Refraction seismic

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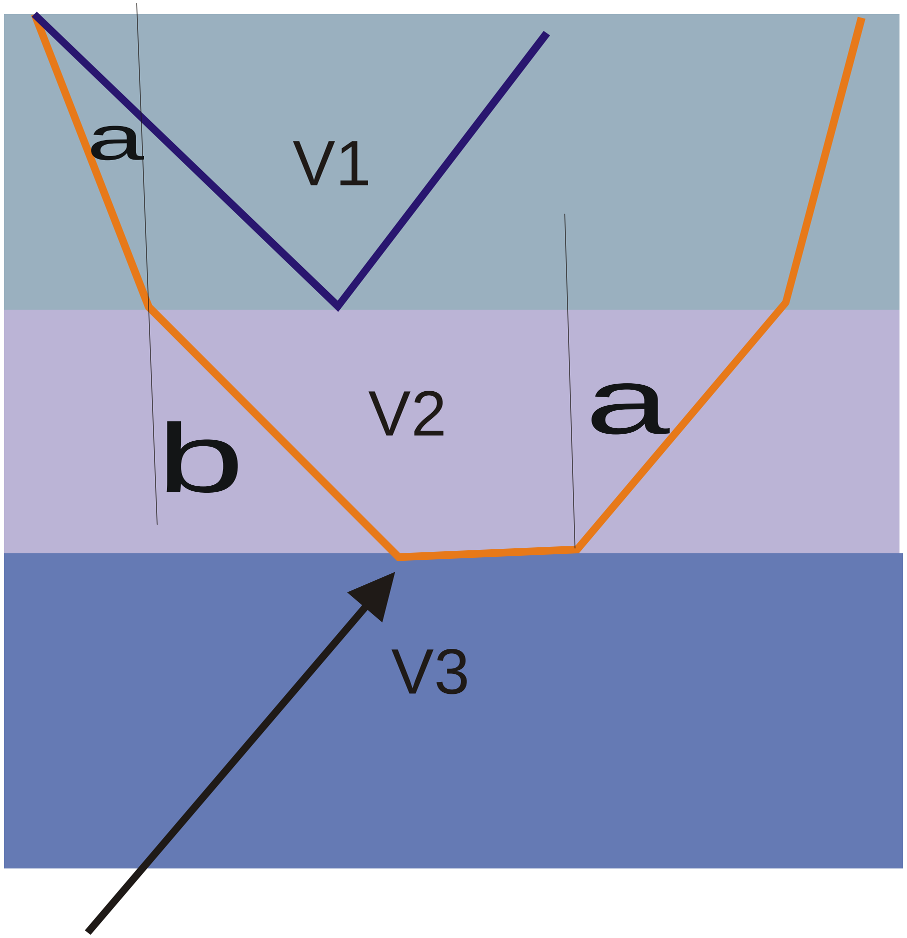
Seismic refraction principes

Reflexion

Refraction

$$\frac{Sin\alpha}{Sin\beta} = \frac{Vitesse\,1}{Vitesse\,2}$$



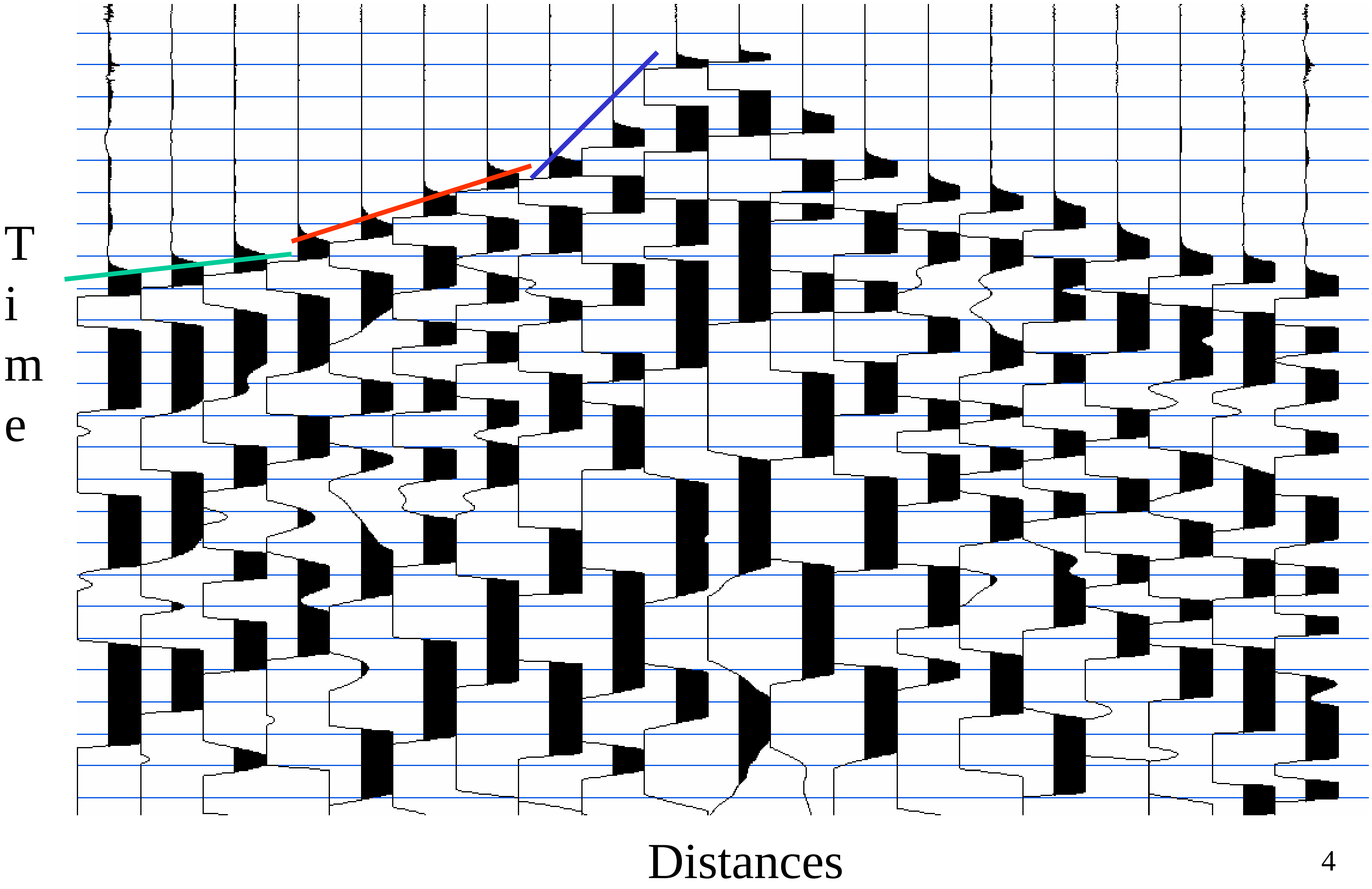
Refraction totale

Réfraction totale $Sin\,\alpha = \frac{Vitesse\,1}{Vitesse\,2}\;2$

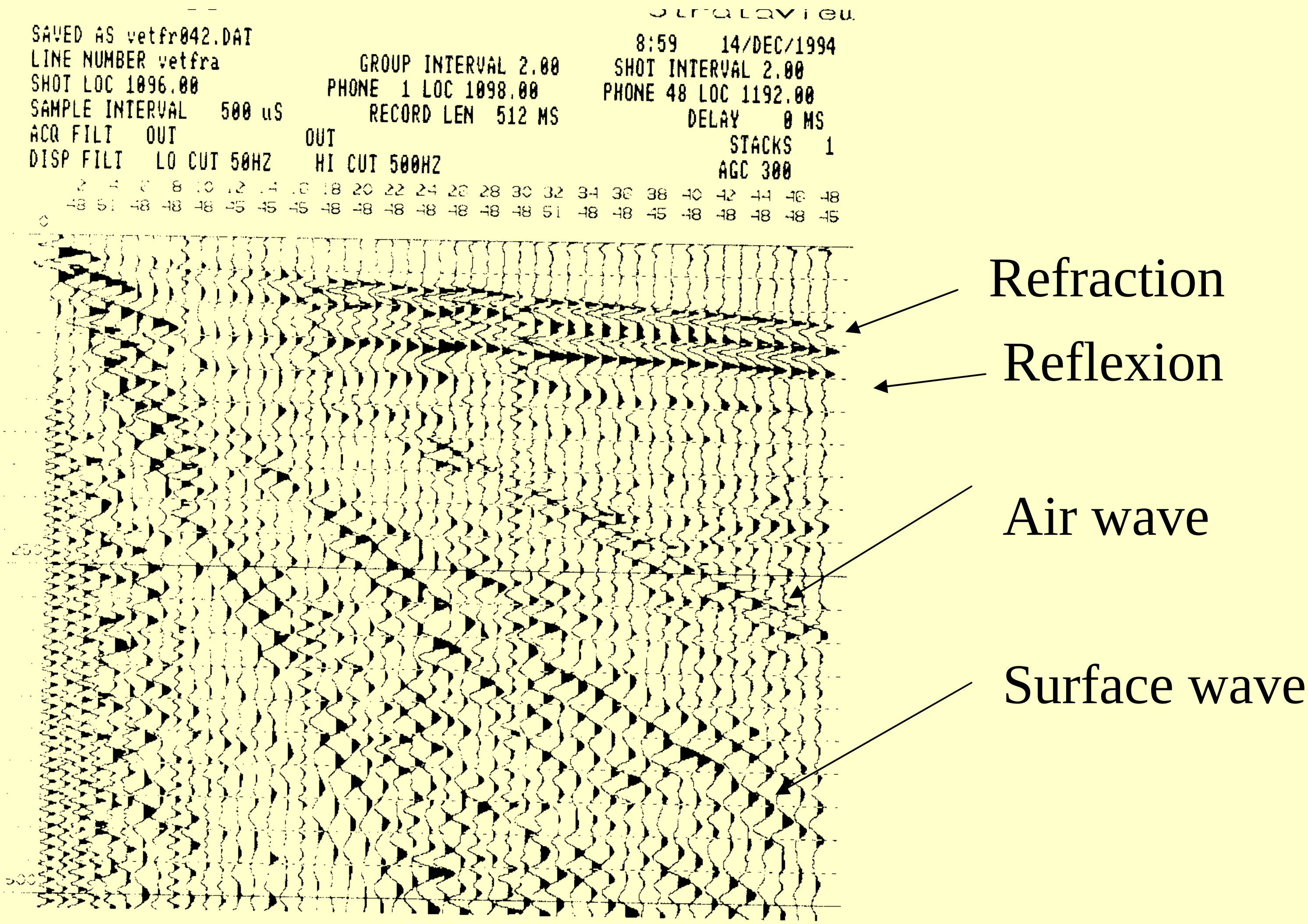
Applications

- Oil in 1920 th
- Geotechnic
- Water prospecting
- Mineral research
- Landslide study
- Wheathering zone determination (for reflection seismic statics)

Record example V1 V2 V3



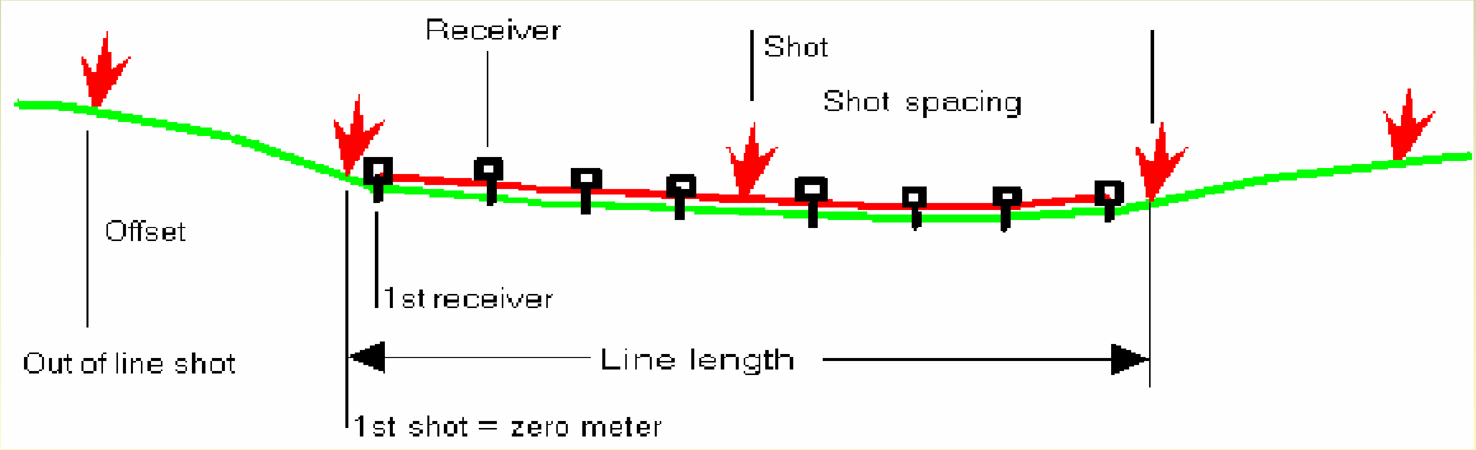
Record example

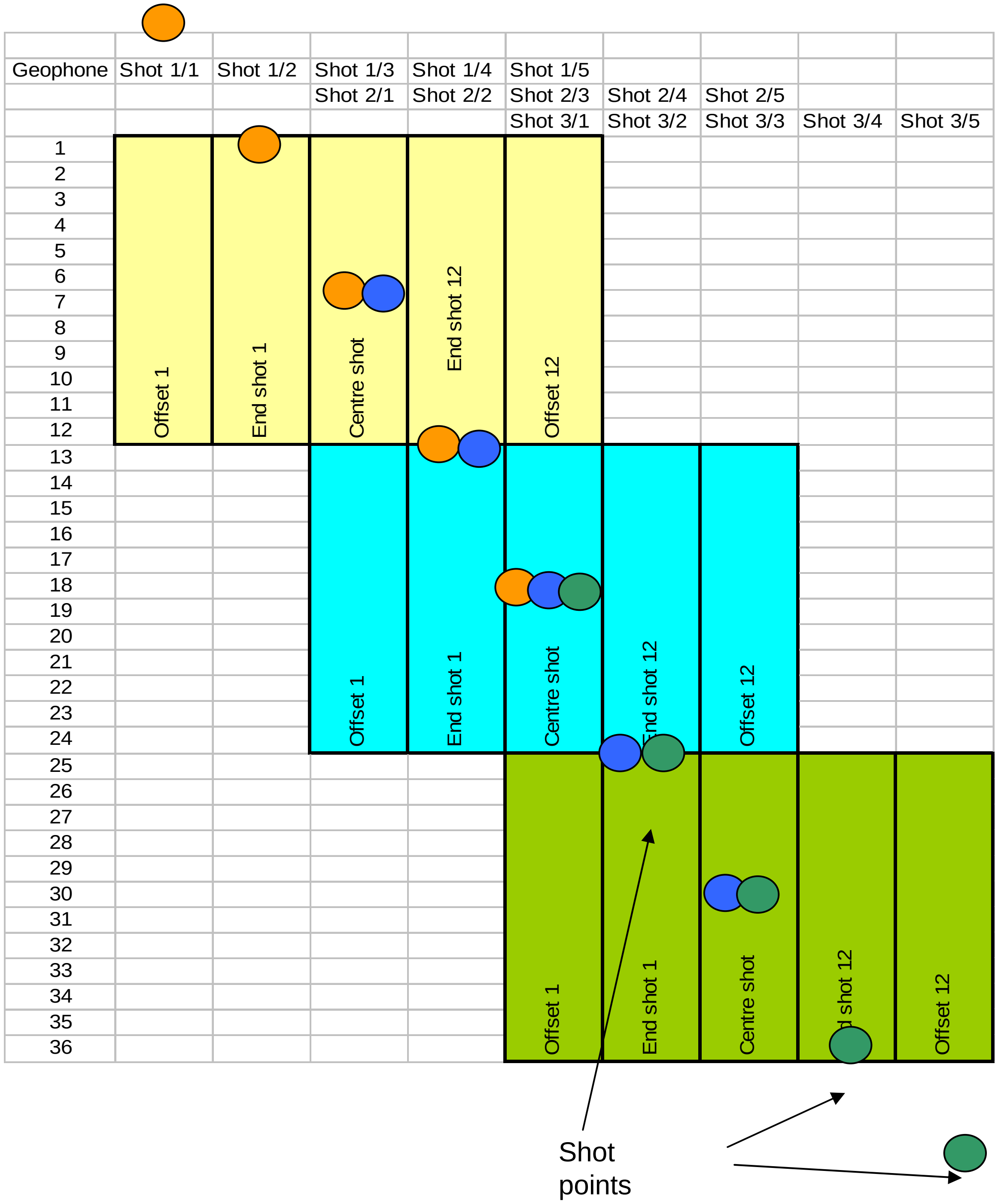


Refraction data acquisition

For a efficient processing, you need at least:

- 2 Offset shots (half spread distance)
- 2 End shots
- 1 Center shot





Example of a complex acquisition with 12 channels

Equipment

- Geophones
- Seismograph
- Battery
- Cables
- (Blasting box)
- Radio
- Portable drill

Energy sources

- **Sledge hammer (Easy to use, cheap)**
- **Buffalo gun (More energy)**
- **Explosives (Much more energy, legal problems)**
- **Drop weight (Need a flat area)**
- **Vibrator (Uncommun use for refraction)**
- **Air gun (For lake / marine prospection)**

Sledge hammer

Produce a good energy with high frequencies,
Possible investigation depth 10-50 m

You can add (stack) few shots to improve signal/noise ratio

To avoid aerial projection and improve energy, explosives can be burried into a small drilling (1-1.5 m) using a portable mechanic drill or a jumper.

Explosives

To buy and use explosive is often difficult, impossible in some countries. A miner licence is required

Processing

- Few specific softwares are found to process seismic refraction
- Most of them use conventional methods like Intercept Time (IT), ABC, GRM
- New inversion softwares can produce tomography interpretation

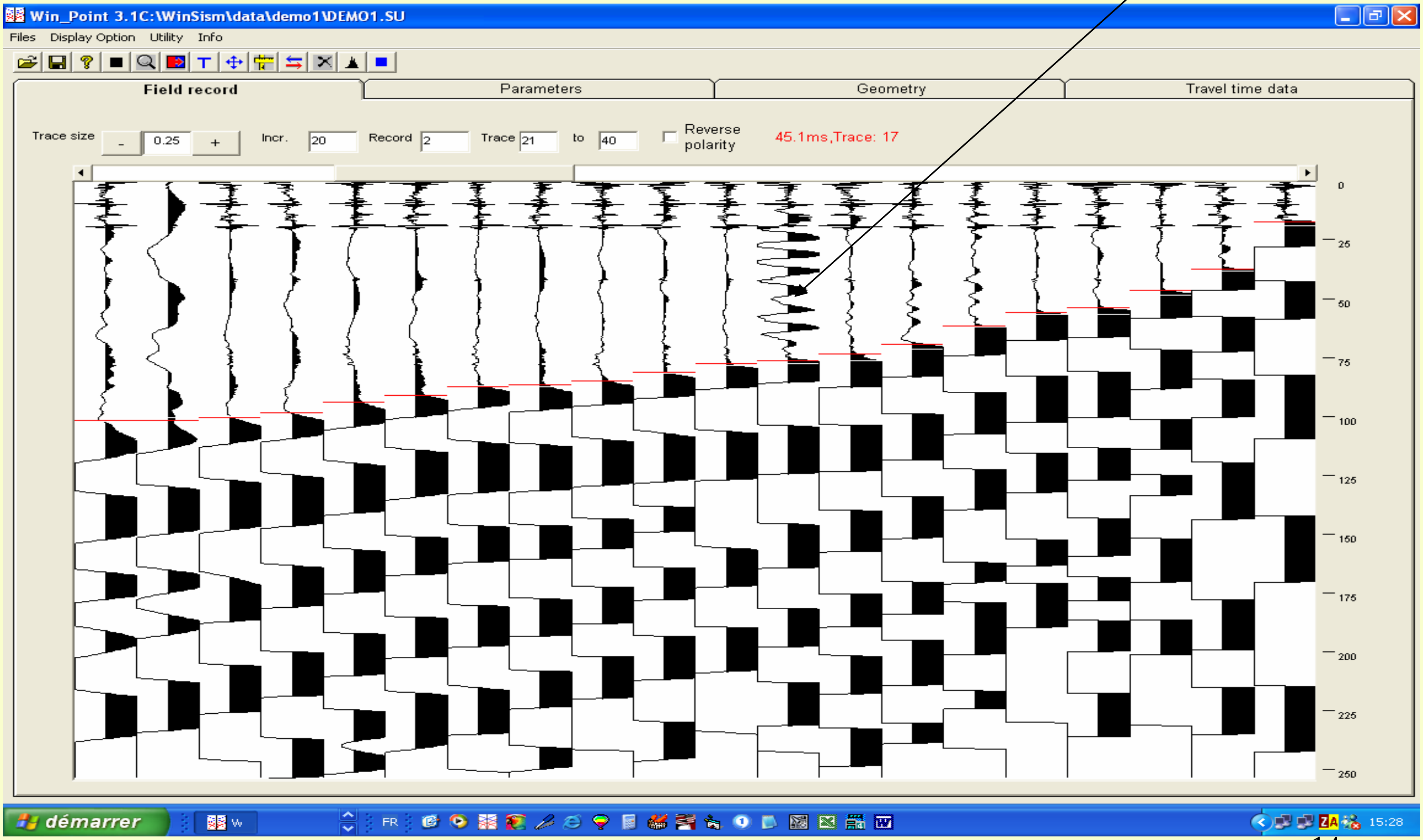
First Break Picking

- This is the most important operation, good picking on **good data** !!!!
- A commun problem is the **lack of energy, for far offset geophones**
- Seismographs produce **SEG2, SEGY** or special file format, generaly they must be converted to another file format, like ***Seismic Unix***.

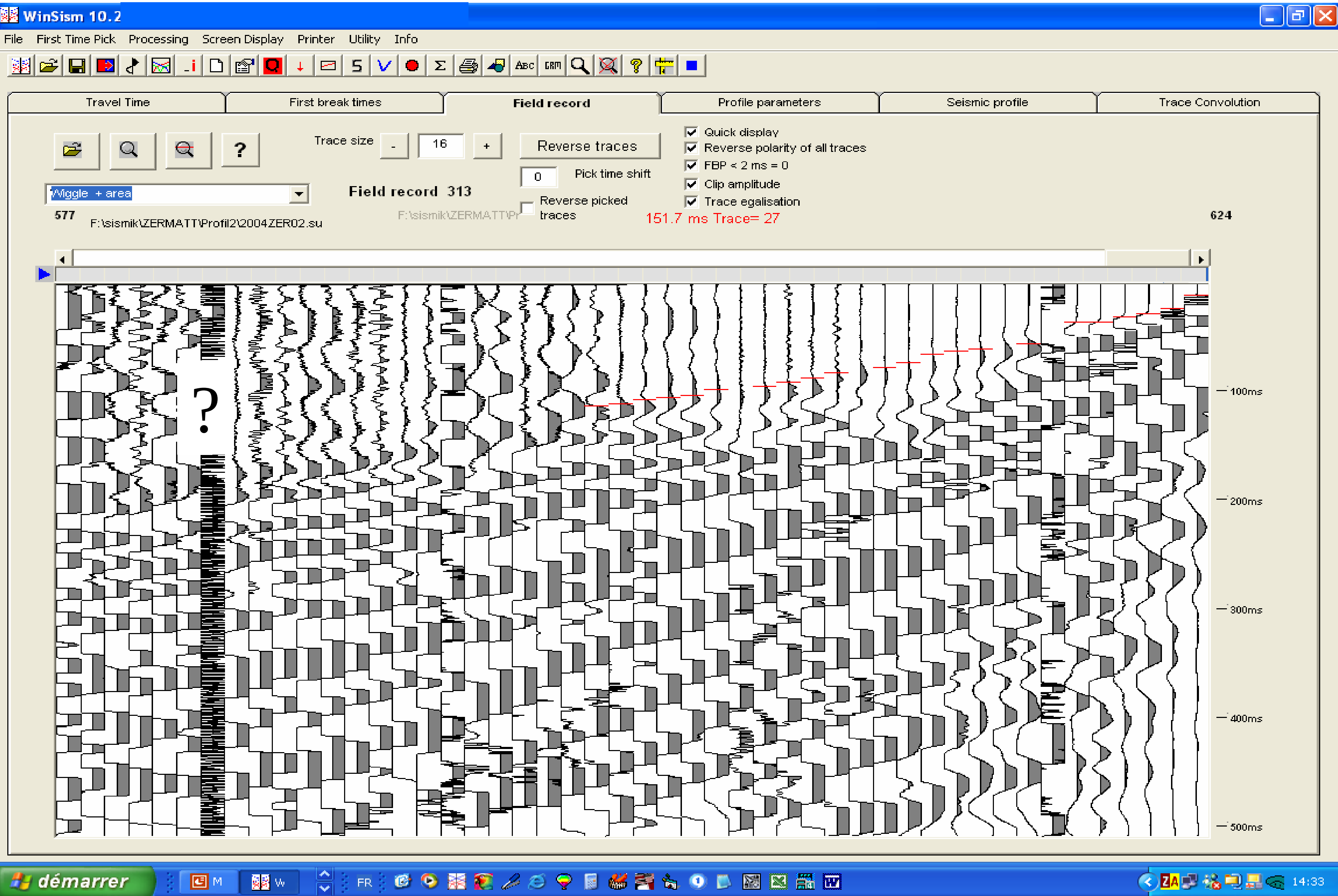
Picking FBP on good data

(Wiggles are clipped)

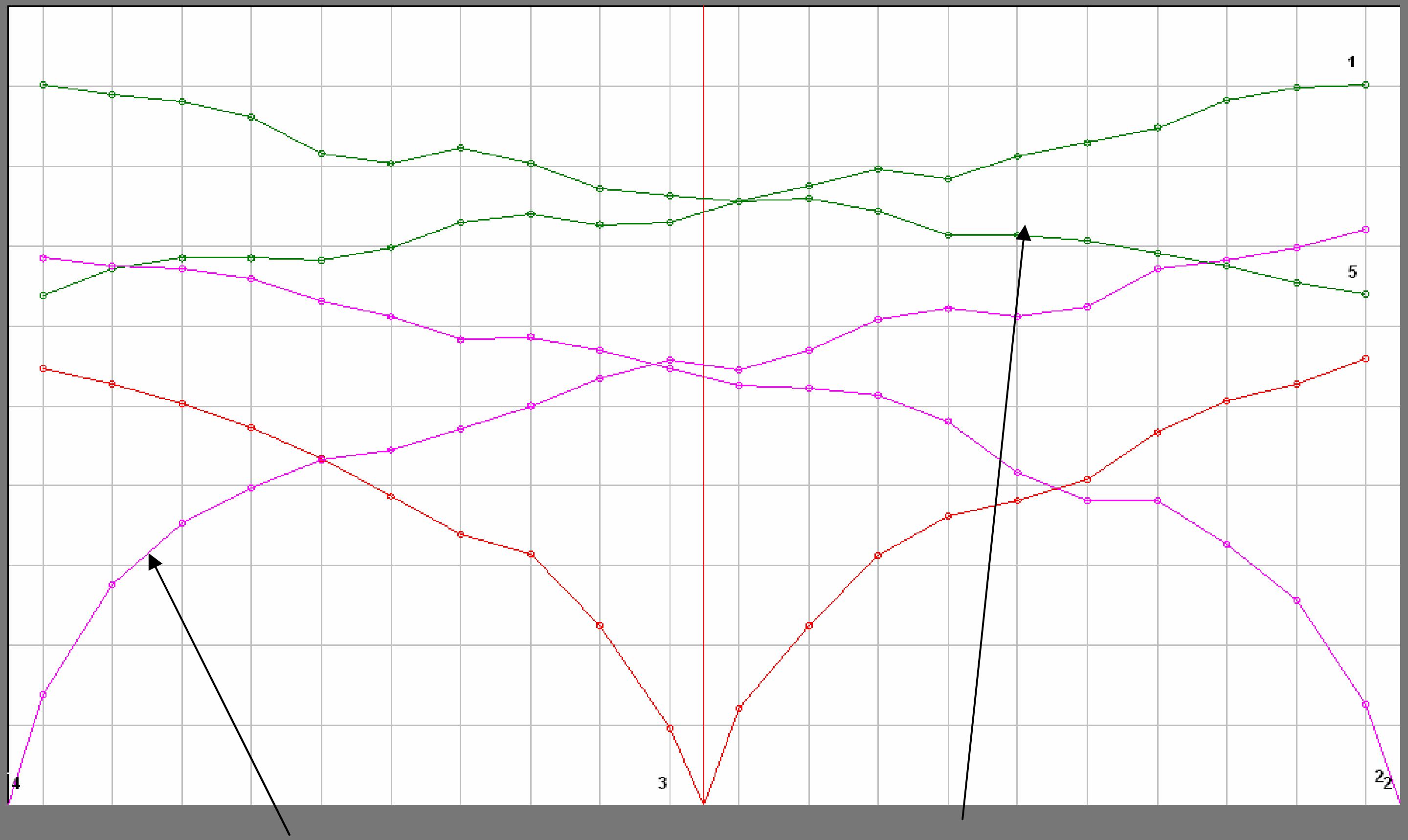
Noise



Picking FBP on poor data



Travel time assembly



Offset 1

End Shot 1

Offset 24

Center shot

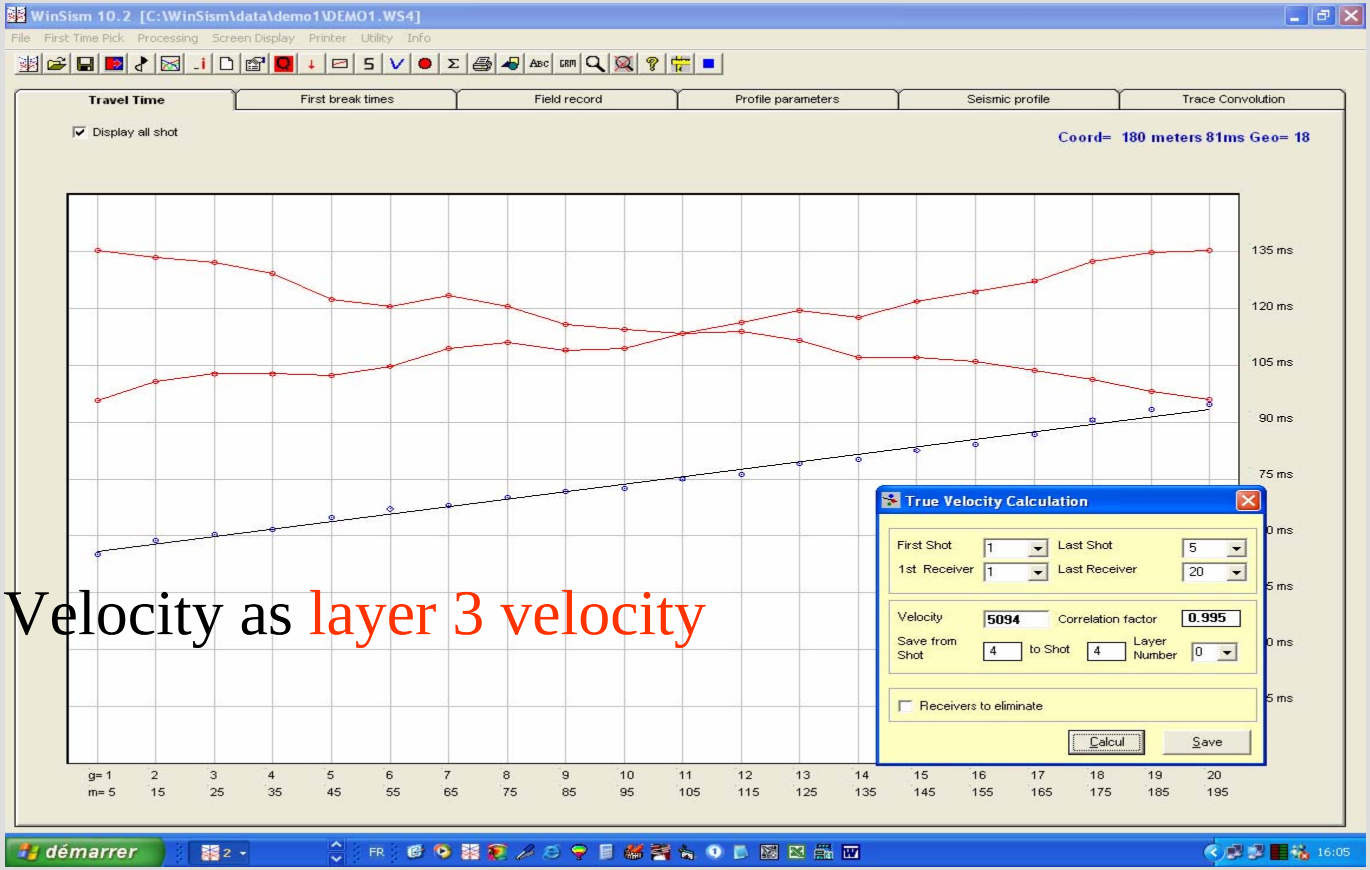
End Shot 24

Steep slope= low velocity   gentle slope = high velocity

X axis = distance Y axis = time Slope=1/velocity

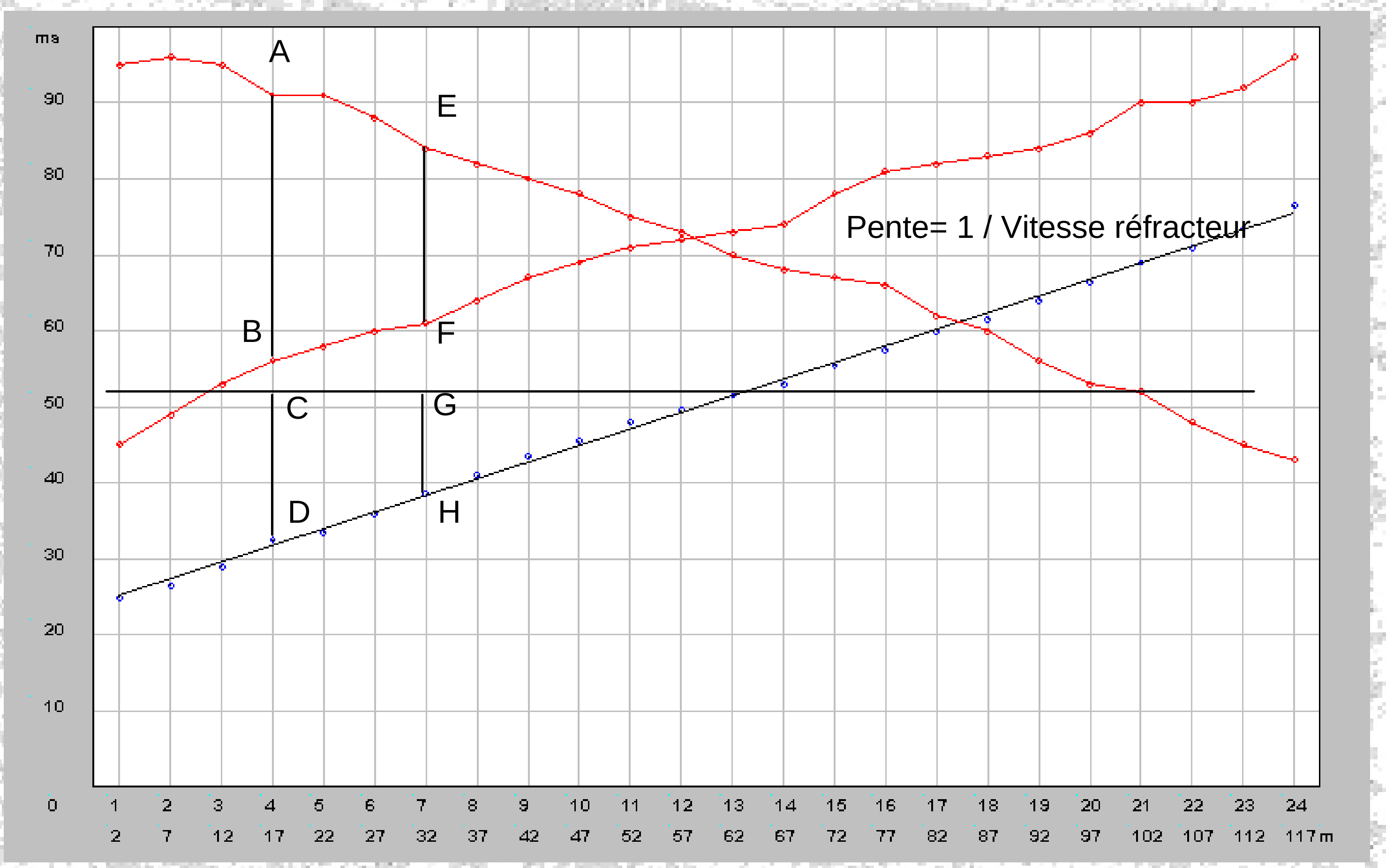
Bedrock velocity

Using only offset shots, we can compute the true velocity of the bedrock, even if the bedrock is dipping. If the points are not straight, it means that bedrock is not homogenous (fault, lithological boundary)



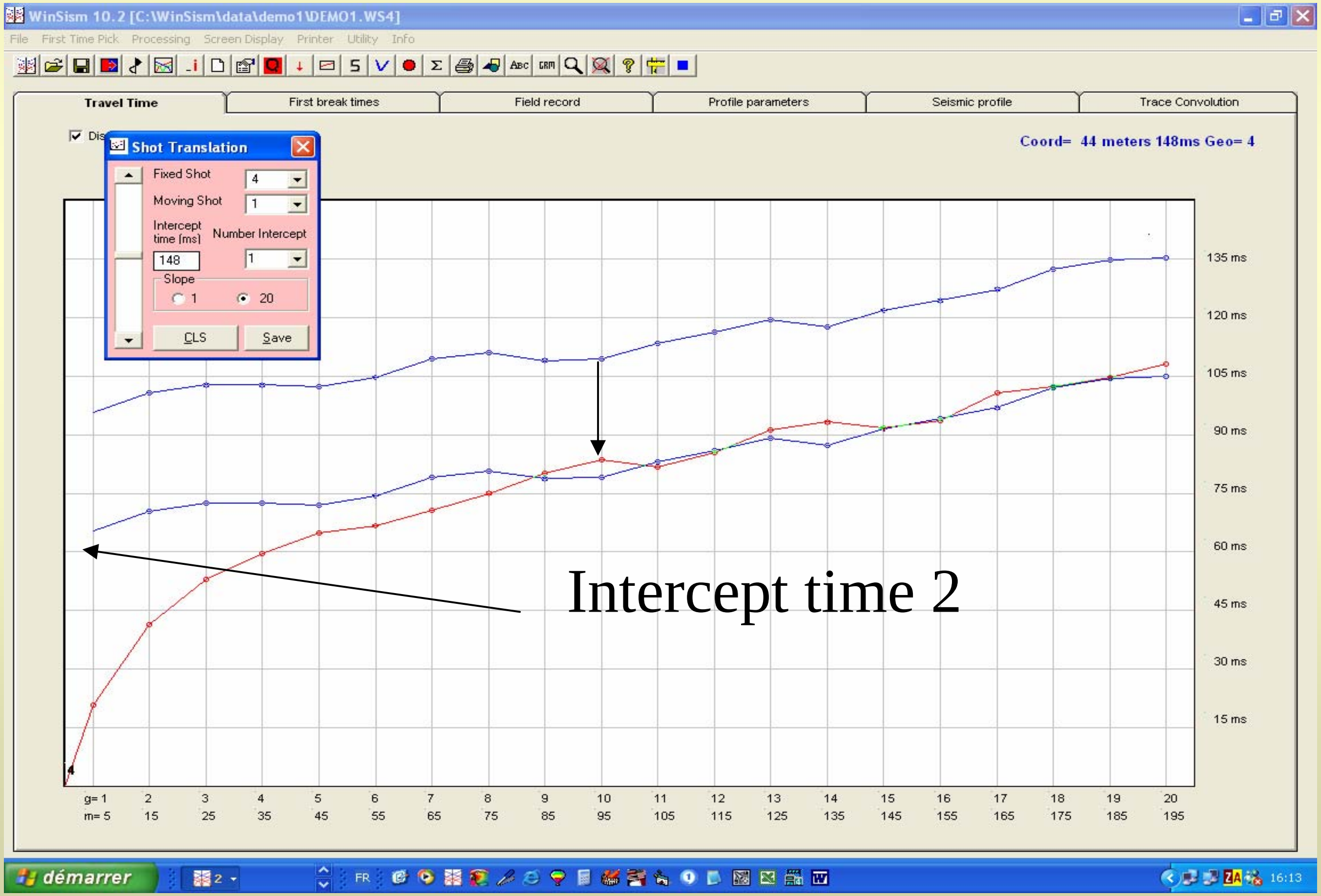
Save the Velocity as layer 3 velocity

Bedrock velocity



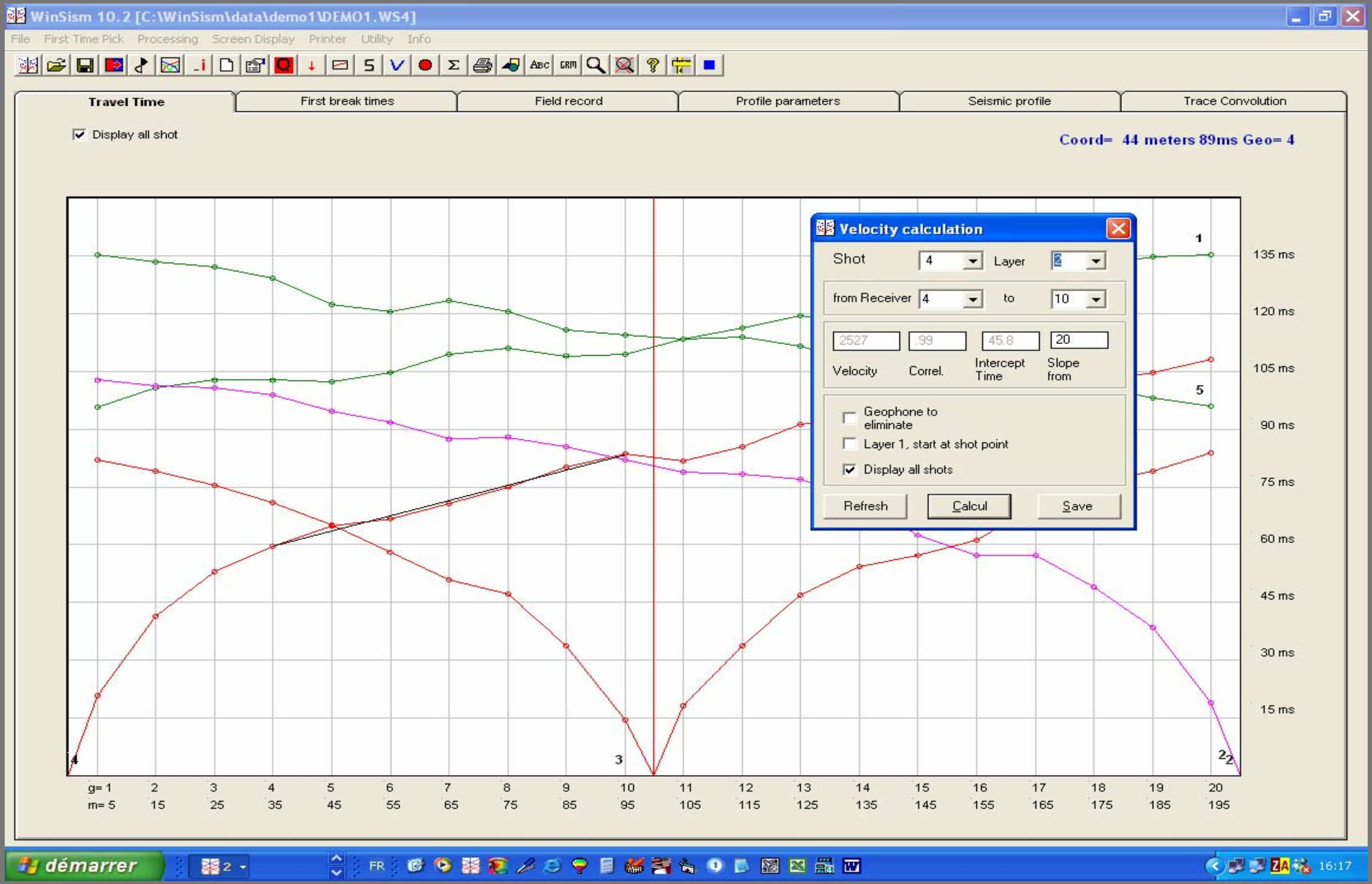
Phantoming

Move offset shot to end shot to determine which part corresponds to bedrock arrivals

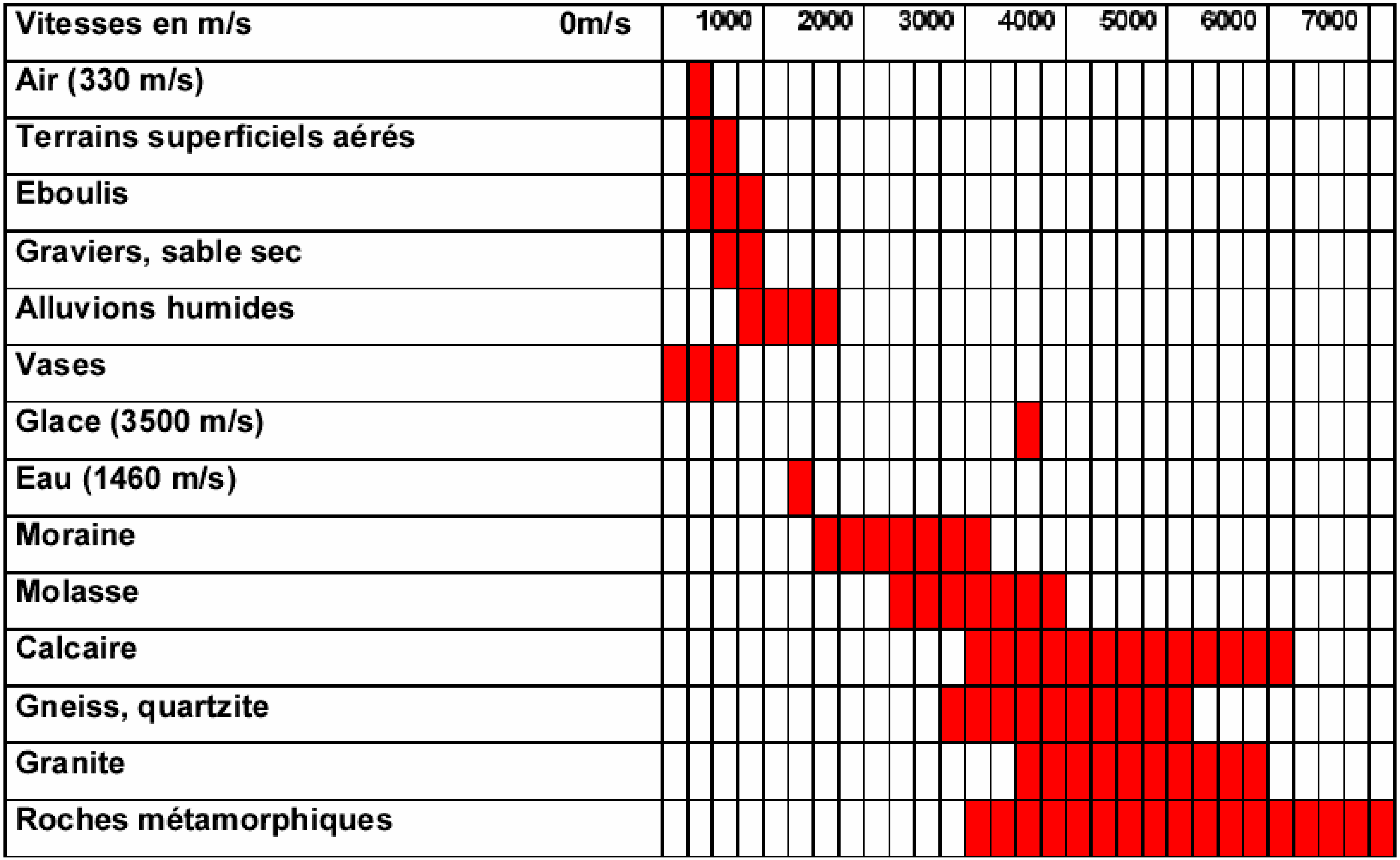


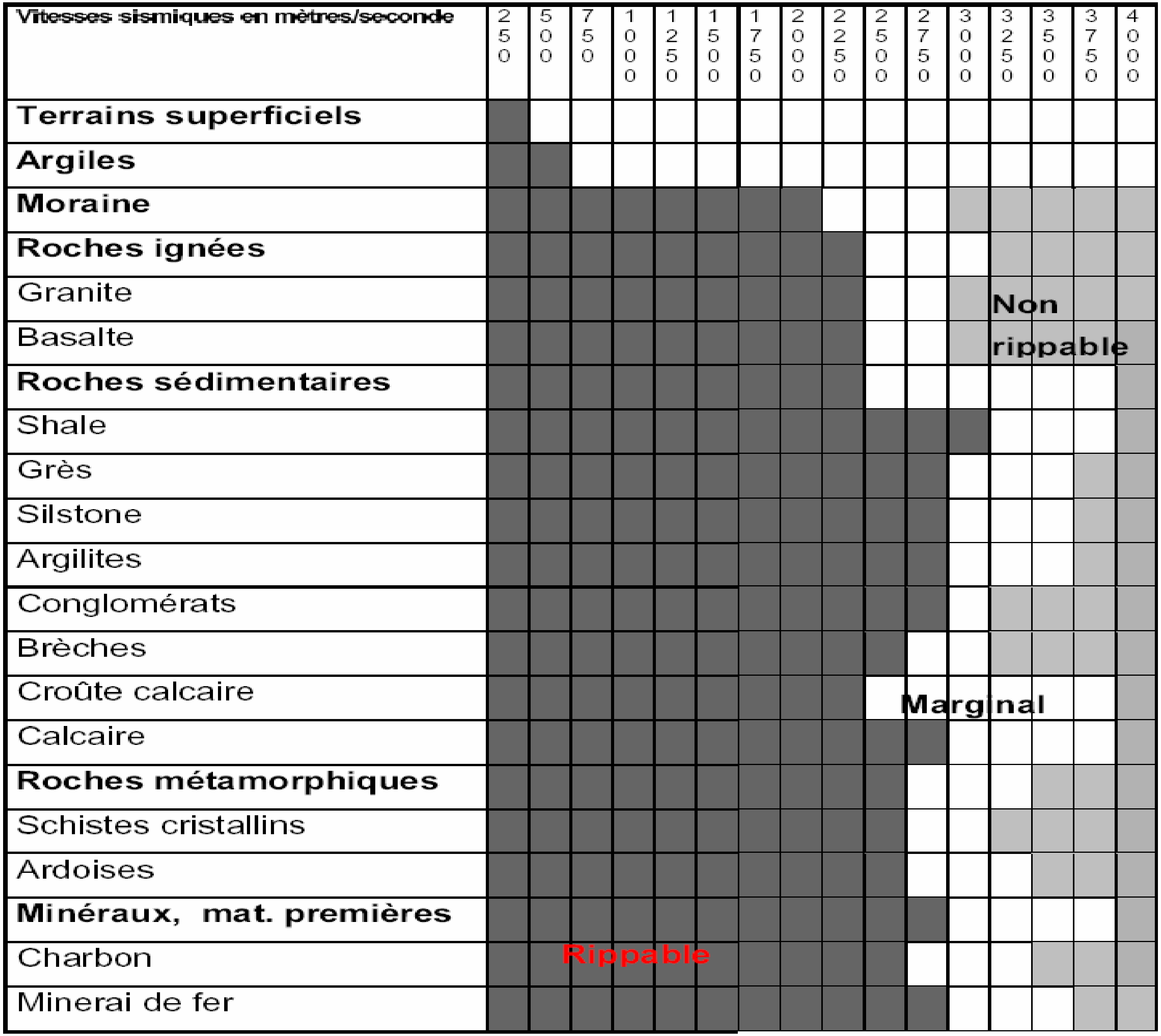
Velocity determination

Velocity = 1 / slope



Seismic velocity of some rocks

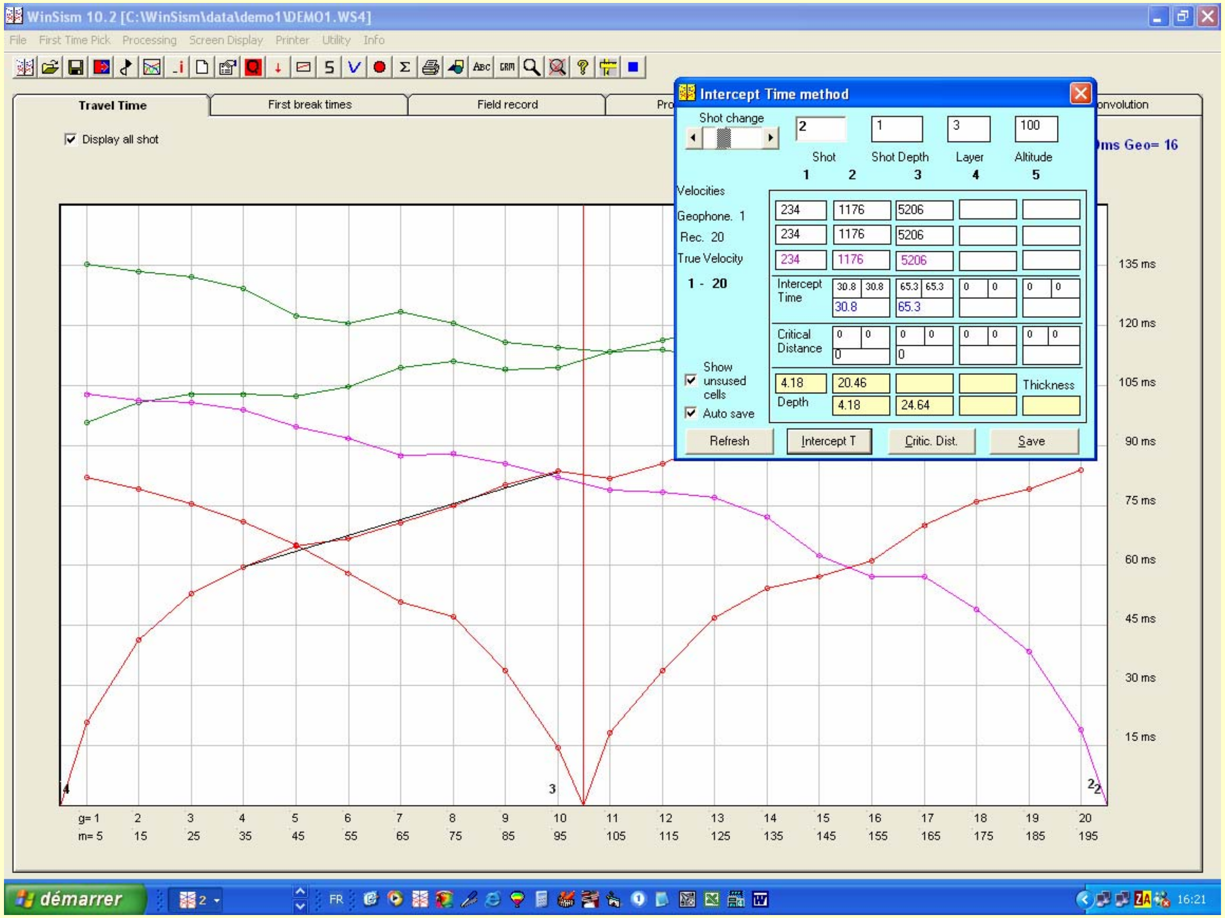



Vitesses sismiques en mètres/seconde
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
4000
Terrains superficiels
Argiles
Moraine
Roches ignées
Granite
Basalte
Roches sédimentaires
Shale
Grès
Silstone
Argilites
Conglomérats
Brèches
Croûte calcaire
Calcaire
Roches métamorphiques
Schistes cristallins
Ardoises
Minéraux, mat. premières
Charbon
Minerai de fer
Non rippable
Marginal
Rippable

Rock rippability

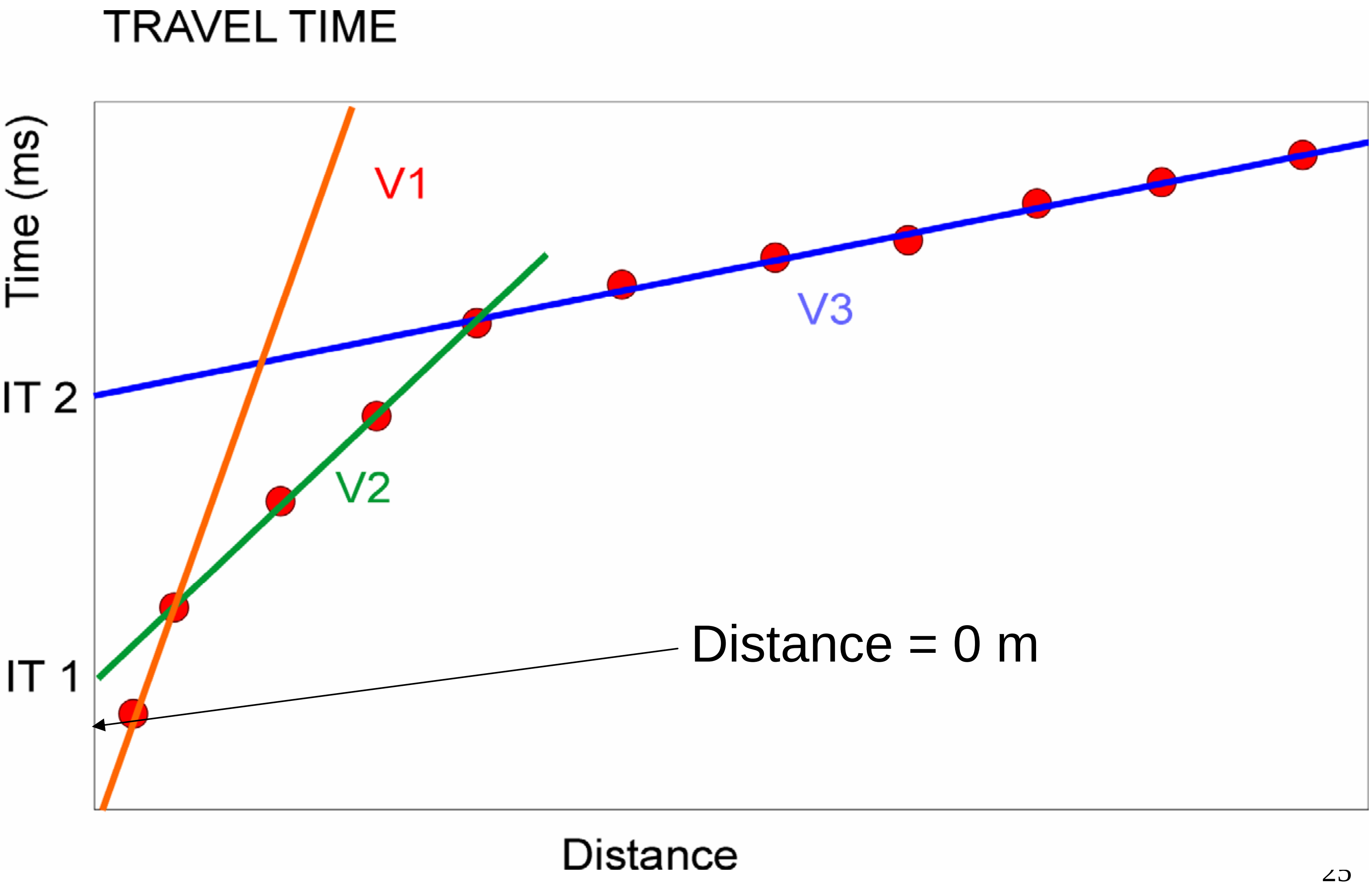
- Rippability (bulldozer) is related with rock velocities.
- A refraction profil can be used to determine if explosives use will be necessary instead bulldozer
- Refraction survey can also be used to caracterize soils: soft, hard to set excavation rates

If you know all velocities and Intercept times, thickness can be computed below all shots, except offset shots



Intercept time (IT) method

What is an Intercept time



IT Formula

Z1= thickness layer 1
T1= intercept 1
V1=layer 1 velocity
V2=ayer 2 velocity

$$T = \frac{2Z_1 \cos\alpha}{V_1} + \frac{X}{V_2}$$

If we now let X = 0, then T becomes the intercept time, T_i, and we can rewrite the last expression as:

$$Z_1 = \frac{T_i V_1}{2\cos\alpha},$$

i.e.,

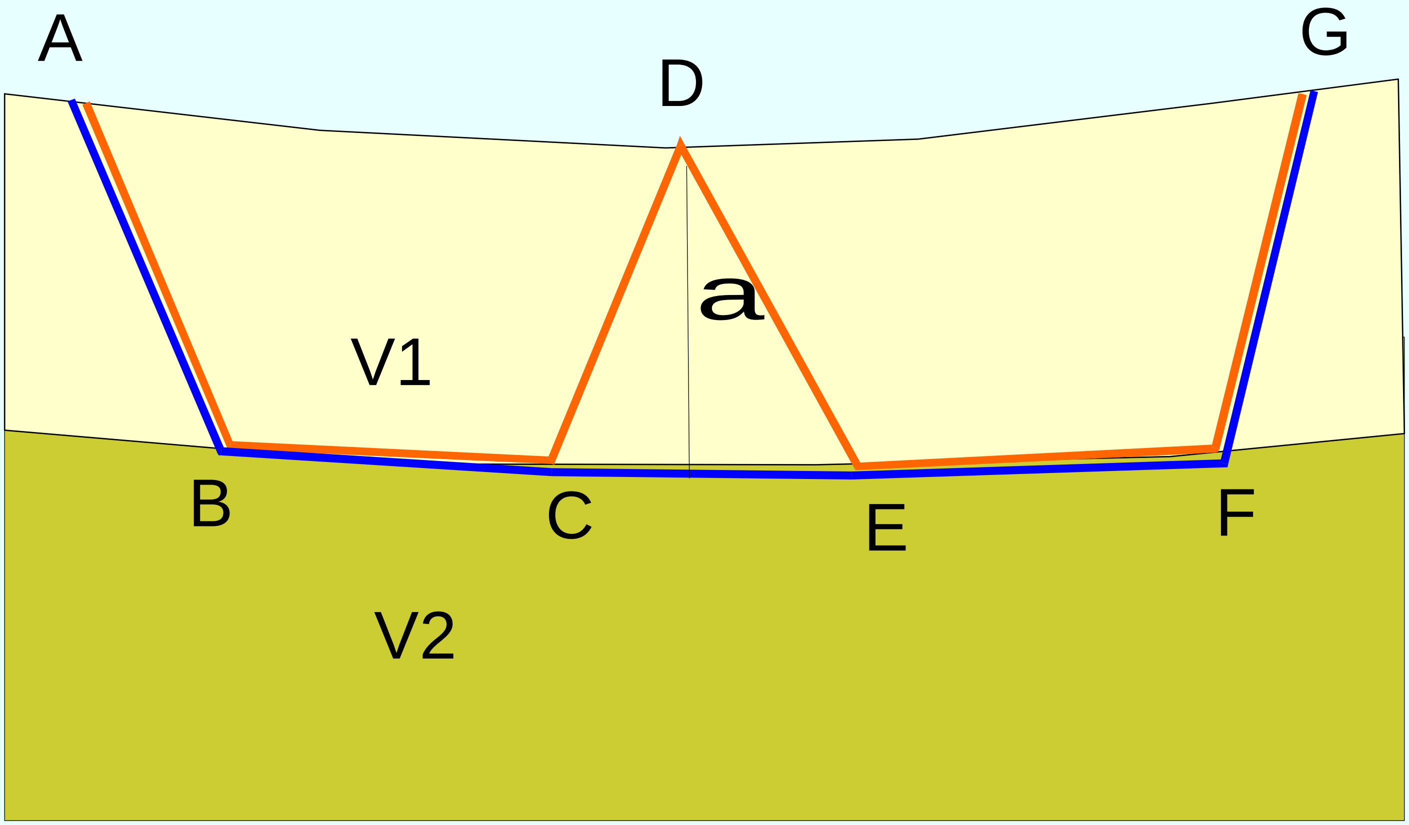
$$Z_1 = \frac{T_i V_1}{2\cos\left(\sin^{-1} V_1/V_2\right)}. \quad (2)$$

Plus minus Method Principle

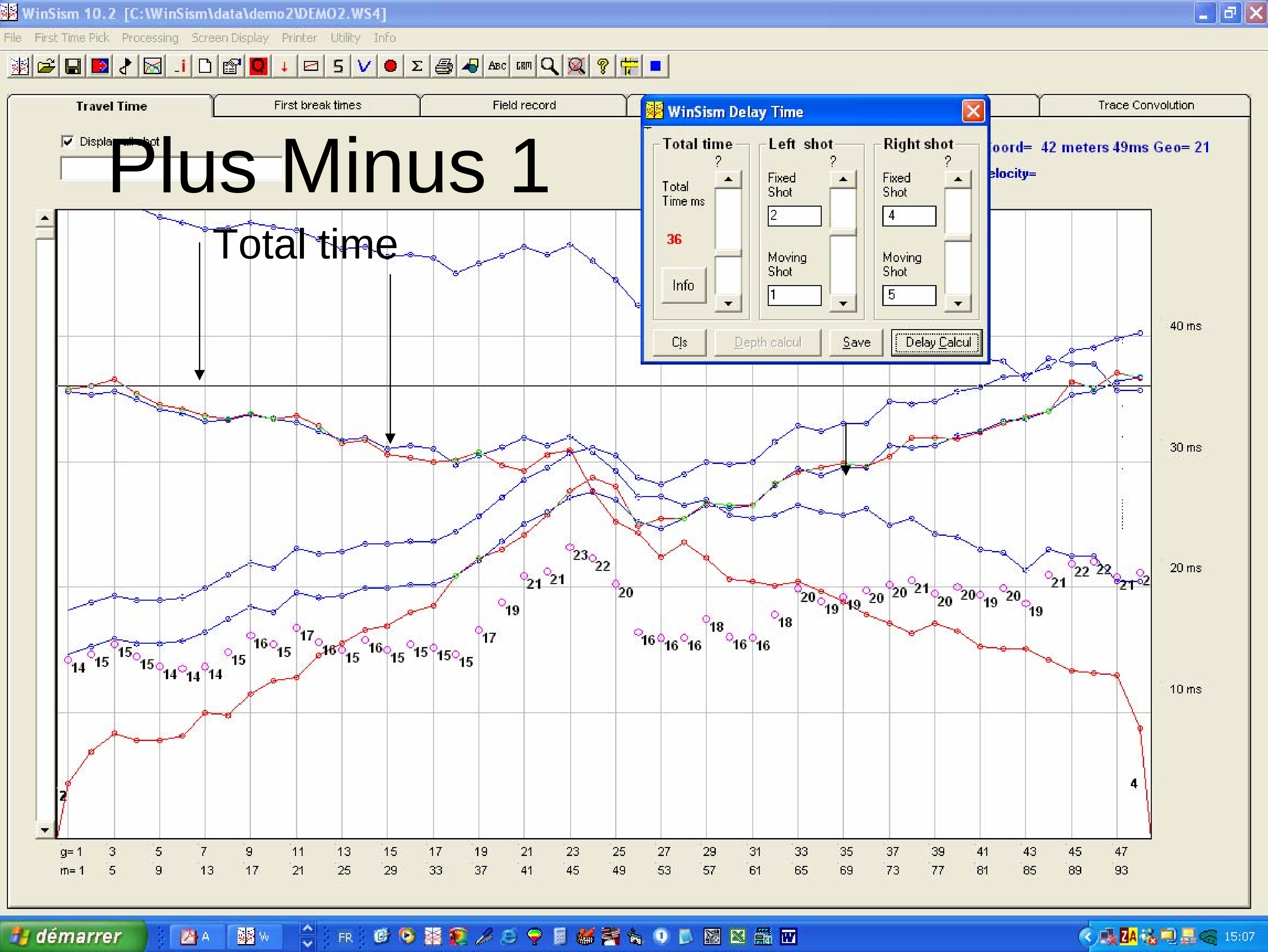
Total time

Sin a = V1/V2

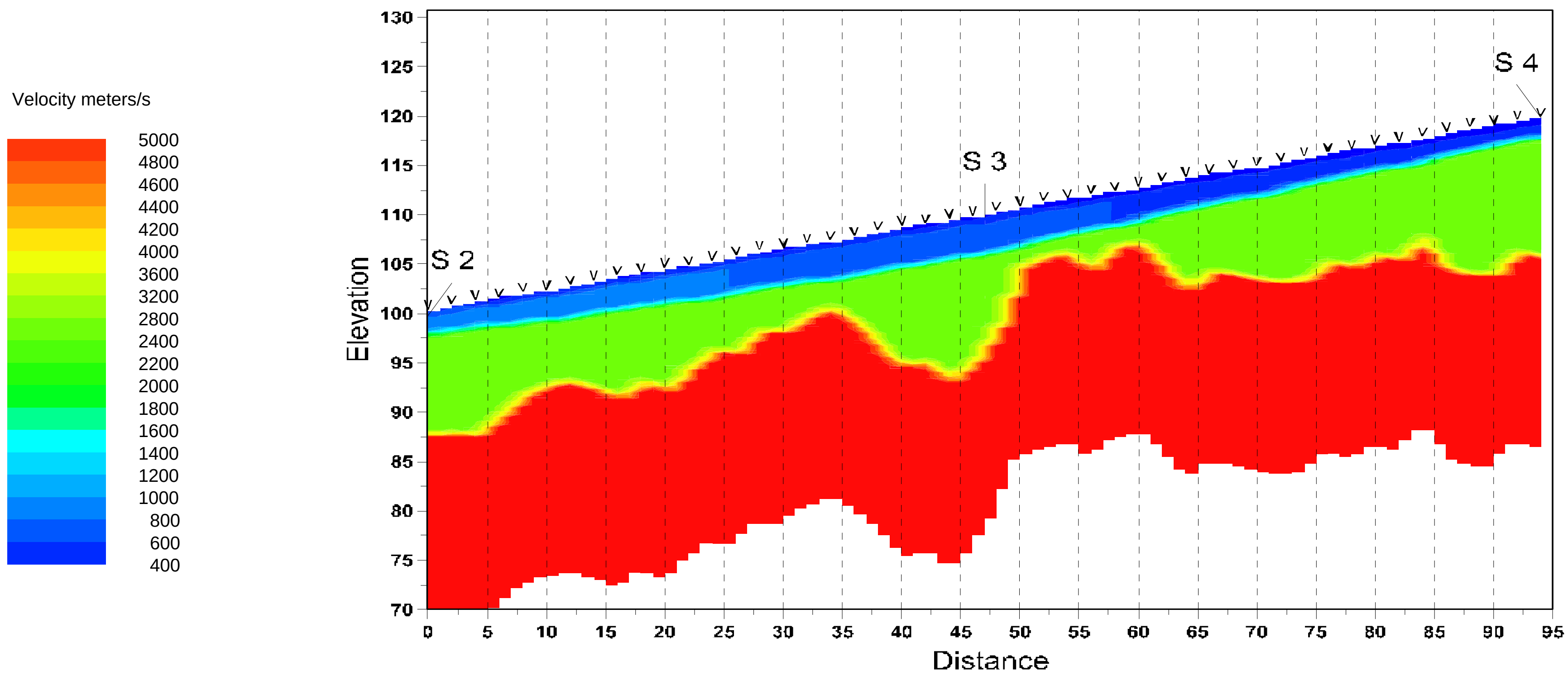
Time CDE = Time ABCD + DEFG - Time ABCEFG



Plus Minus 1


WinSism 10.2 [C:\WinSism\data\demo2\DEMO2.WS4]
File First Time Pick Processing Screen Display Printer Utility Info
Travel Time
First break times
Field record
Trace Convolution
Total time
WinSism Delay Time
Total time
Total Time ms
36
Info
Left shot
Fixed Shot
2
Moving Shot
1
Right shot
Fixed Shot
4
Moving Shot
5
Cls
Depth calcul
Save
Delay Calcul
oord= 42 meters 49ms Geo= 21
elocity=
40 ms
30 ms
20 ms
10 ms
g= 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47
m= 1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93
démarrer
15:07

ABC method depth computation



DEMO2.WS4

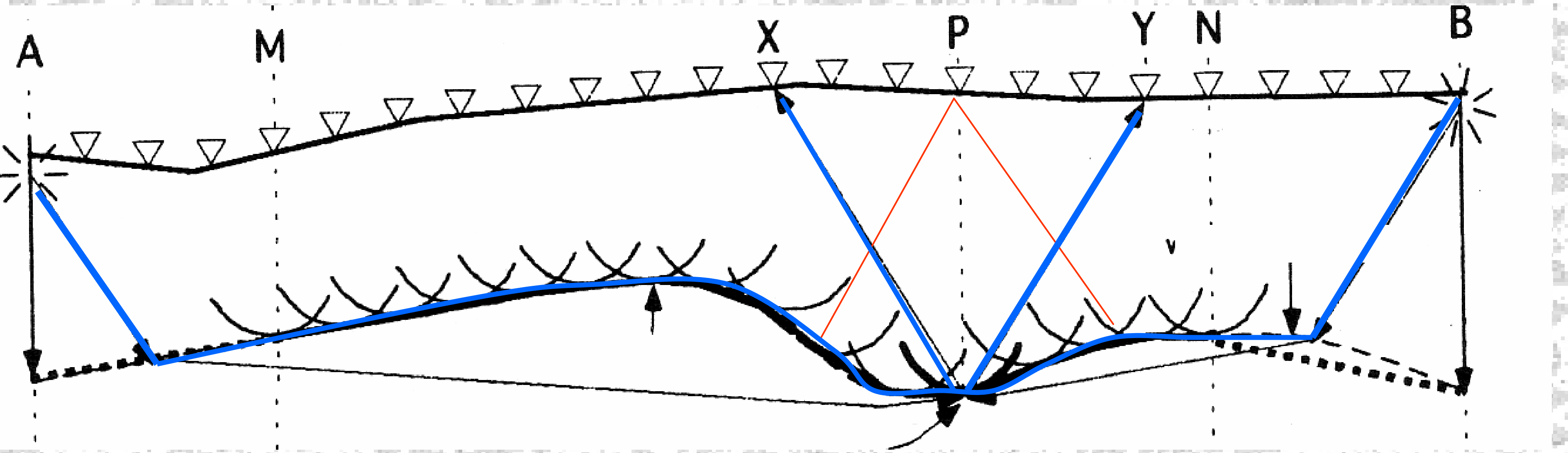
Depth is computed below all receivers

GRM principle

- Generalized Reciprocal Method (see PALMER papers) is a variant of the ABC method. It takes in account noncoincidence of the stations used for calculating plus values
- GRM requires more receivers than IT or ABC
- Different distances are used to compute time to bedrock, geophysicist must select the optimal distance (XY)

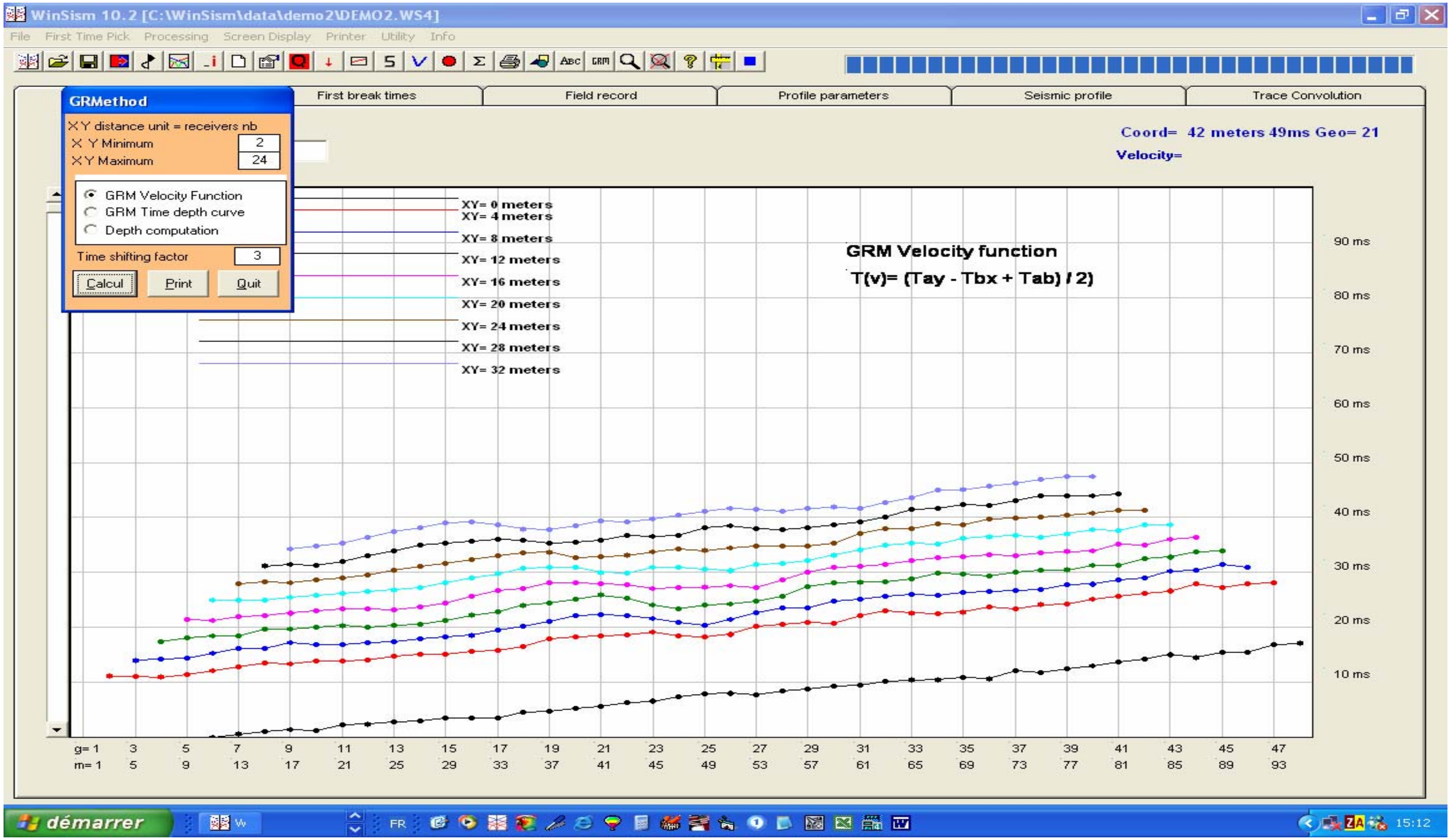
Generalized Reciprocal Method

XY = Optimal distance

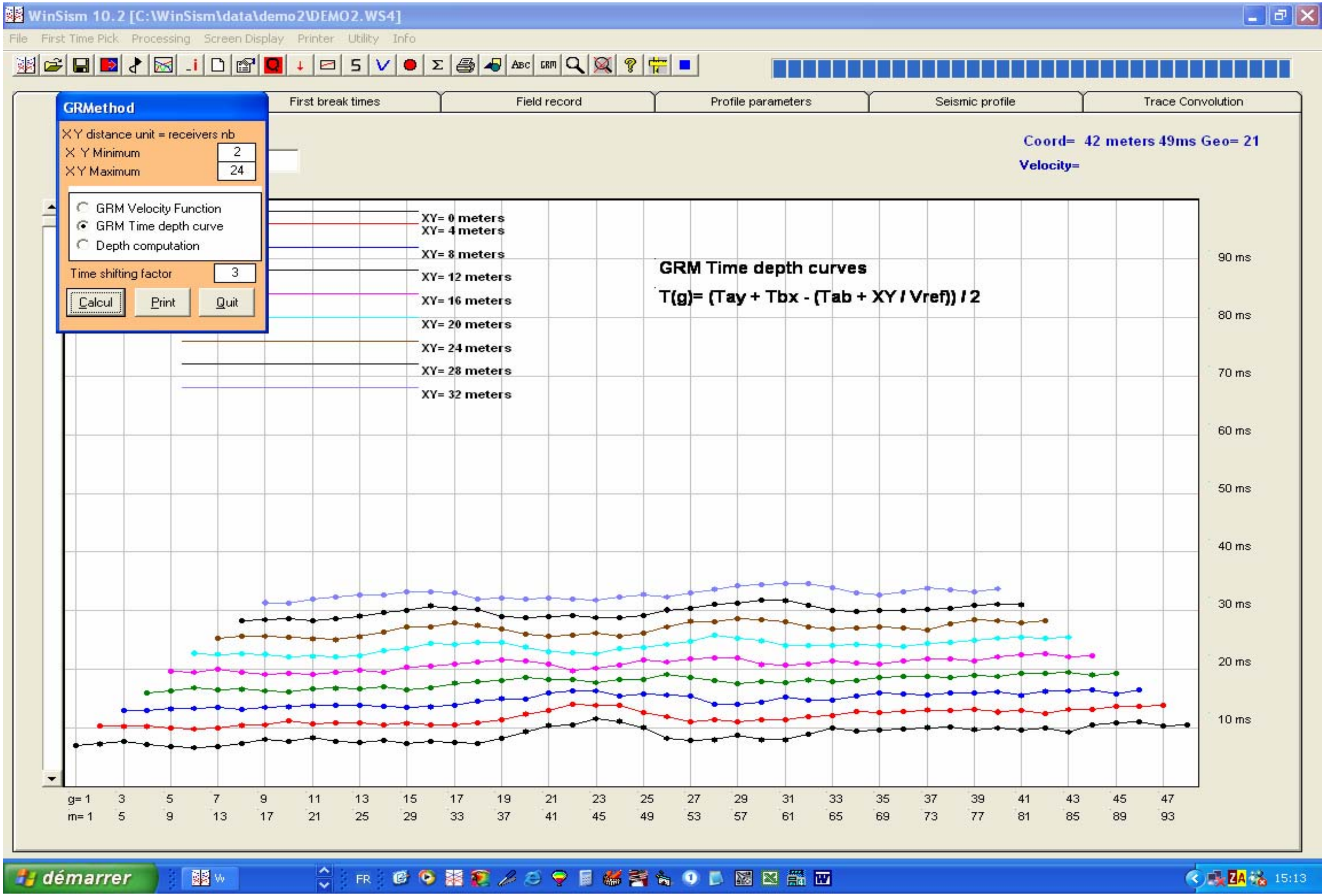


Red = plus-minus path   Blue = plus-minus path

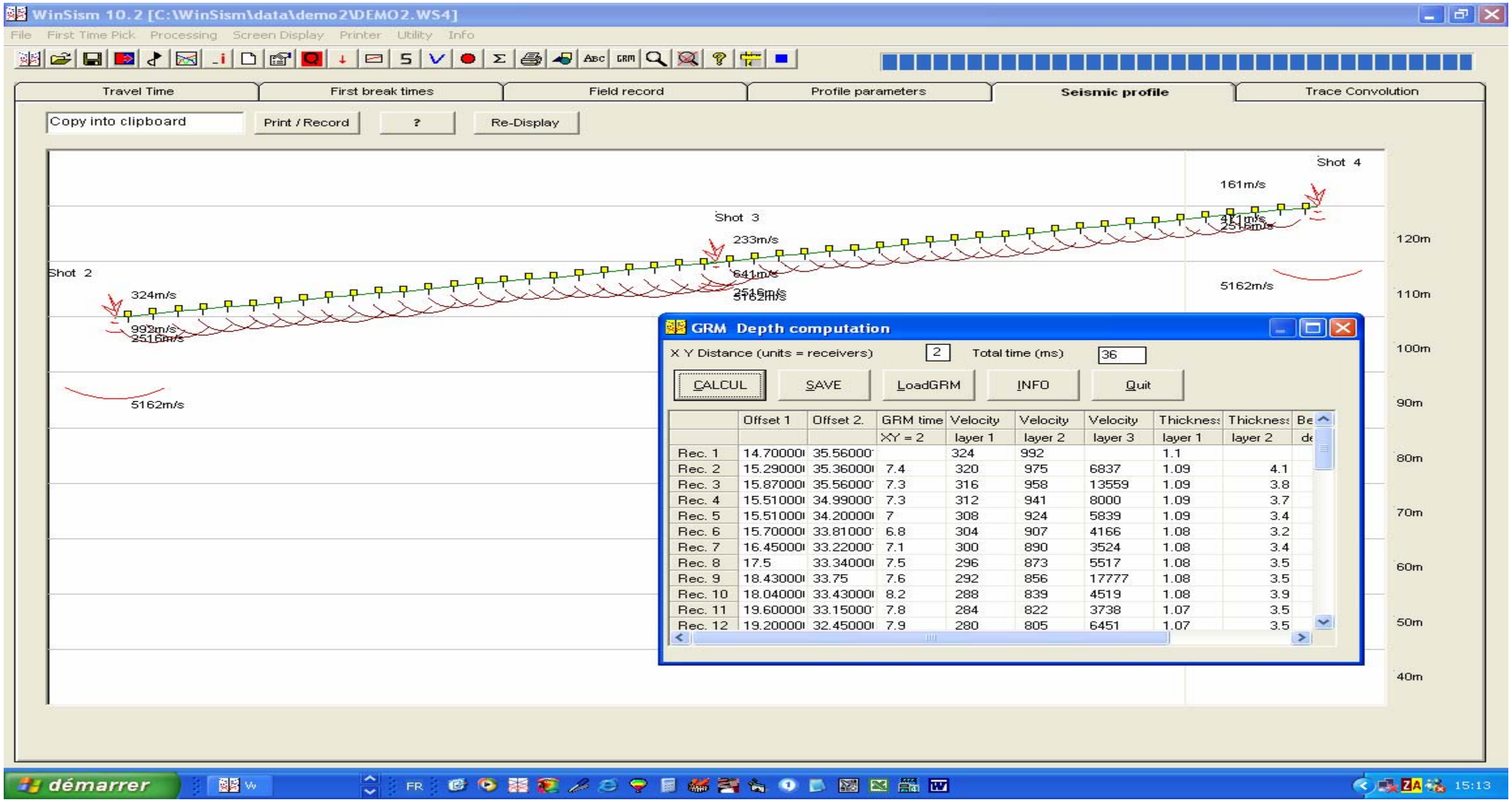
GRM 1 XY optimal distance selection



GRM 2: Depth with differents XY



GRM 3



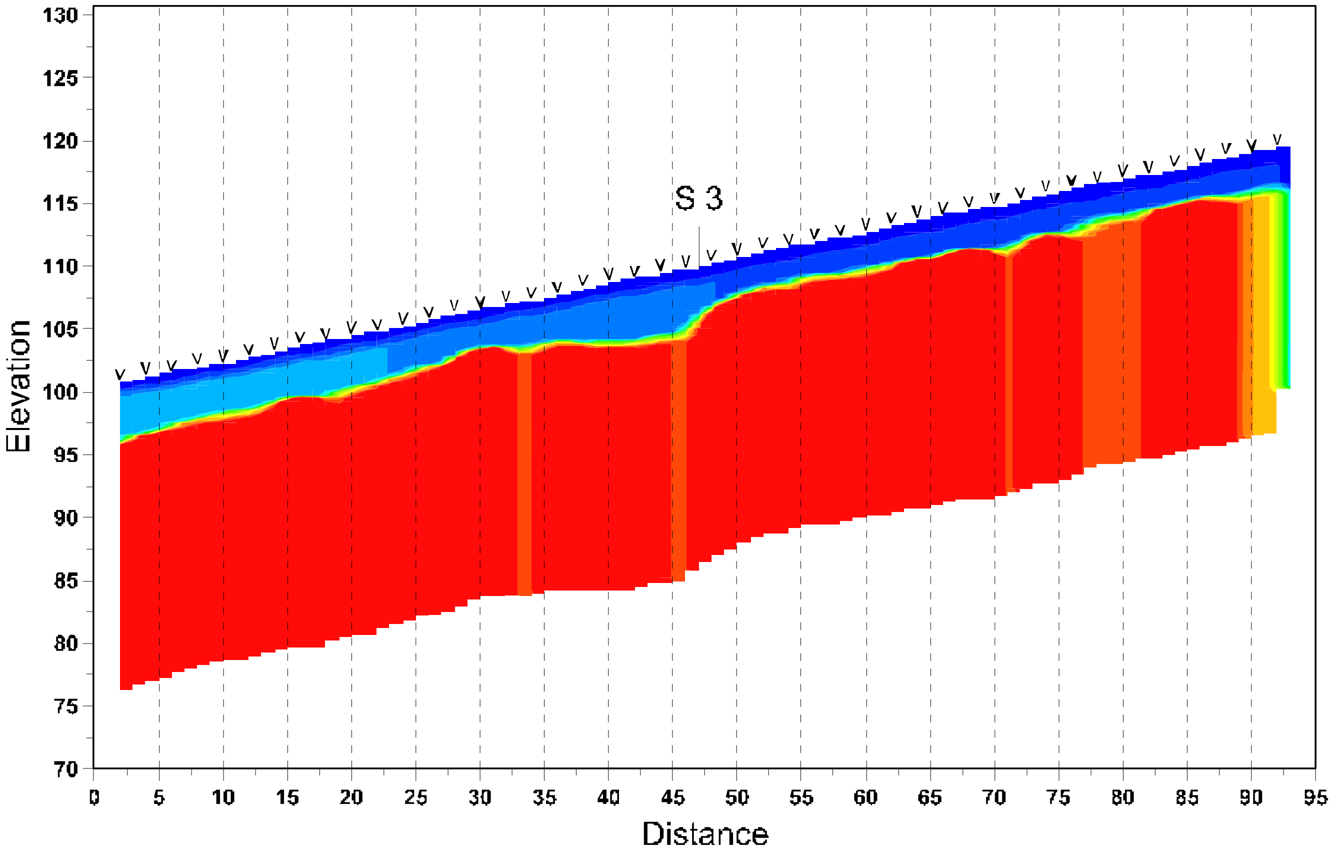
	Offset 1	Offset 2.	GRM time XY = 2	Velocity layer 1	Velocity layer 2	Velocity layer 3	Thickness layer 1	Thickness layer 2	Be de
Rec. 1	14.70000	35.56000		324	992		1.1		
Rec. 2	15.29000	35.36000	7.4	320	975	6837	1.09	4.1	
Rec. 3	15.87000	35.56000	7.3	316	958	13559	1.09	3.8	
Rec. 4	15.51000	34.99000	7.3	312	941	8000	1.09	3.7	
Rec. 5	15.51000	34.20000	7	308	924	5839	1.09	3.4	
Rec. 6	15.70000	33.81000	6.8	304	907	4166	1.08	3.2	
Rec. 7	16.45000	33.22000	7.1	300	890	3524	1.08	3.4	
Rec. 8	17.5	33.34000	7.5	296	873	5517	1.08	3.5	
Rec. 9	18.43000	33.75	7.6	292	856	17777	1.08	3.5	
Rec. 10	18.04000	33.43000	8.2	288	839	4519	1.08	3.9	
Rec. 11	19.60000	33.15000	7.8	284	822	3738	1.07	3.5	
Rec. 12	19.20000	32.45000	7.9	280	805	6451	1.07	3.5	

GRM Seismic profil

Velocity meters/s

	3600
	3200
	2800
	2400
	2200
	2000
	1800
	1600
	1400
	1200
	1000
	800
	600
	400

GRM method depth computation



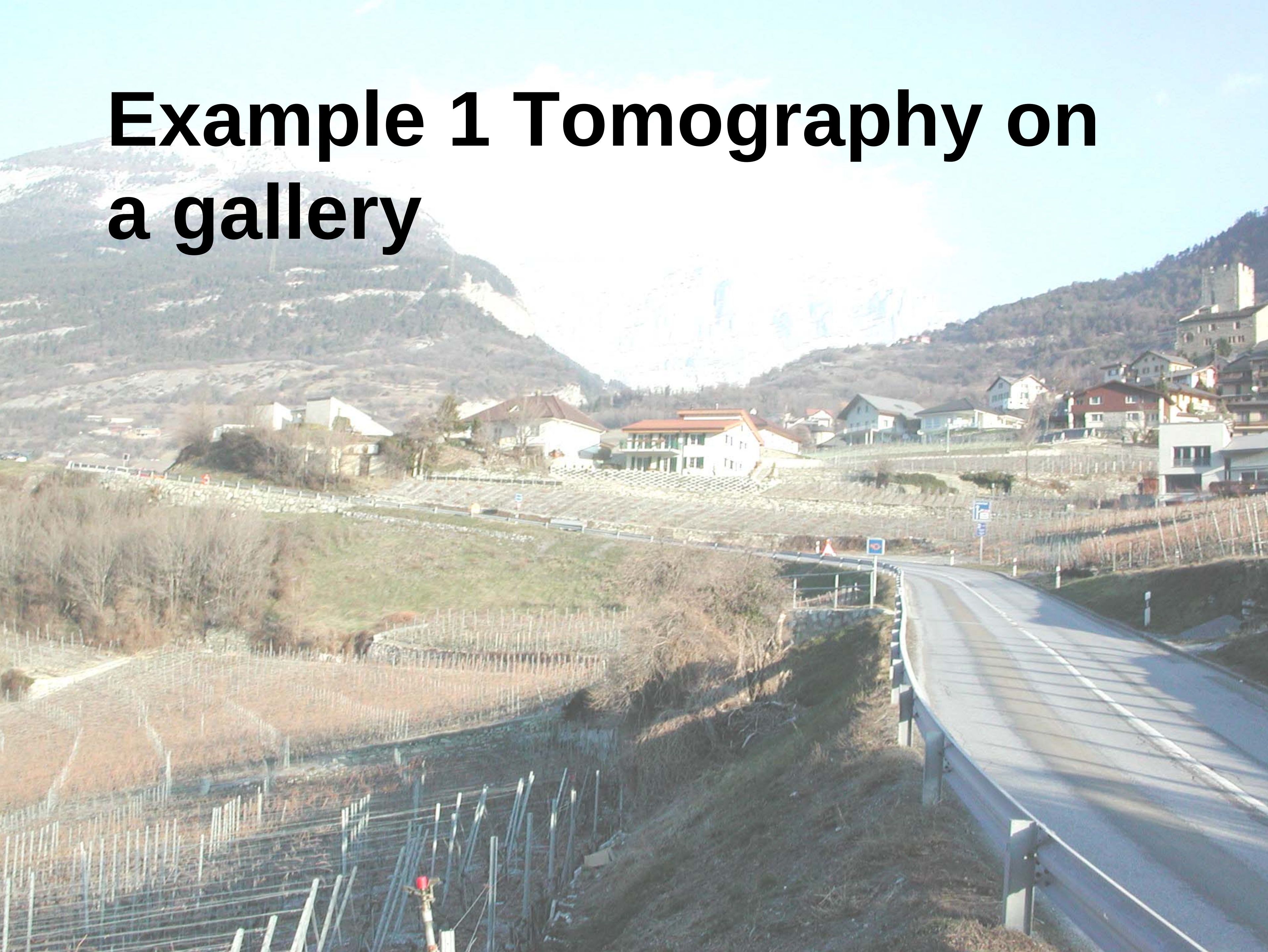
DEMO2.WS4

Tomography

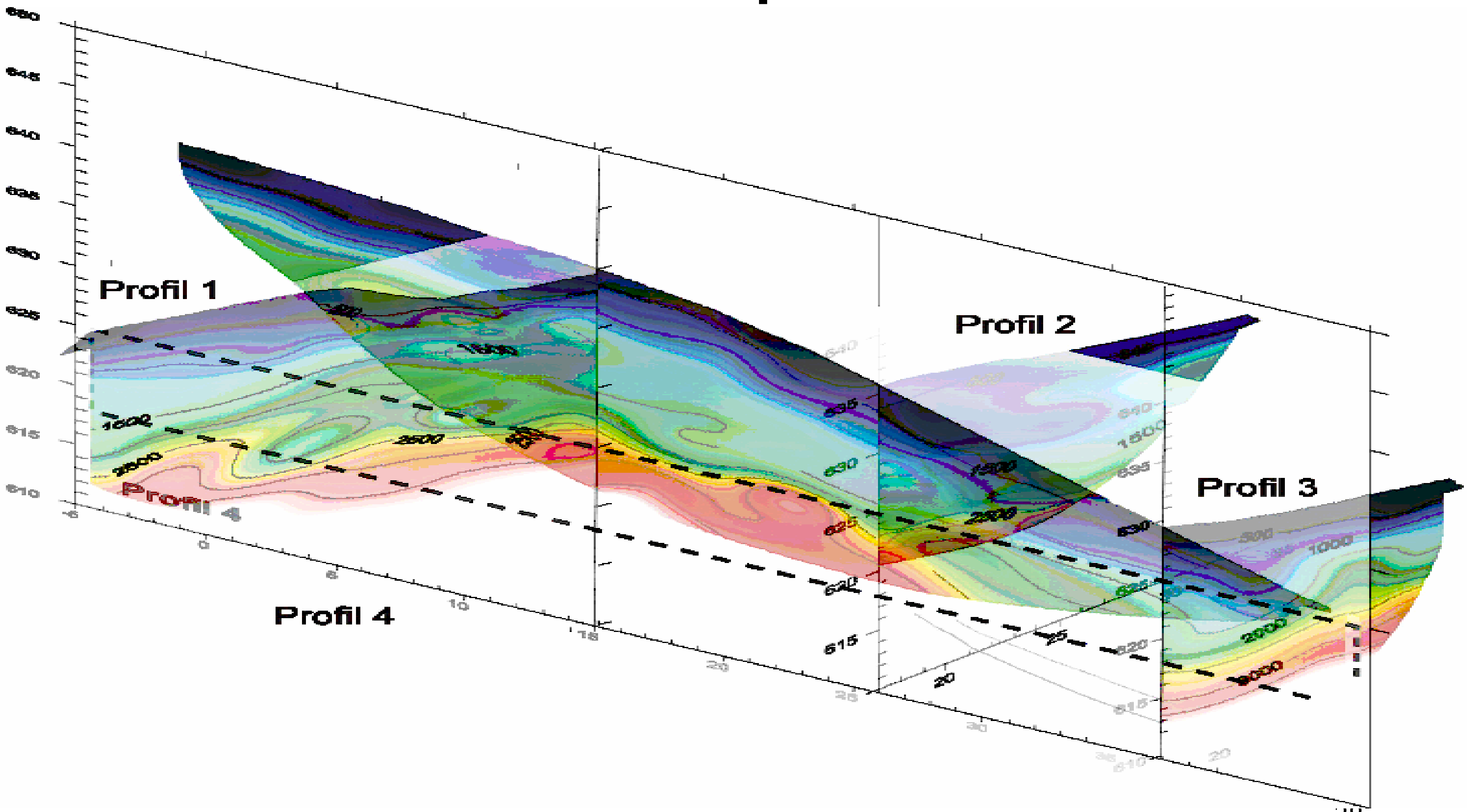
If you input all geometrical data and first break picks, computer can build a theoretical model as close as possible to field data using different algorithm.

A very precise picking and closer shots are required to give accurate results.

Example 1 Tomography on a gallery

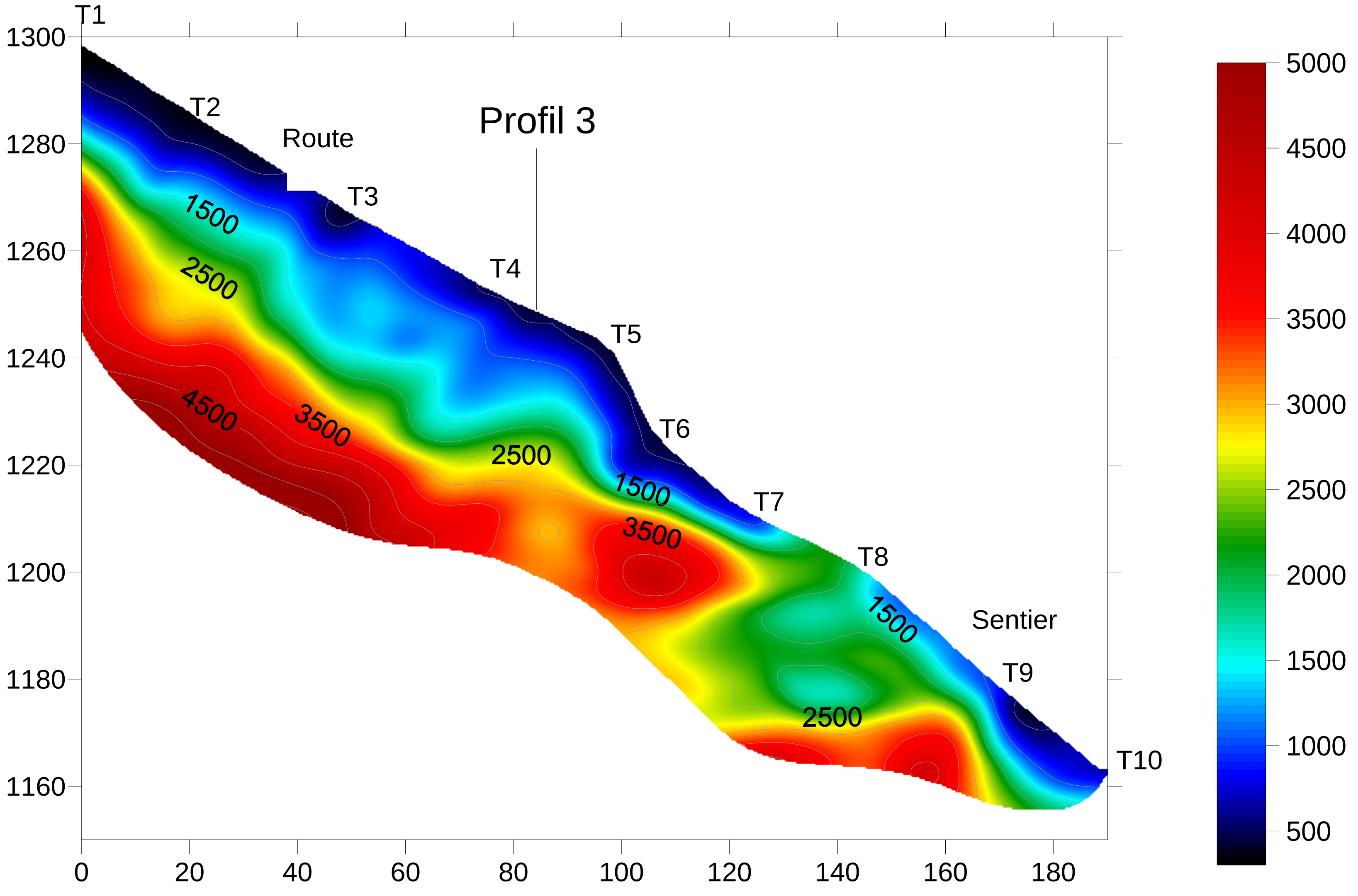


Example 1



Example 2 Landslide in Swiss Alps

Example 2



Profil 3
T1
T2
Route
T3
T4
T5
T6
T7
T8
Sentier
T9
T10
1500
2500
4500
3500
2500
1500
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1500
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1280
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1200
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0
20
40
60
80
100
120
140
160
180
5000
4500
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FIN END