An illustration of VSP* efficiency

to design a geothermal well while drilling

**Vertical Seismic Profiling*

Joachim PLACE

Charles NAVILLE

Edouard Le Garzic

Yves Geraud

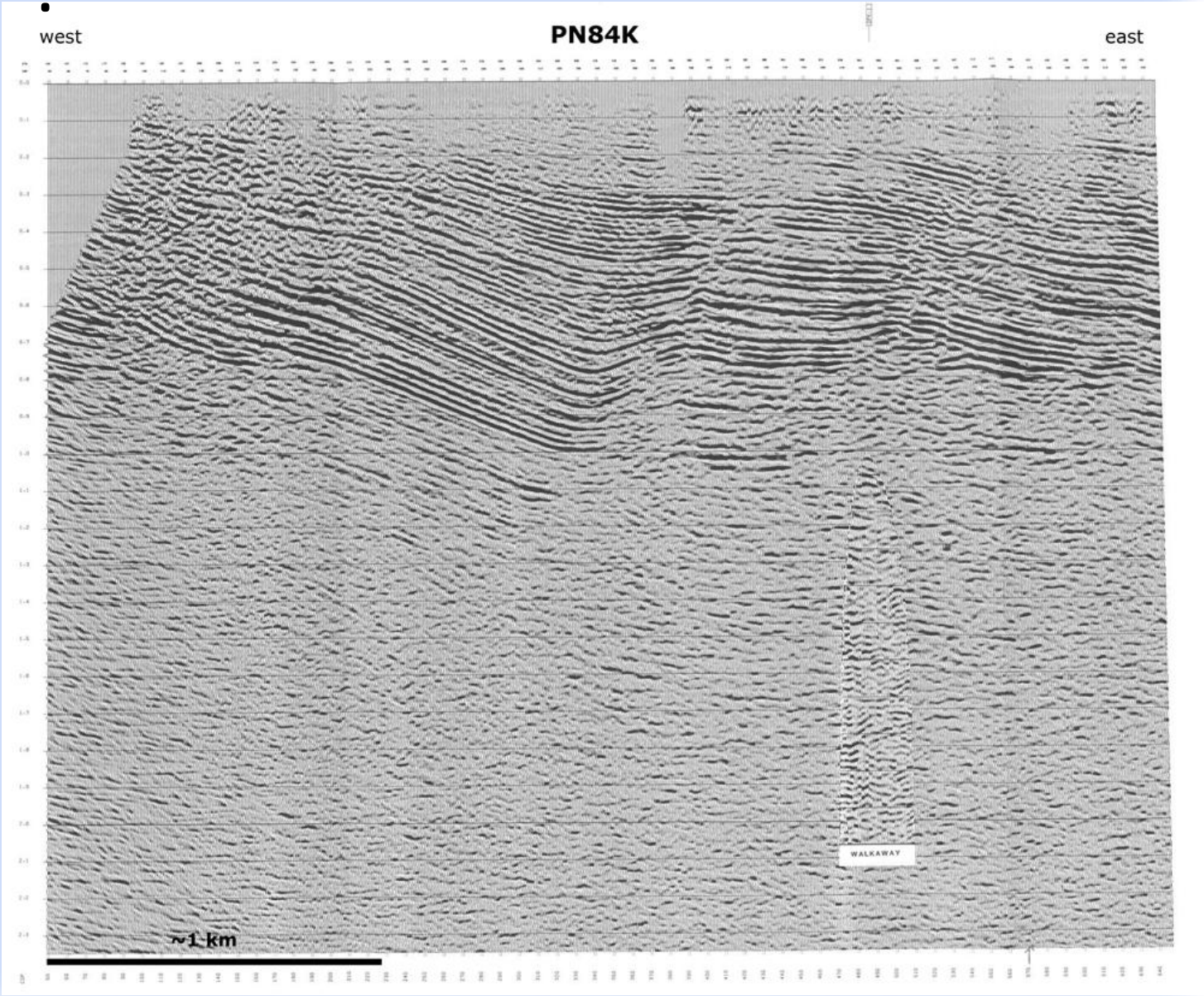
Marc Diraison

ENGINE Workshop 4, Reykjavik, 1-5 July 2007

Summary

- The interest of VSP
- After preprocessing
- After isotropic 3C processing
- Conclusion

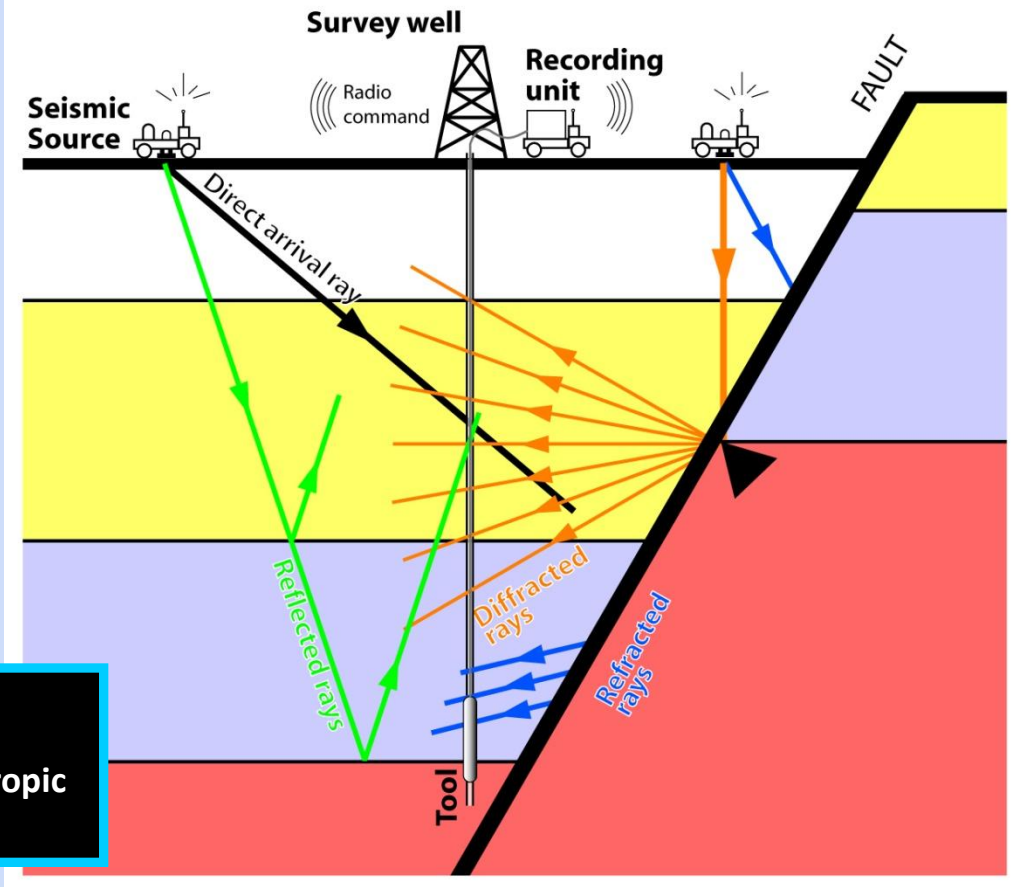
Why VSP ?



What is a VSP ?

Vertical Seismic Profiling

- Zero-offset VSP
- Offset VSP



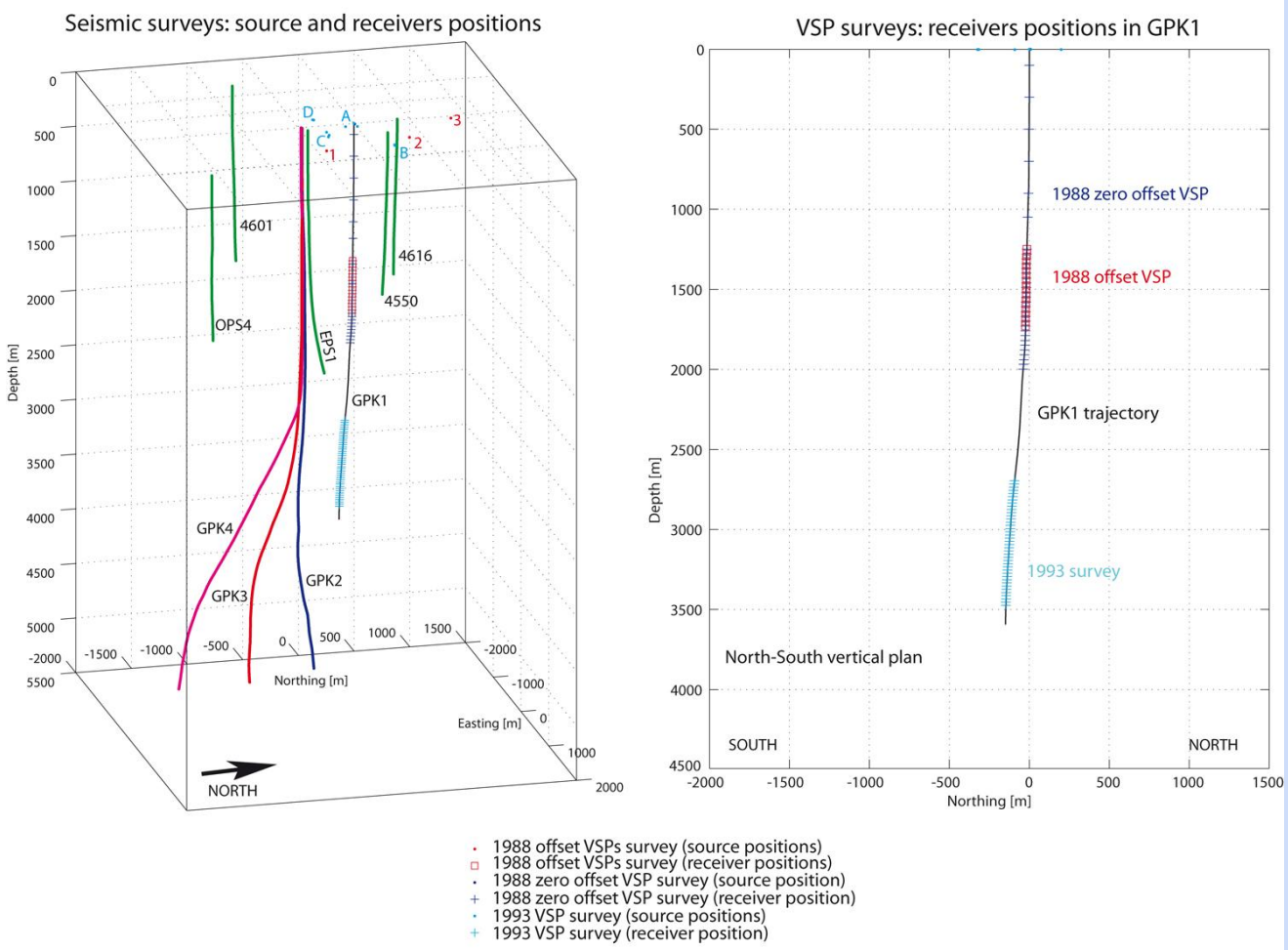
TOOL :

3 orthogonal geophones ⇨ "3C"

1 hydrophone ⇨ "4C"

1. **Velocity survey**
2. **Structural investigation** (after isotropic processing)

The VSP surveys in GPK1



1988

1 zero offset VSP

+ check shots

3 offset VSPs

1 EW-NS walkaway

Data only on paper

1993

VSP survey in GPK1 and EPS1 before and after massive fluid injection in GPK1

Data on magnetic tapes

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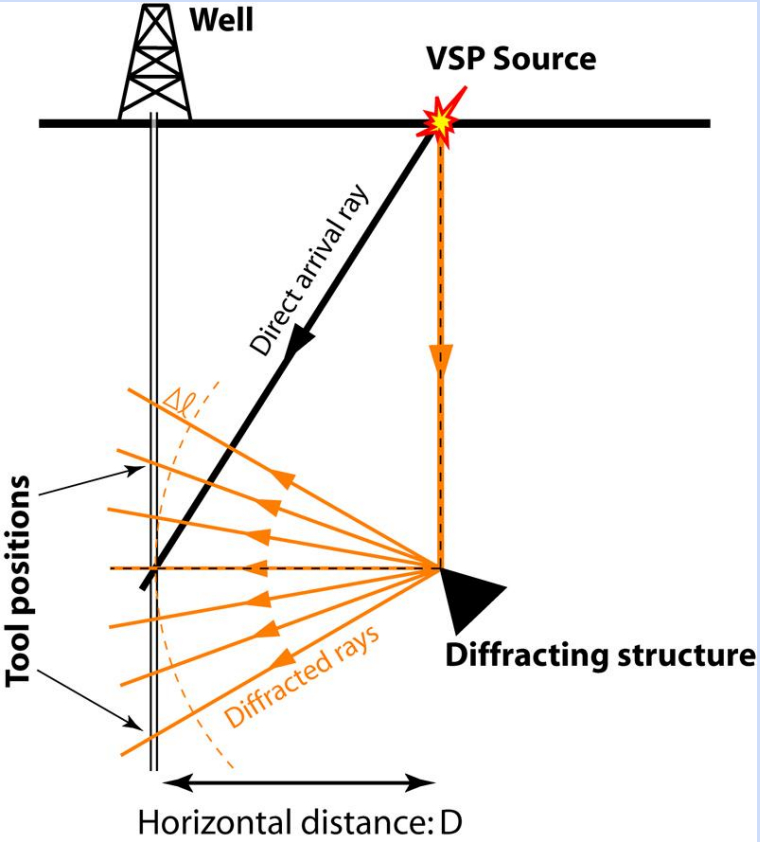
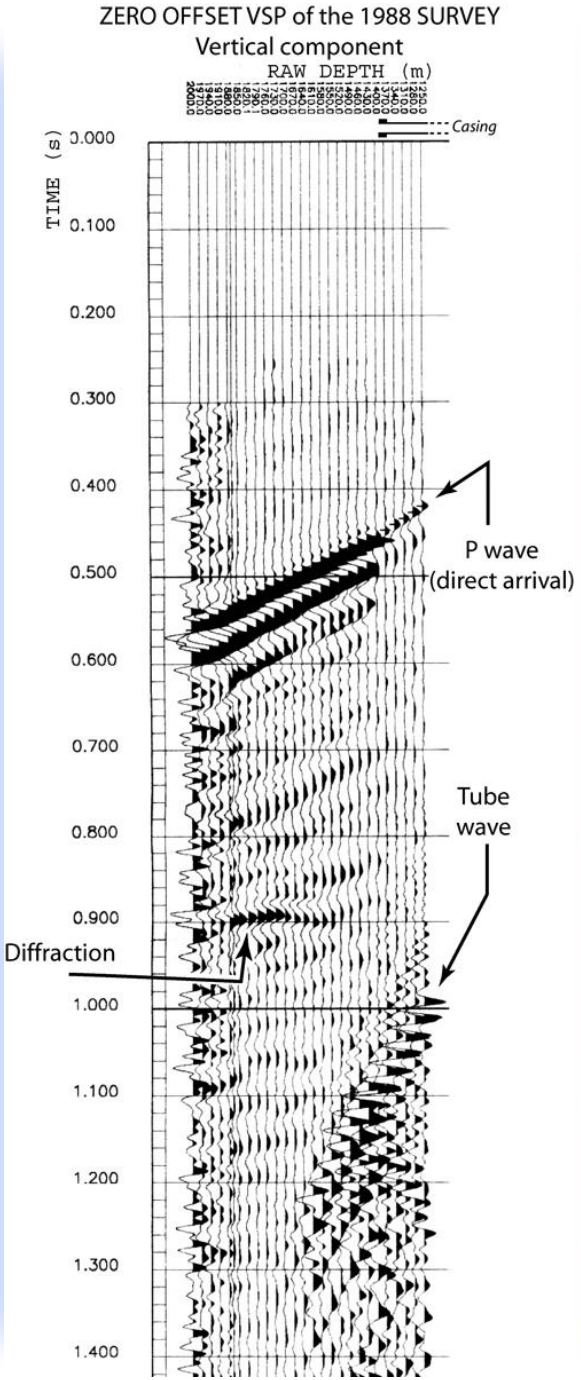
Example of structural investigation from preprocessed data (1988)



Distance D estimation from :

- **Curvature**
- **Travel time**

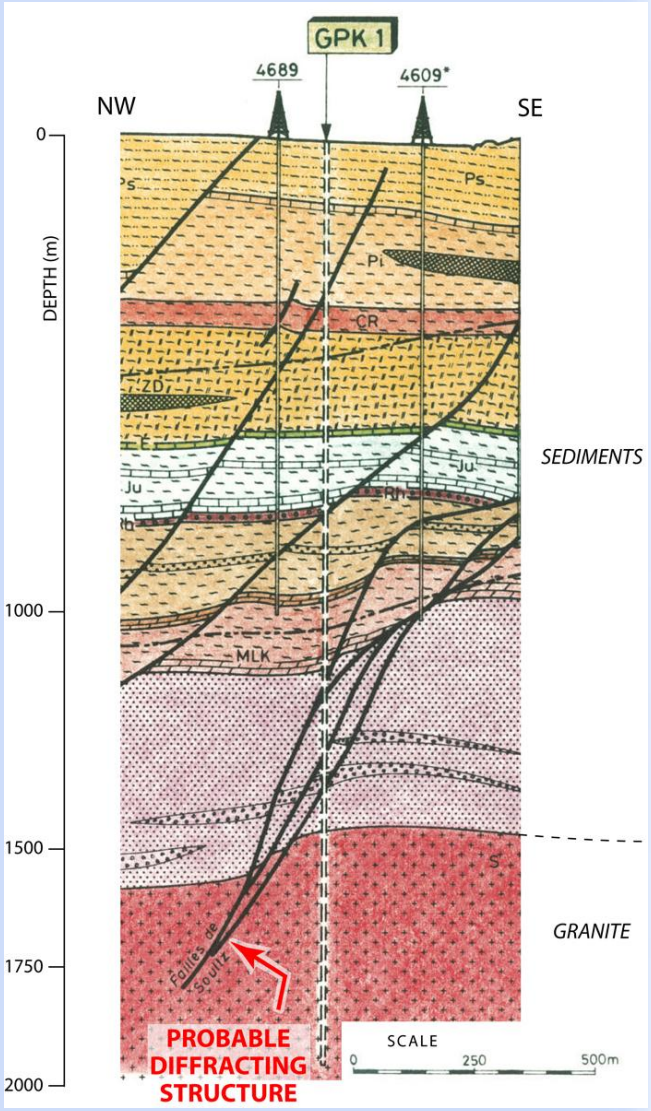


Example of structural investigation from preprocessed data (1988)

The results indicate a distance D of 300 m

The diffraction is produced by a major fault affecting the well vicinity

Thus, the precise position of the well can be derived from preprocessed data



Summary

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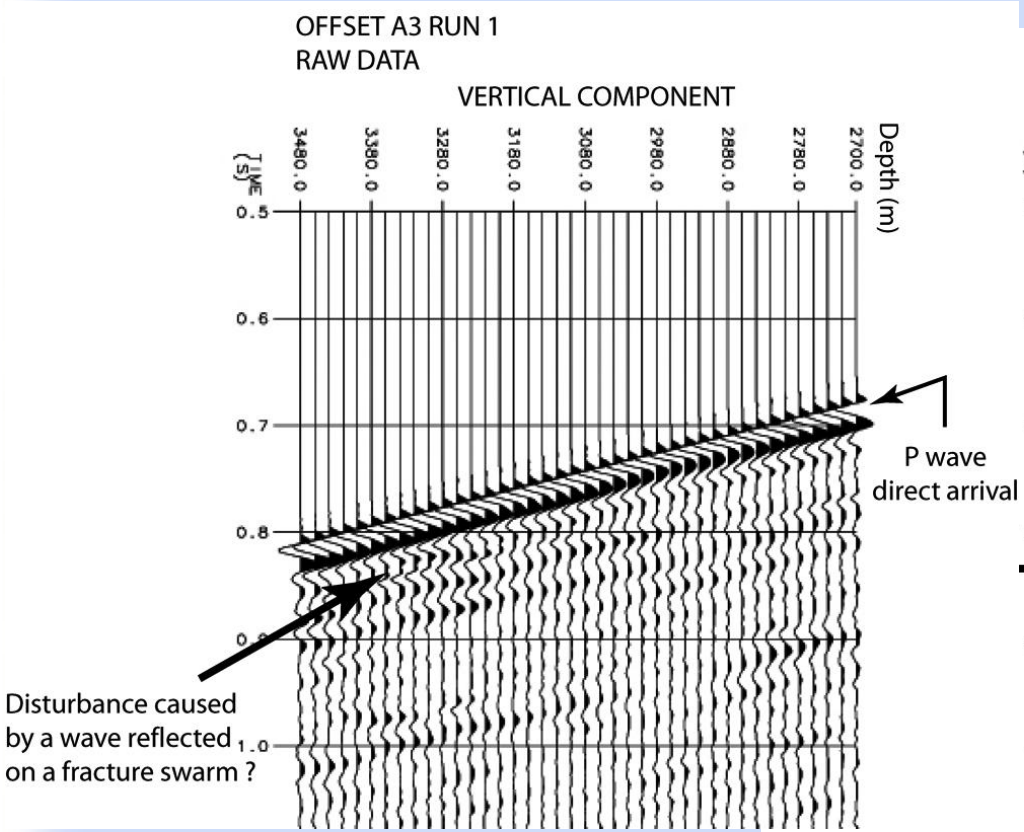
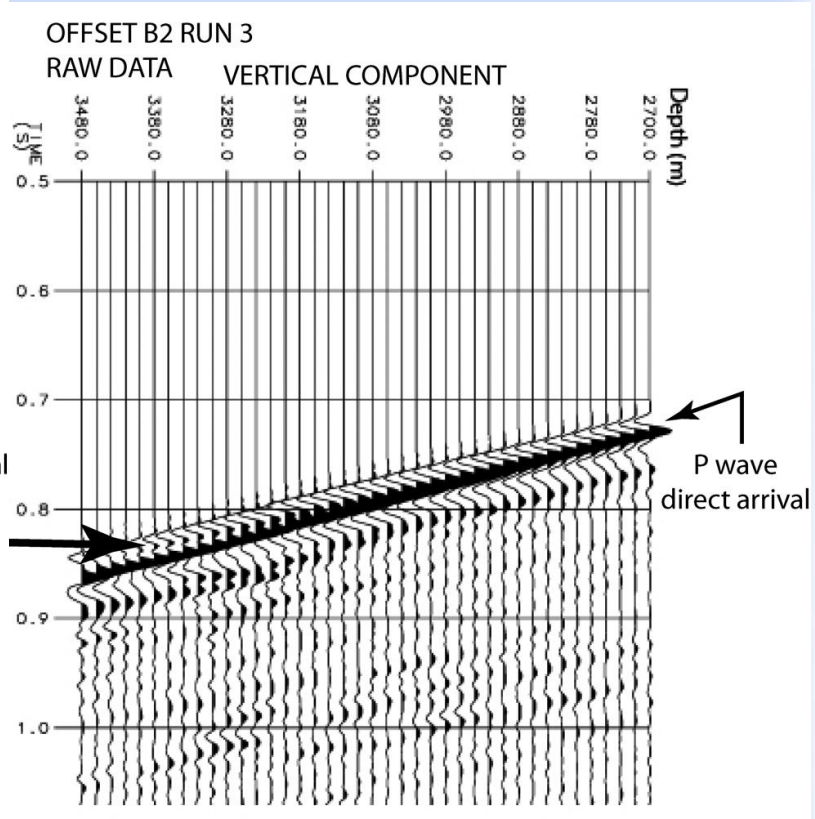
Isotropic 3C data processing

Examples of pre-processed data (1999)





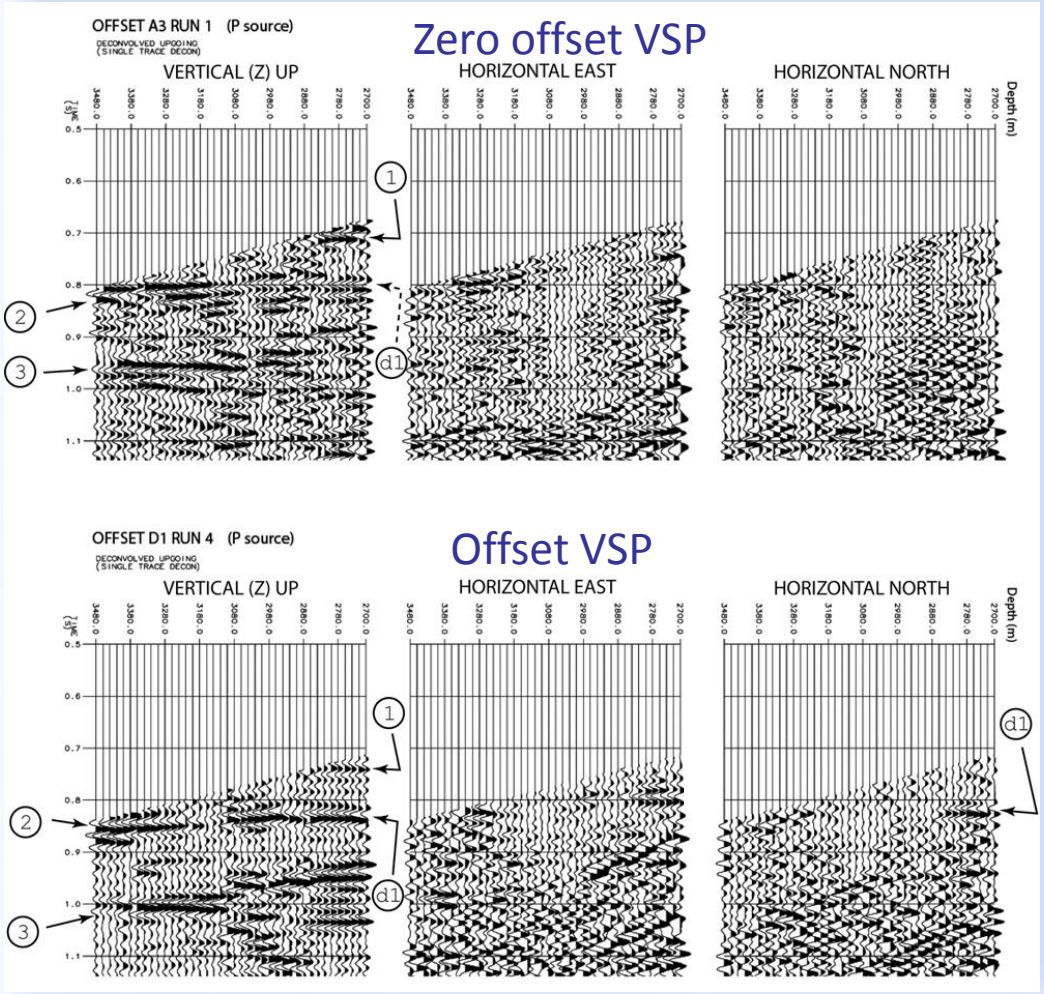
Isotropic 3C data processing

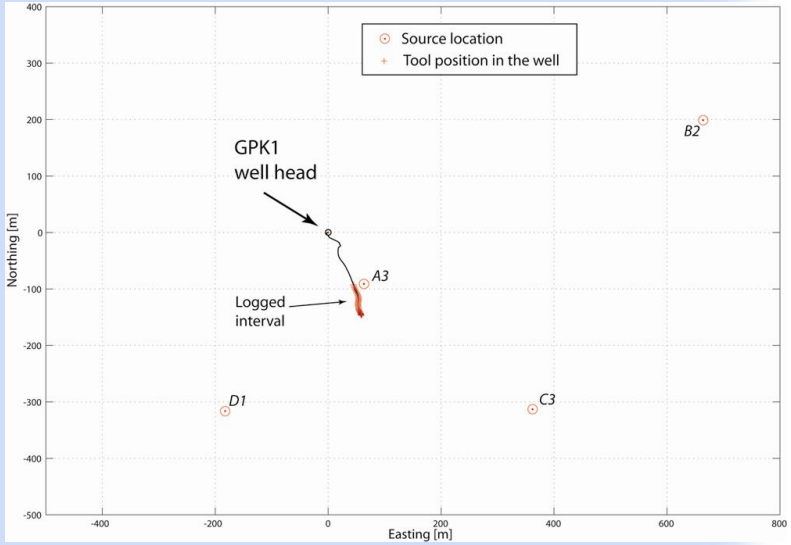
Applied by VSfusion

1. Isotropic upgoing/downgoing separation

2. Single operator deconvolution of the three components

Most interesting results





Arrivals 1 & 2 correspond to well known permeable faults

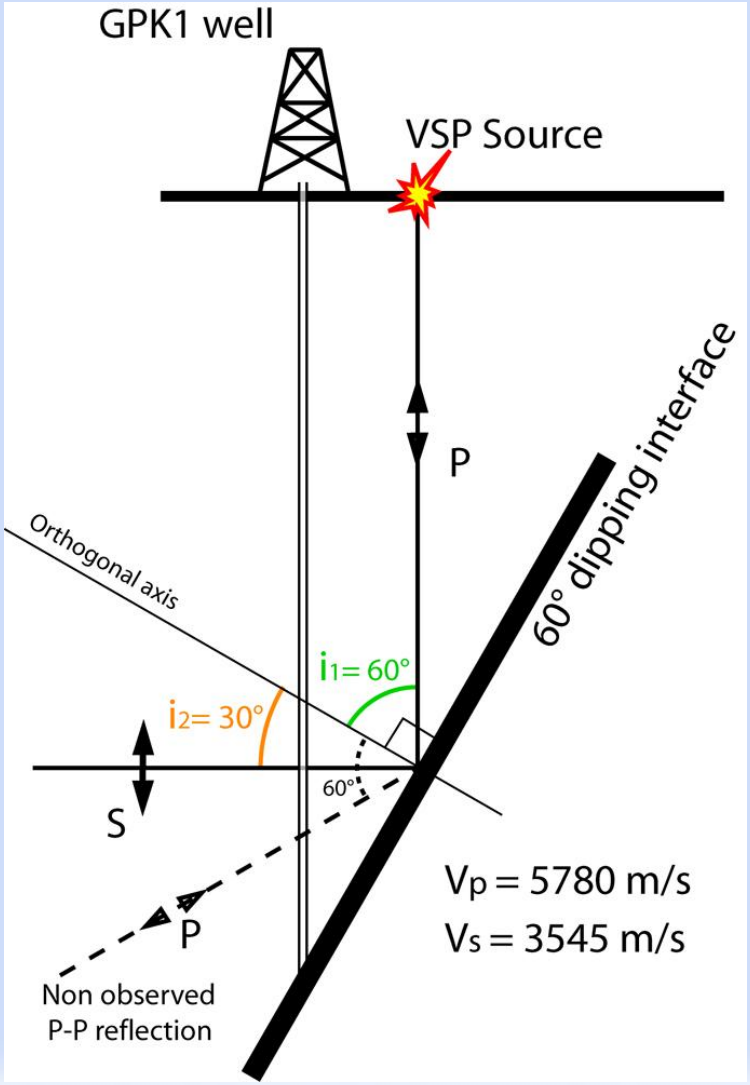
P-S reflection

Descartes' law

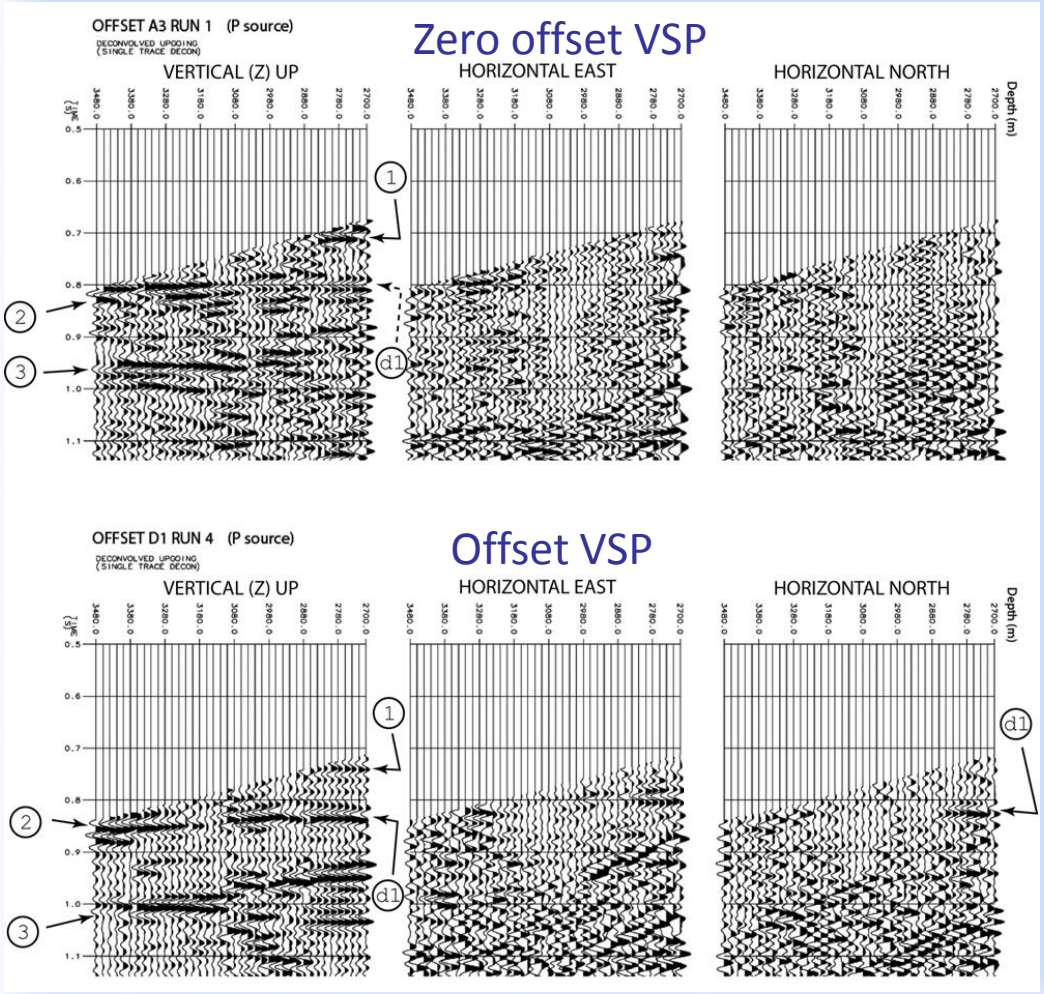
$$\frac{\sin i_1}{V_P} = \frac{\sin i_2}{V_S}$$

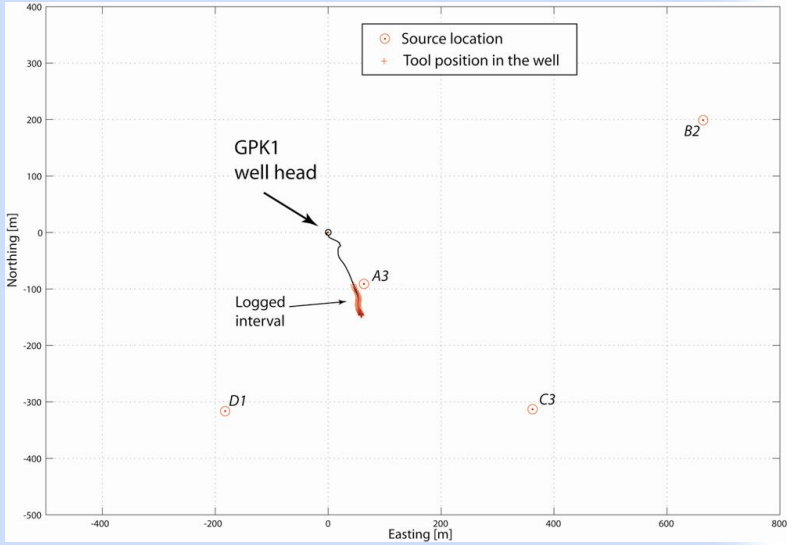
Thus:

$$i_2 = \sin^{-1}\left(\frac{V_2}{V_1} \times \sin i_1\right) = \sin^{-1}\left(\frac{3545}{5780} \times \sin 60°\right) \approx 32°$$



Most interesting results





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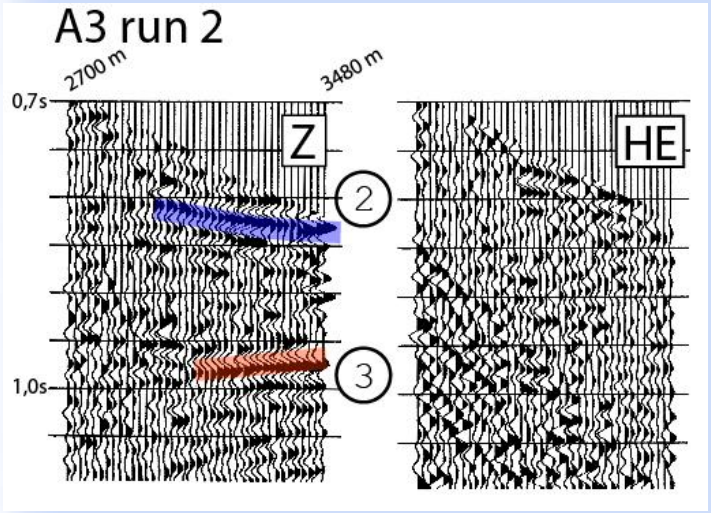
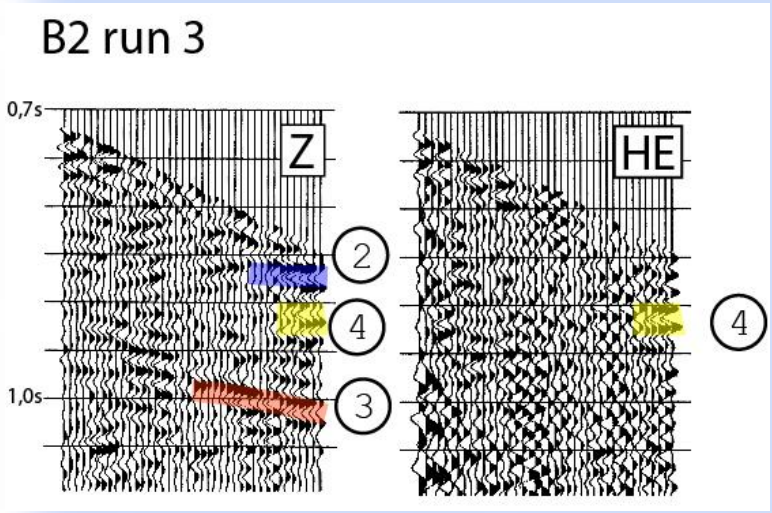
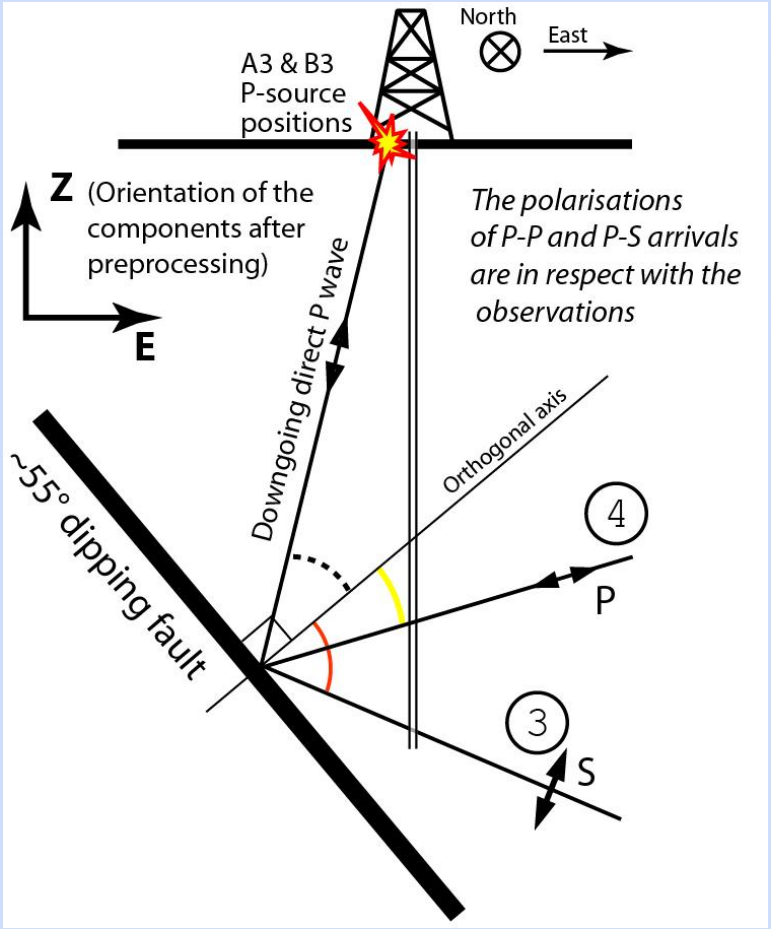
Event ③



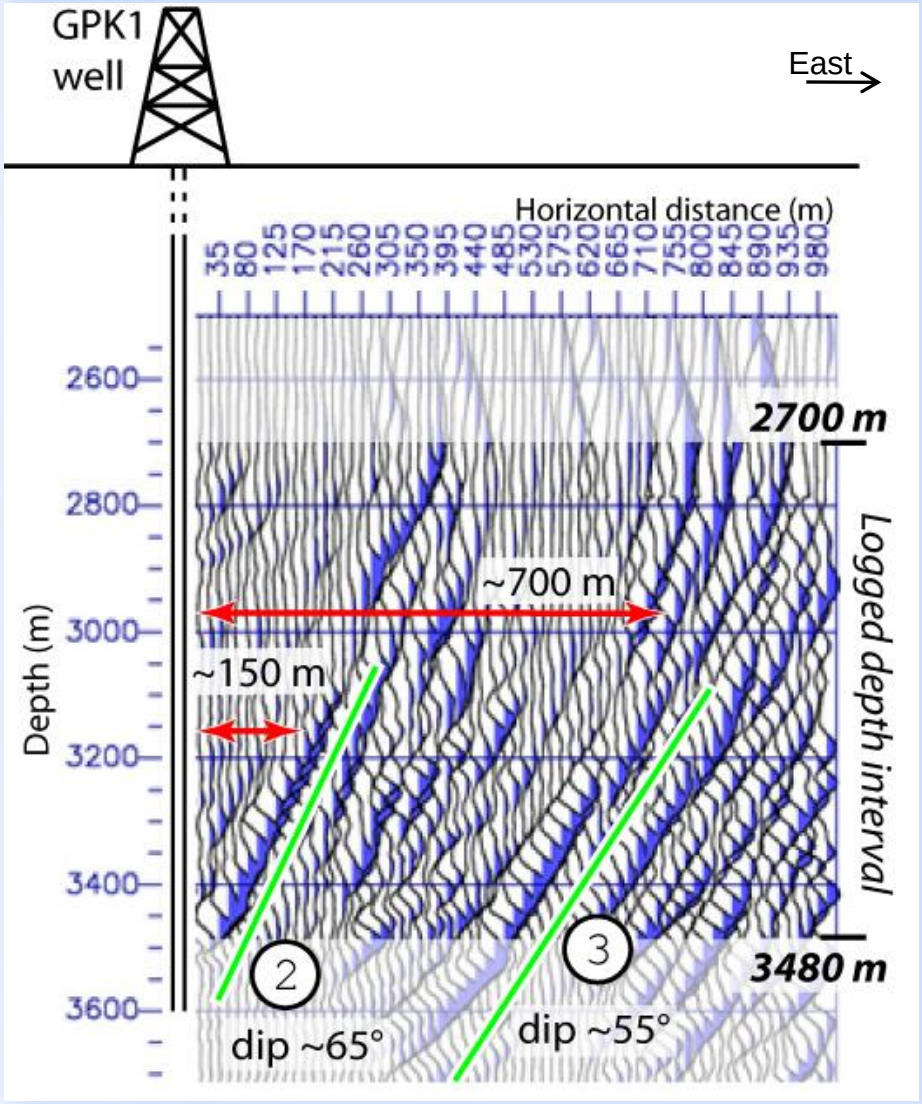




In total contradiction with Descartes' law !!

FINAL IMAGE

(from 2D depth migration on Z component)



Agreement with borehole imagery

1. **Dip value of the faults**
2. **Horizontal distance between the well and structures**
3. **Discover structures which are not drilled**

Deepening/deviation of the well

Conclusion

VSP is efficient for a structural investigation several hundreds of meters away from a well

Design of the deepening/deviation, OR a second geothermal well

A preliminary structural investigation can be performed only from preprocessed data !

BUT : processing time are still too long…

Conclusion

Proposed investigation flow chart :

1. **Identification of targets (faults) from 2D or 3D reflection seismics**
2. **VSP while drilling**
3. **Borehole deepening or deviation**

To reach the targets

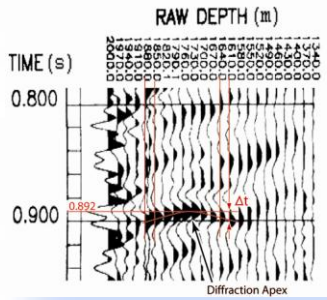
4. **Complementary VSP logging**

Reservoir characterisation and design of other wells

On the long view : **Seismic While Drilling**

Example of structural investigation from preprocessed data

Curvature



Distance D estimation by curvature
from Zero offset VSP (vertical component - Fig. 2)

	Diffraction	Diffraction	Diffraction	Diffraction
Diffraction by	**P-S mode**	**P-S mode**	**P-S mode**	**P-S mode**
Curvature :	upgoing branch	upgoing branch	downgoing branch	downgoing branch
Depth Apex (m)	**1745**	**1745**	**1745**	**1745**
Level (m)	1610	1640	1850	1880
Delta T (ms)	8	5	5	8
Delta Z (m)	135	105	105	135
V-diffr. (m/sec.)	**3470**	**3470**	**3470**	**3470**
Distance (m)	**314**	**309**	**309**	**314**

Travel time