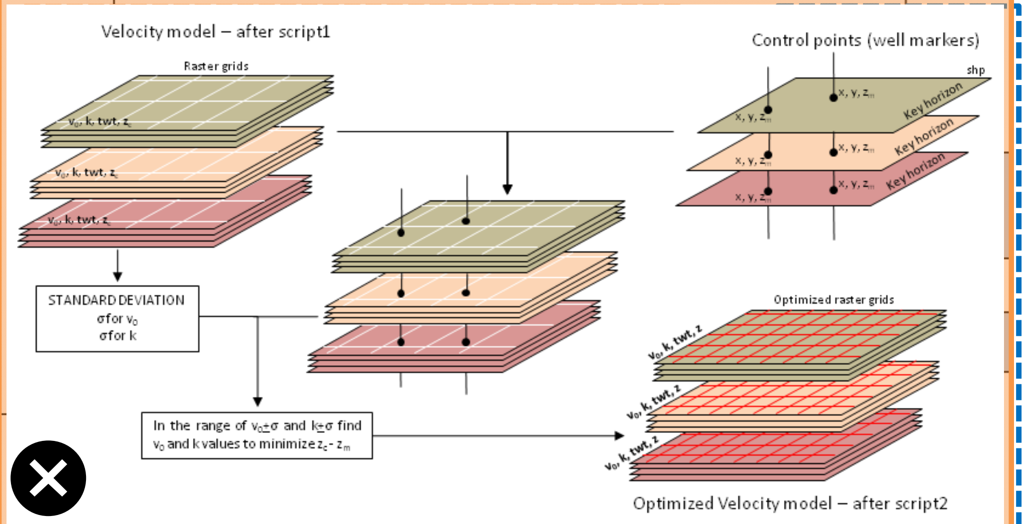
Barriers (e.g. faults) delimiting sub-areas with statistically consistent velocity parameters can be included.

Motivations
Workflow
Vel-IO 3D
Results

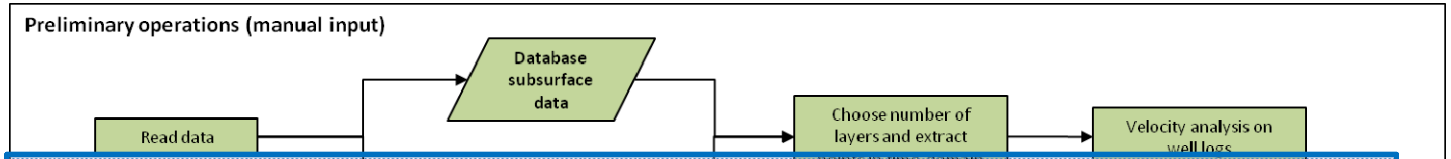


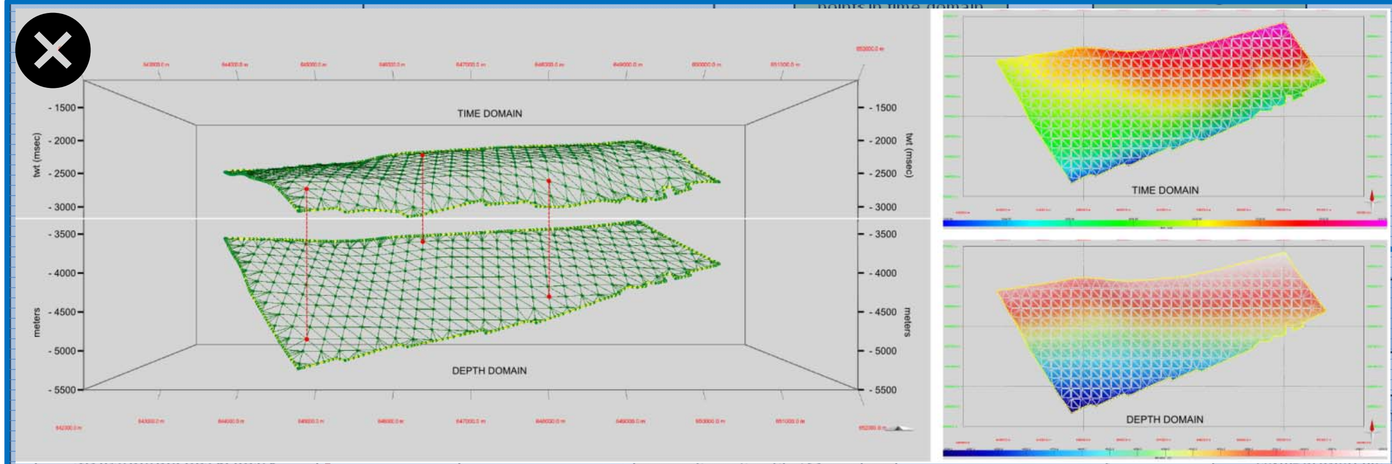
Script 2 improves the consistency of the velocity model adding new values of v_0 and k derived from a minimization algorithm applied to well markers, not provided with velocity data, and thus not included in the previous script.

The algorithm generates the best velocity (v) and gradient (k) values for each control point in order to minimize the difference between the measured (at the control points) and the calculated depth values (by the script).

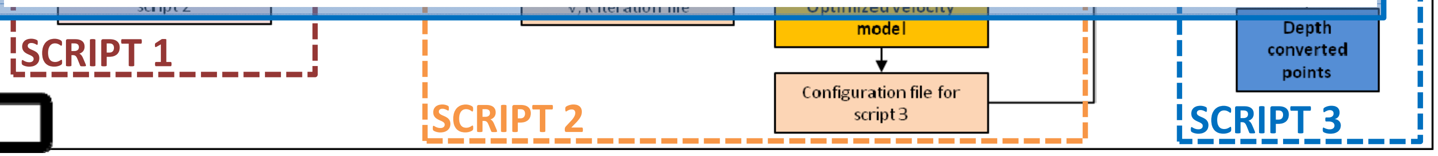


Motivations
Workflow
Vel-IO 3D
Results





Script 3 is designed to depth convert any object inside a 3D model in time domain, using the instantaneous velocity model made in the two previous scripts. Comparison of nodes and meshes before and after time-depth conversion procedure = location of points and boundaries are preserved.



Motivations
Workflow
Vel-IO 3D
Results