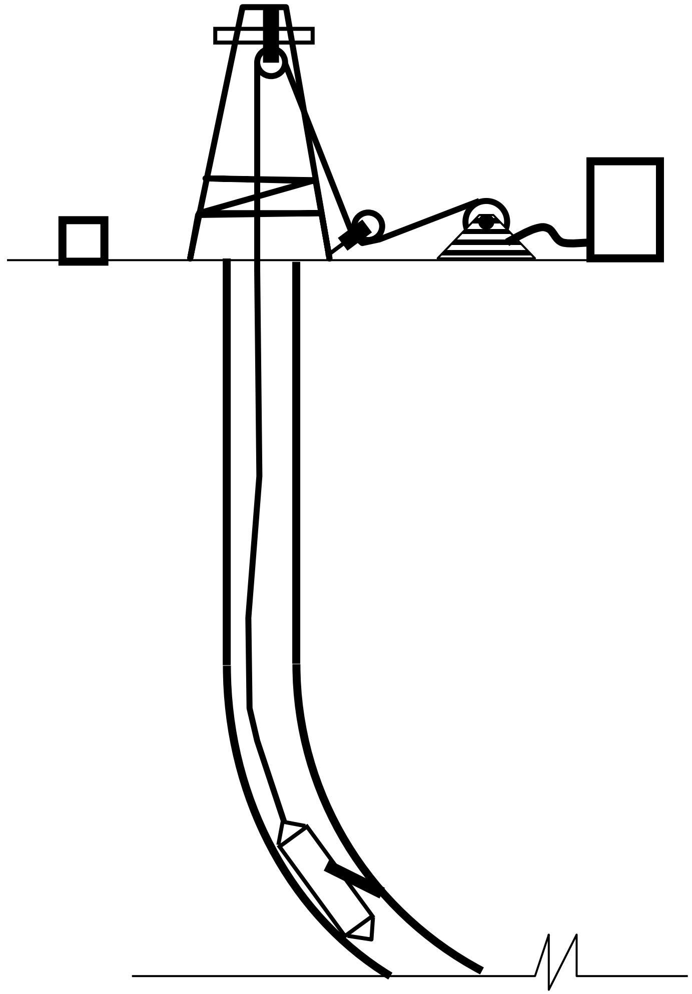
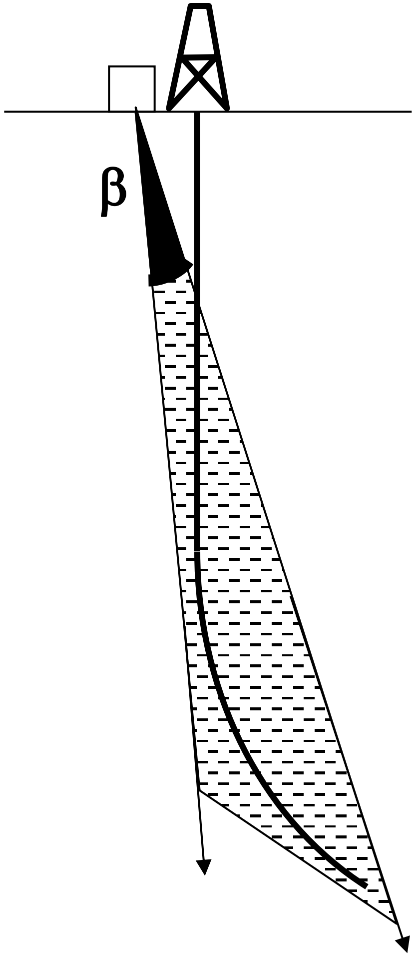
3C VSP data orientation method in vertical to low deviated borehole intervals, cased hole or open hole





3Component trihedron VSP data orientation in vertical to low deviated well intervals: **Fig.1**

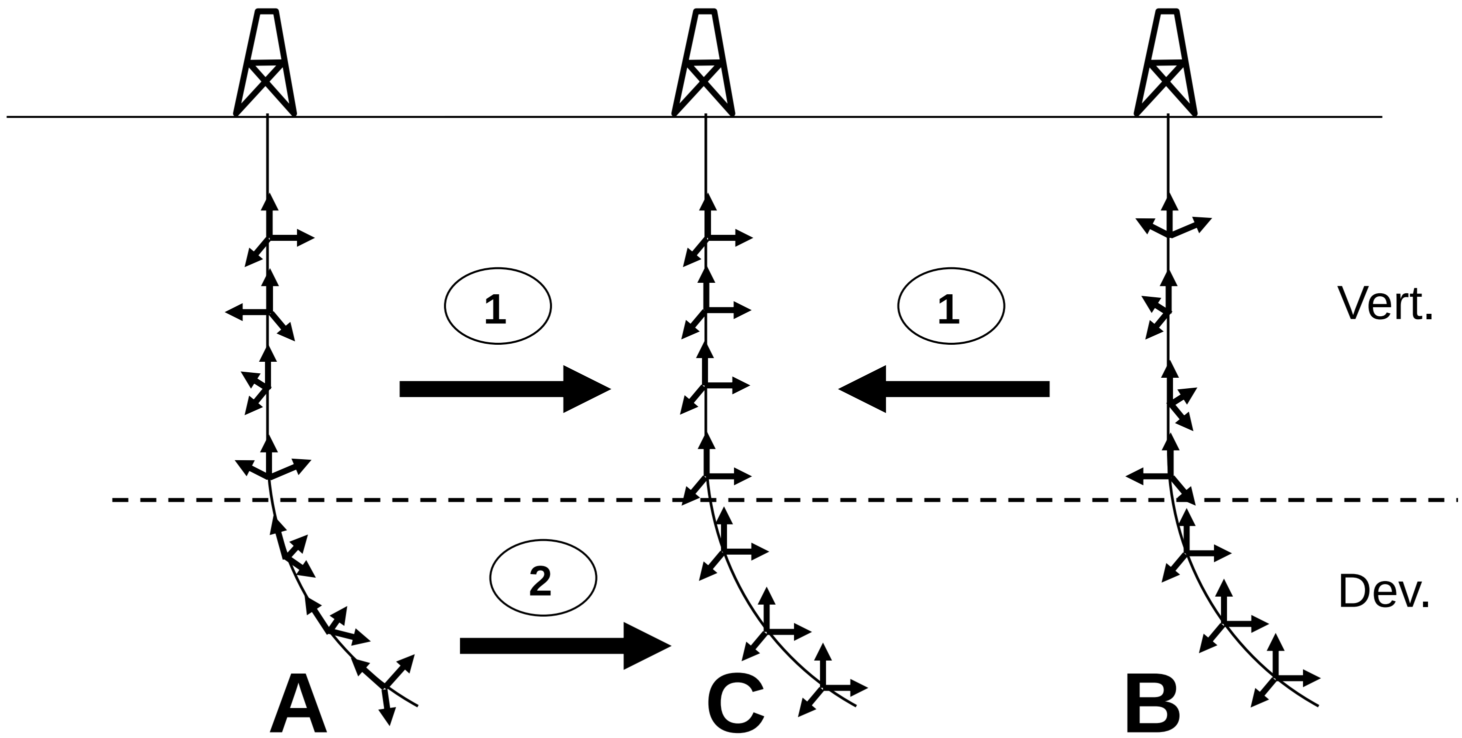
Configurations A or B represent the input 3C data orientation from field measurements.

Configuration C represents the output from the 3C data orientation preprocessing **method**

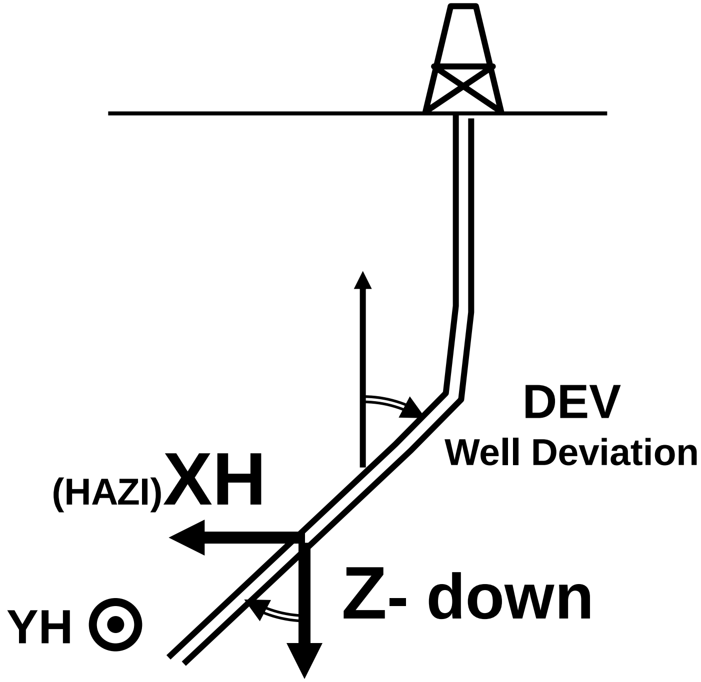
Configuration A: 3C data are recorded with a FIX 3 component sensor setting in VSP tool :
Z component in well axis, X, Y are orthogonal, in random direction versus depth

Configuration B: 3C data are recorded with a gimbal 3 component sensor setting in VSP tool :
Z component is vertical, X, Y are orthogonal, in random direction versus depth

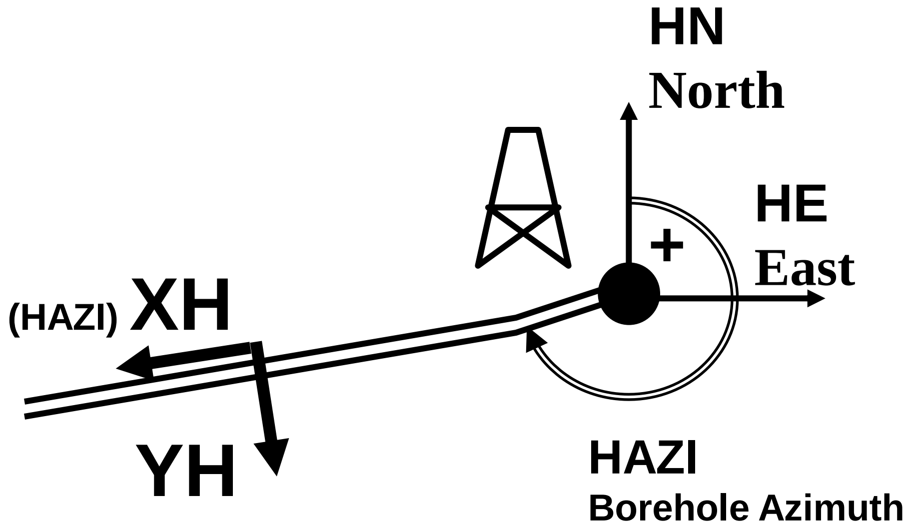
Configuration C: 3C data are oriented in a the SAME coordinate system for ALL depth stations:
Z component is vertical, X, Y are orthogonal, oriented in SAME azimuth, known or unknown, allowing 3C data processing: the X & Y azimuth is CALIBRATED into geographic direction using external information, from a tool orientation device, or geological knowledge of downdip azimuth from 3D surface seismic or other logs



Orientation of components recorded Fig.2a by the gimbal CSI tool in a deviated well

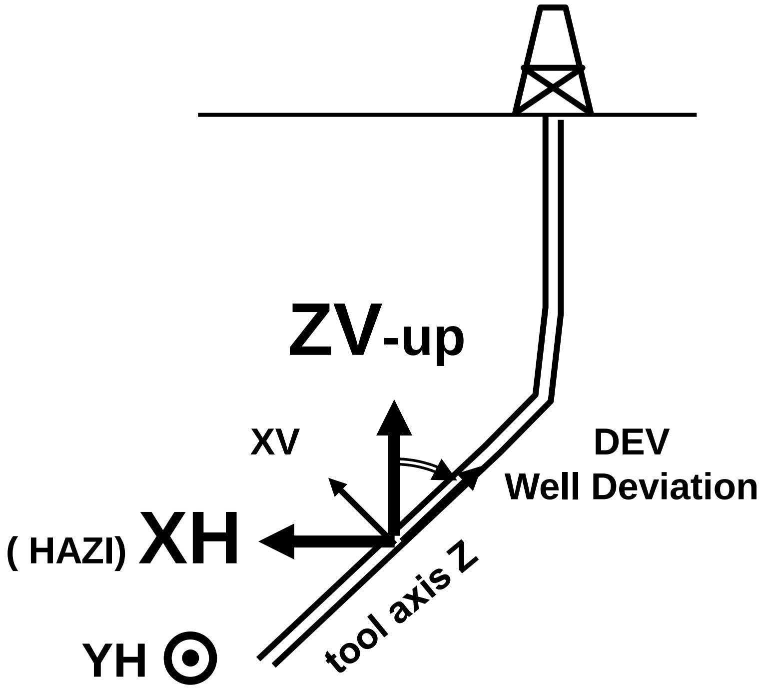


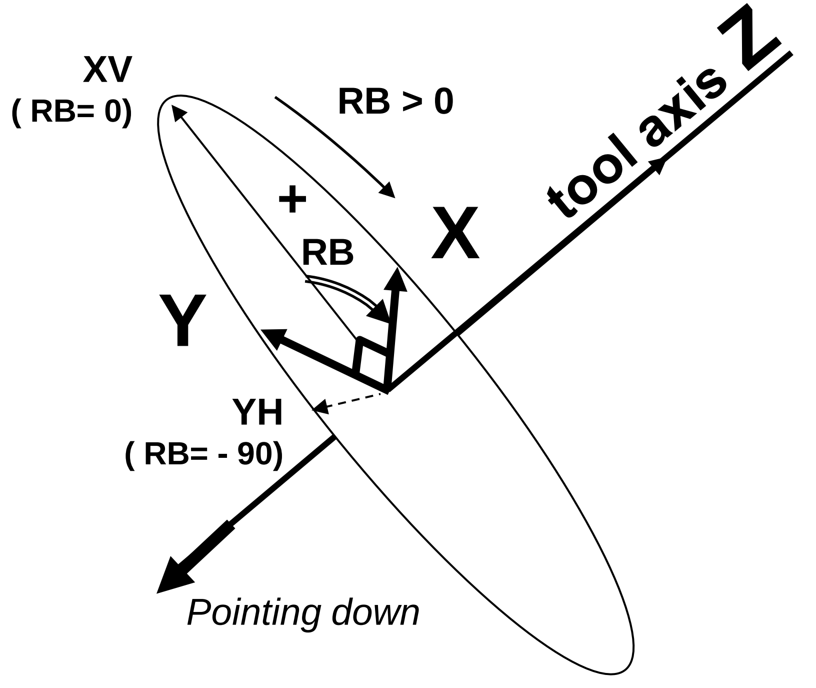
Vertical plane of deviation tangent to borehole



Horizontal plane, looking Down
[HN,HE] = Rot(-HAZI). [YH,XH]

Orientation of three fix components, Fig.2b of a VSI tool, with RB sensor, in a deviated well

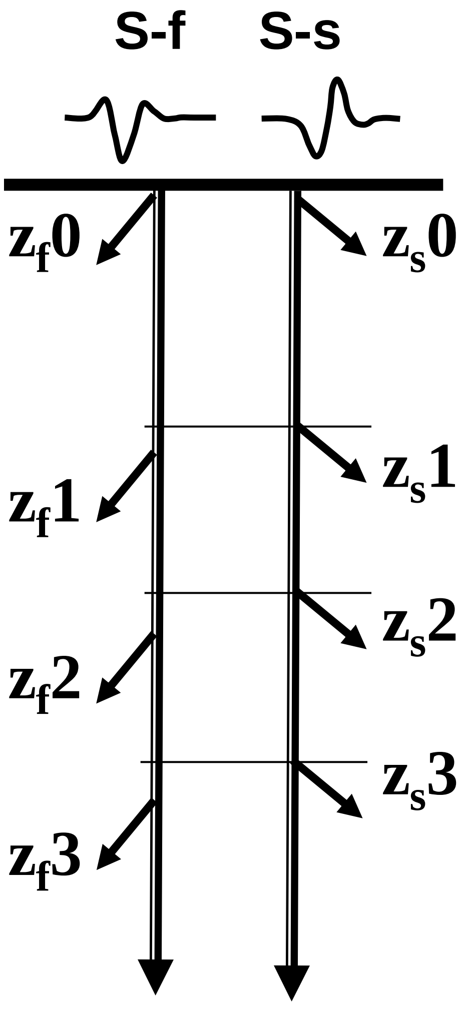


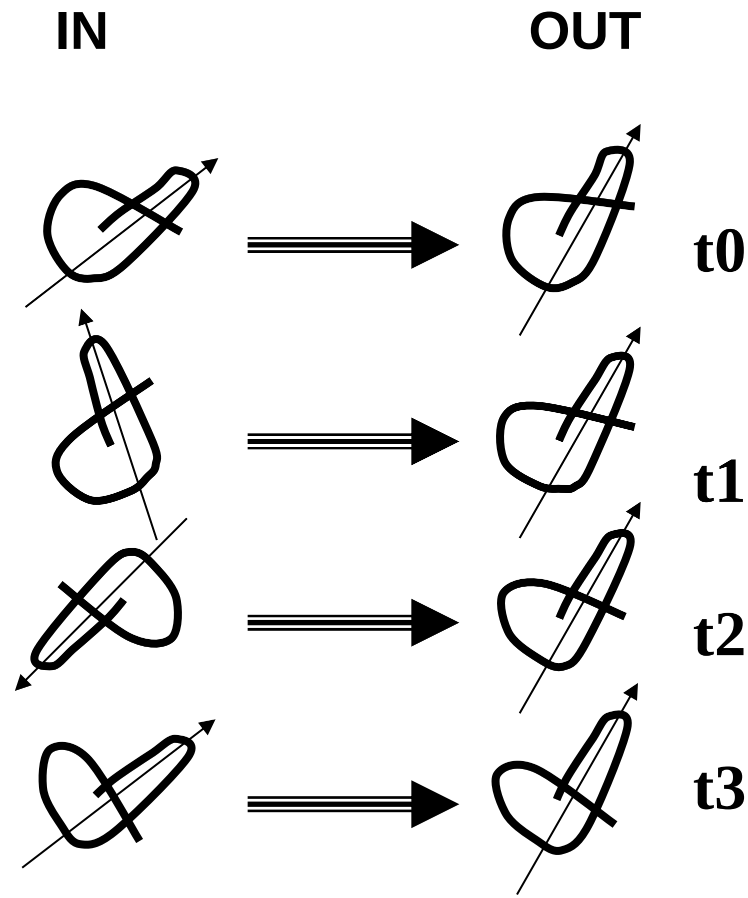


Vertical plane of deviation tangent to borehole:
[ZV-up,XH] = Rot(DEV). [Z,XV]

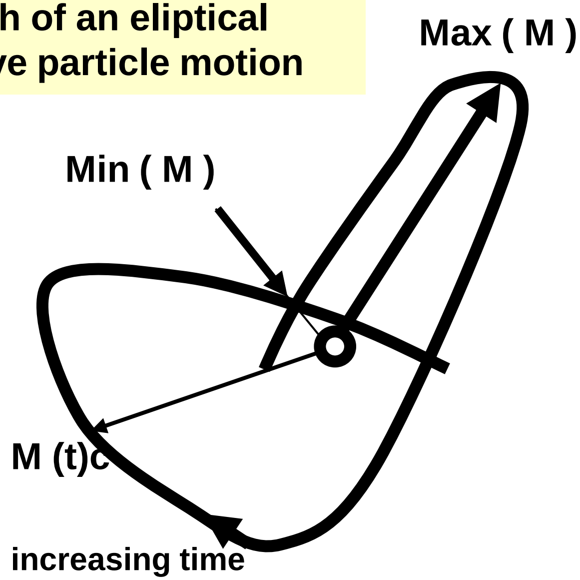
Relative Bearing angle illustration in plane orthogonal to well/tool axis
[XV,YH] = Rot(RB). [X,Y]

Principle: propagation of eigen modes of volumic seismic shear waves in semi-homogeneous medium

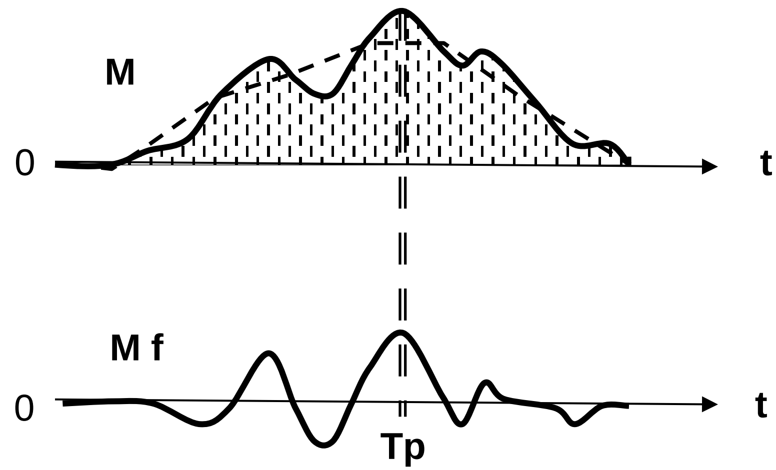


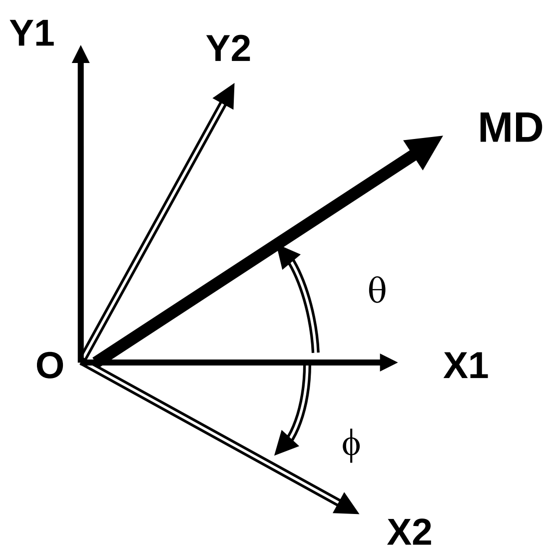


Sketch of an eliptical S-wave particle motion



Modulus trace , M = Raw (top),
Mf = LC filtered (bottom)





Modulus Vector MD coordinates in the X1,Y1 system:
MD = (X1, Y1) in cartesian coordinates
MD = [M , θ] in polar coordinates

Modulus Vector MD coordinates in the X2,Y2 system:
MD = (X2, Y2) in cartesian coordinates
MD = [M , (θ + ϕ)] in polar coordinates

By definition, the amplitude of Modulus vector remains invariant versus coordinate system orientation, for any time sample :
therefore, the modulus trace M(t) remains invariant versus coordinate system orientation, which allows to pick times accurately BEFORE orientation

FIRST Z-VSP orientation example,

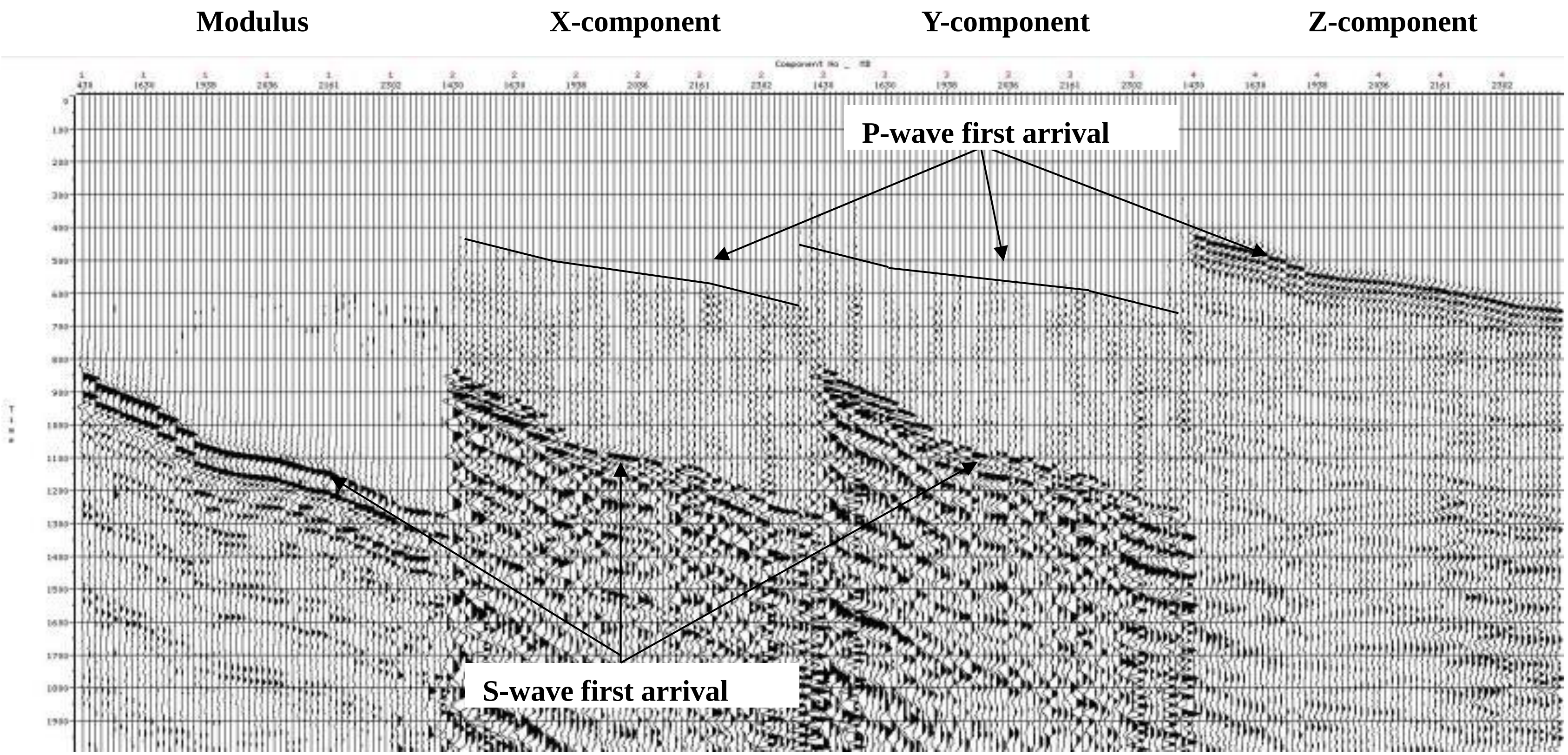
Ref. Kazem KAZEMI Ph-D thesis, Chapter 2, Chapter 6,

Seismic imaging of thrust fault structures in Zagros Iranian oil fields, from surface and well data.

https://tel.archives-ouvertes.fr/tel-00403617/ or
https://tel.archives-ouvertes.fr/file/index/docid/414628/filename/Thesis_kazemi.pdf

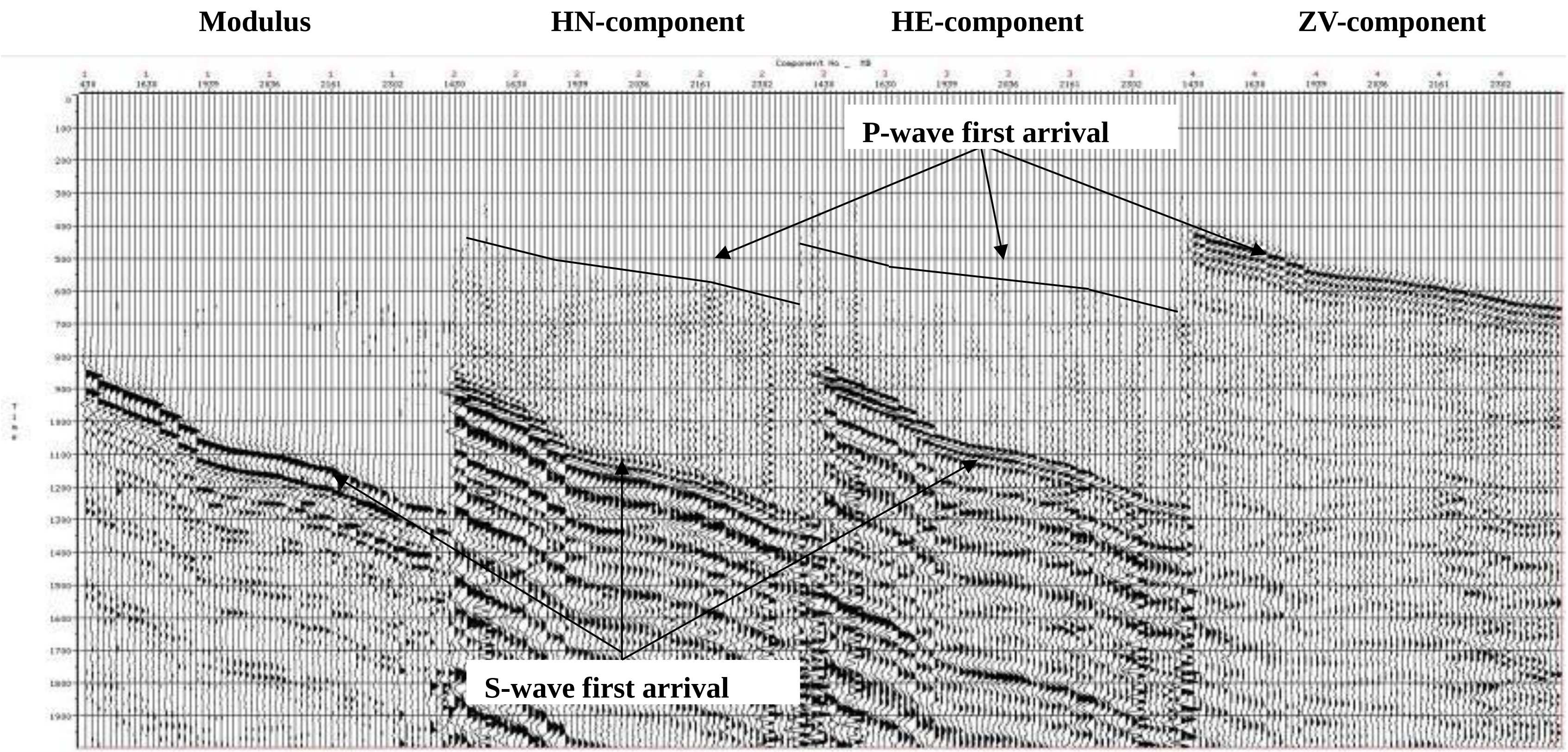
Courtesy of NIOC, IRAN

Modulus and three components before orientation



Courtesy of NIOC, IRAN

Modulus and three components after orientation

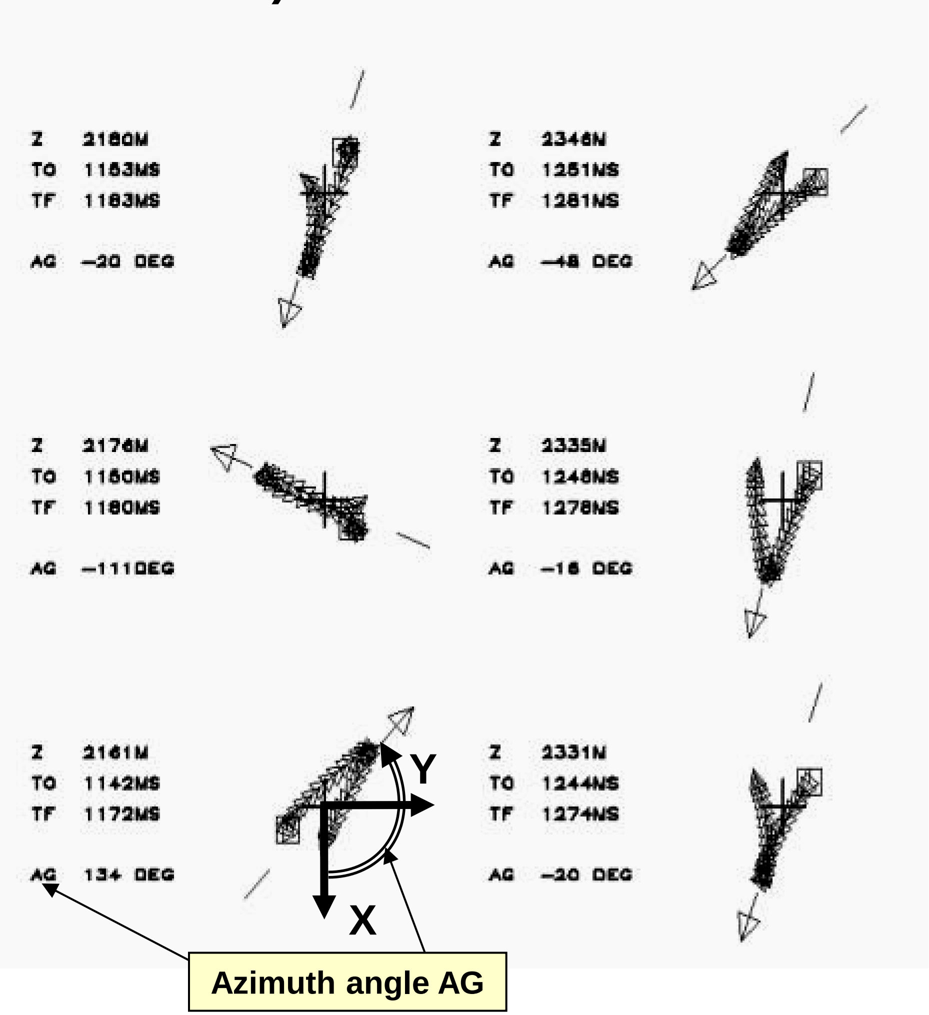


Courtesy of NIOC, IRAN

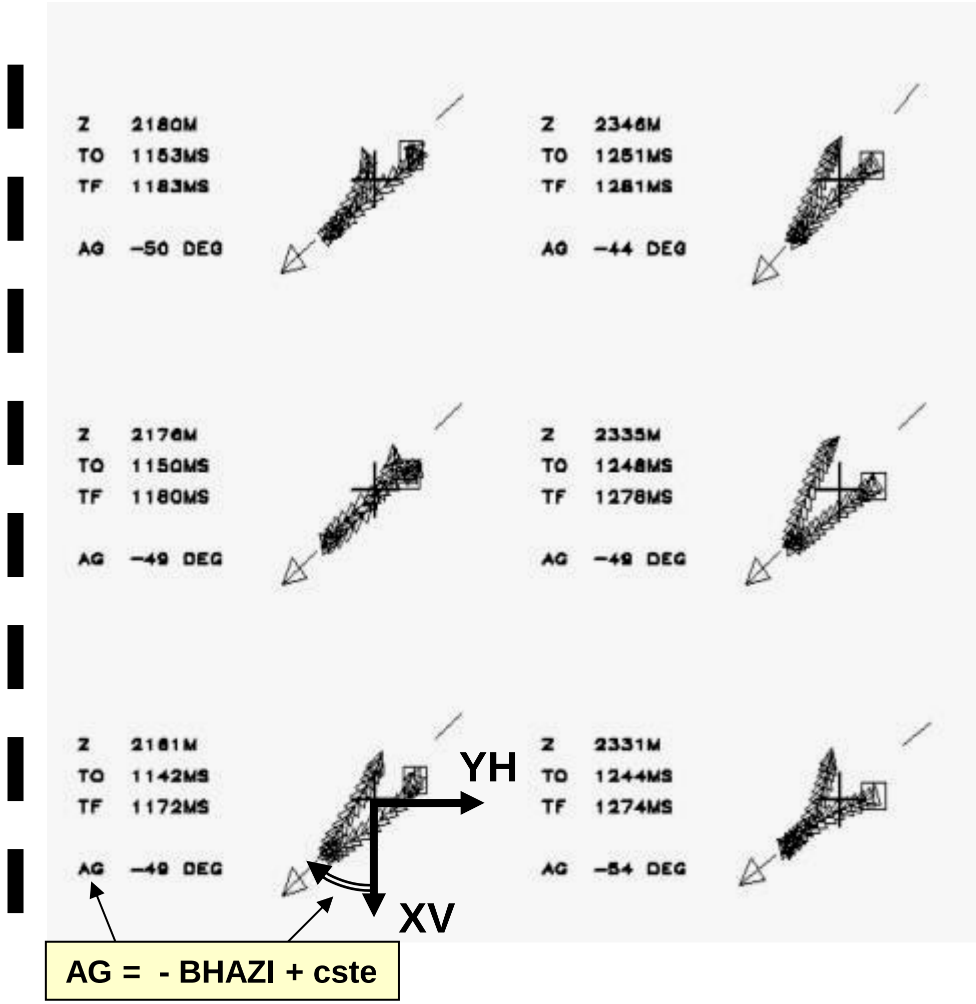
S-wave particle motion in short time window selected for maximization along S- first arrival picked on modulus trace.

By nature, the maximization direction occurs in a near- constant geographical azimuth

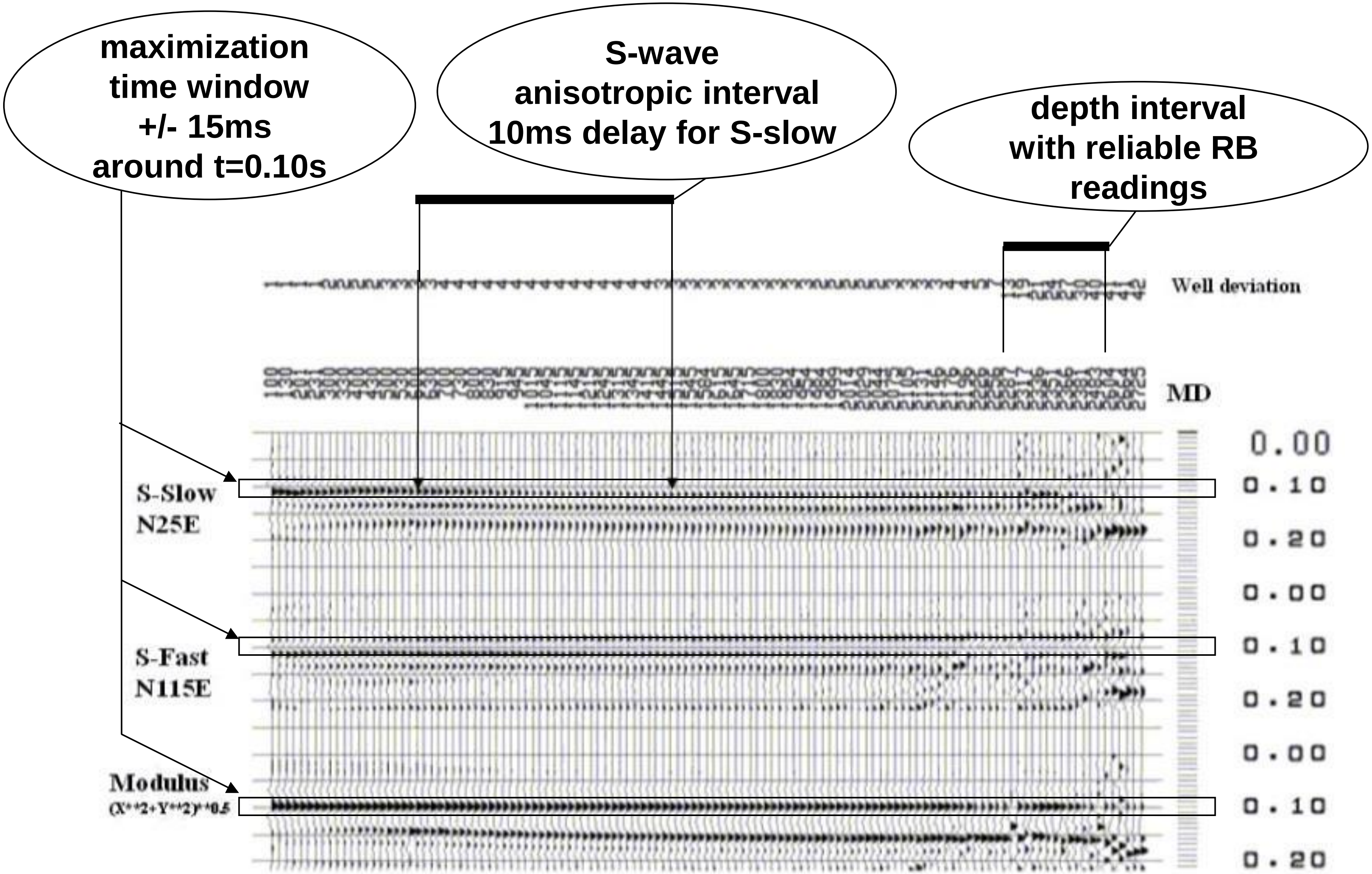
A) before orientation



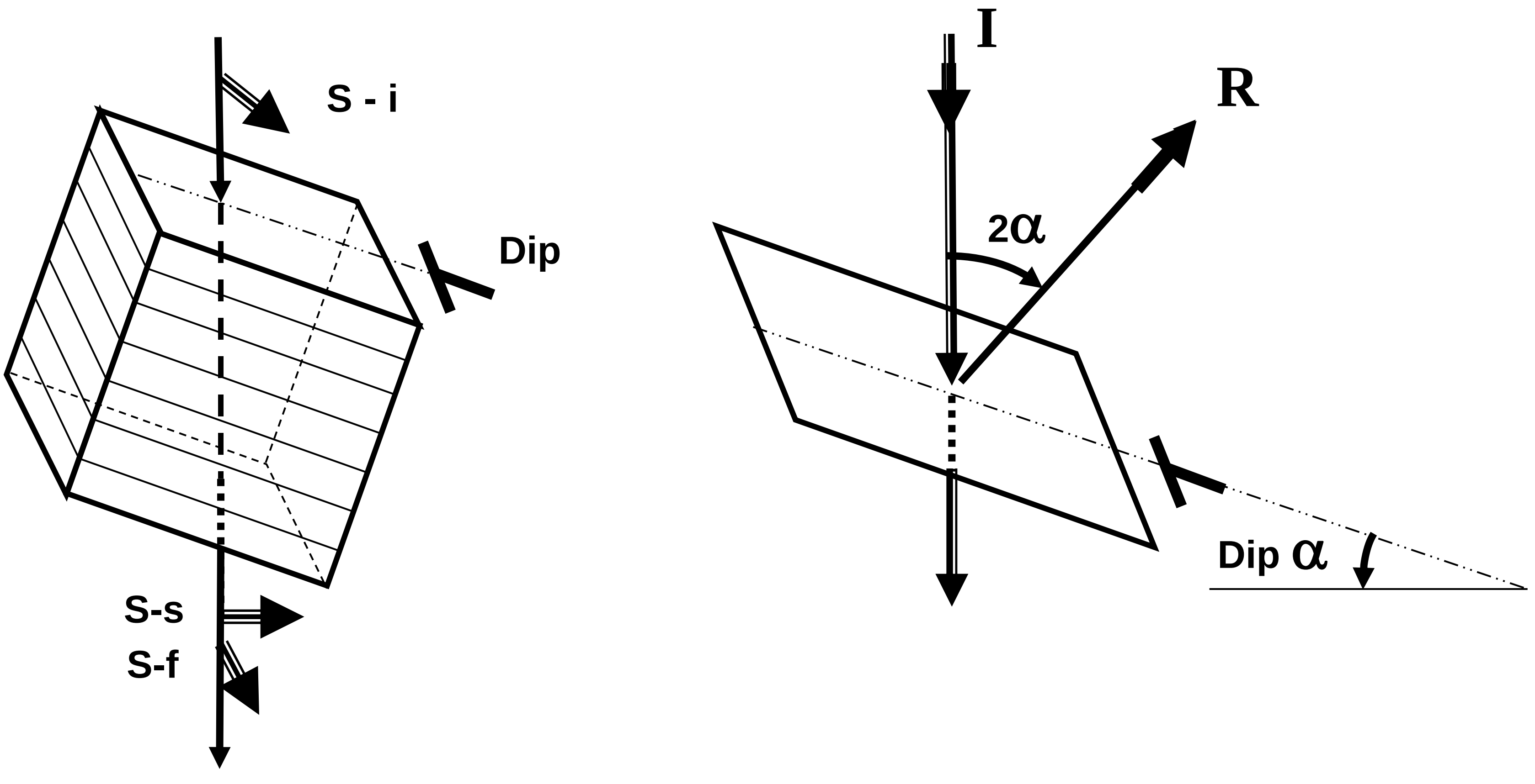
B) after orientation



S-fast, S-slow orthogonal components, from maximisation in a time window along the S-arrival time pick on filtered Modulus trace (bottom)



Courtesy of NIOC, IRAN


S - i
Dip
S-s
S-f
I
R
2α
Dip α

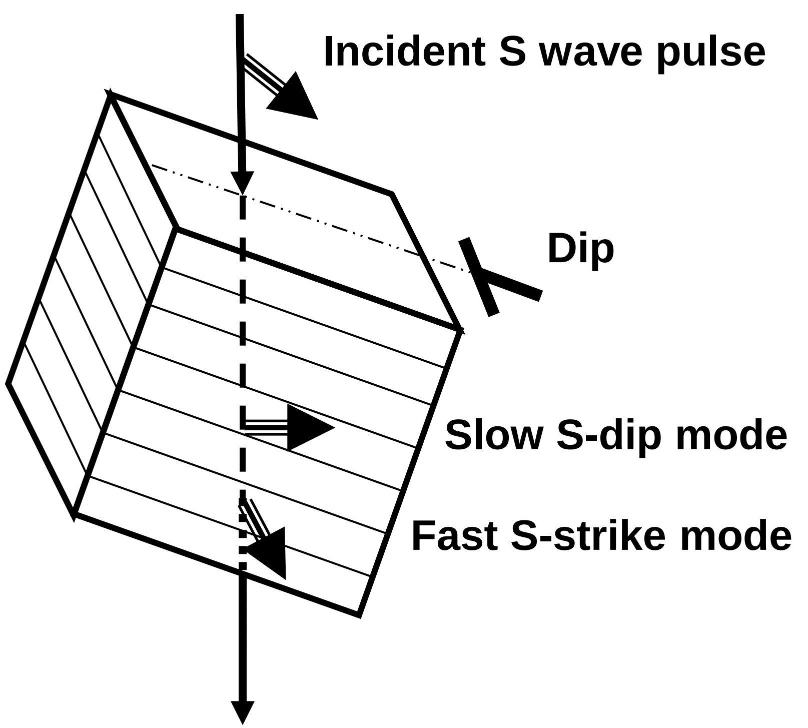
Vertical S-wave propagation in dipping layered medium

- Layering anisotropy induces the splitting of the incident S-wave into:

a) A fast horizontally polarized S-strike wave, in the strike direction parallel to layering.
b) A slow horizontally polarized S-dip wave, polarized in the azimuth of the dip

- Therefore the separation of the splitted direct S-wavetrain can help calibrate the azimuth trend of the general dip, when known from external structural information

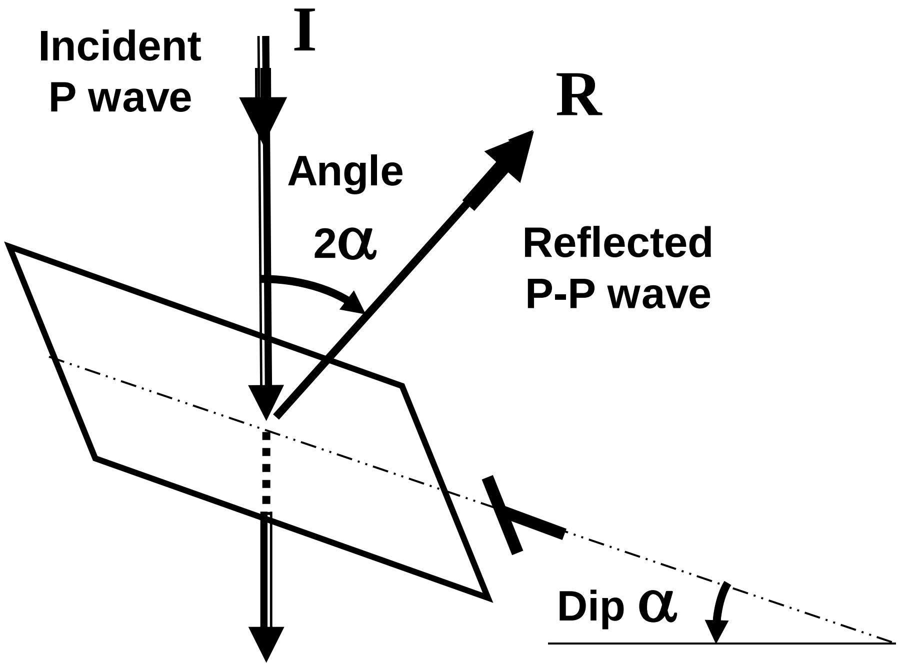
Vertical propagation for zero-offset **VSP**



Vertical P-wave propagation and dipping reflector

- The incident P-wave being is vertical and encounters a reflector dipping with angle (α),
- Then, the reflected P-P wave is polarized in the horizontal direction of the downdip azimuth of the reflector, +/- 360°,
- The vertical incidence angle of the reflected P-P wave equals twice the dip angle (2 α)
- Conversely, the dipping azimuth of a reflector determined from 3C VSP data previously oriented in a coherent coordinate system of unknown azimuth, can be used to calibrate the geographical orientation of the horizontal components of the initial VSP dataset

Vertical propagation for zero-offset **VSP**



SECOND ZO-VSP orientation example,

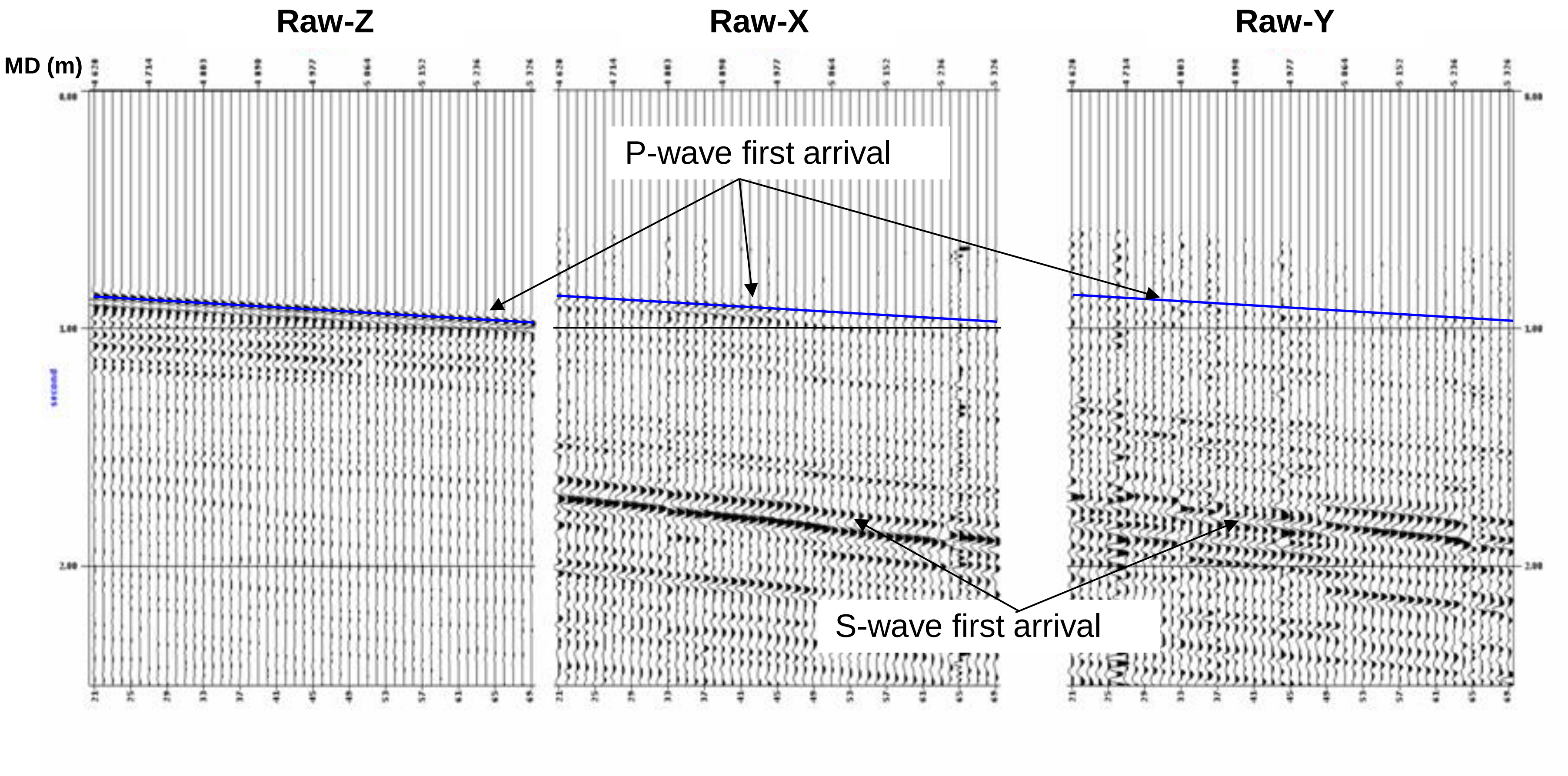
Ref. Kazem KAZEMI Ph-D thesis, Chapter 7

Seismic imaging of thrust fault structures in Zagros Iranian oil fields, from surface and well data.

https://tel.archives-ouvertes.fr/tel-00403617/ or
https://tel.archives-ouvertes.fr/file/index/docid/414628/filename/Thesis_kazemi.pdf

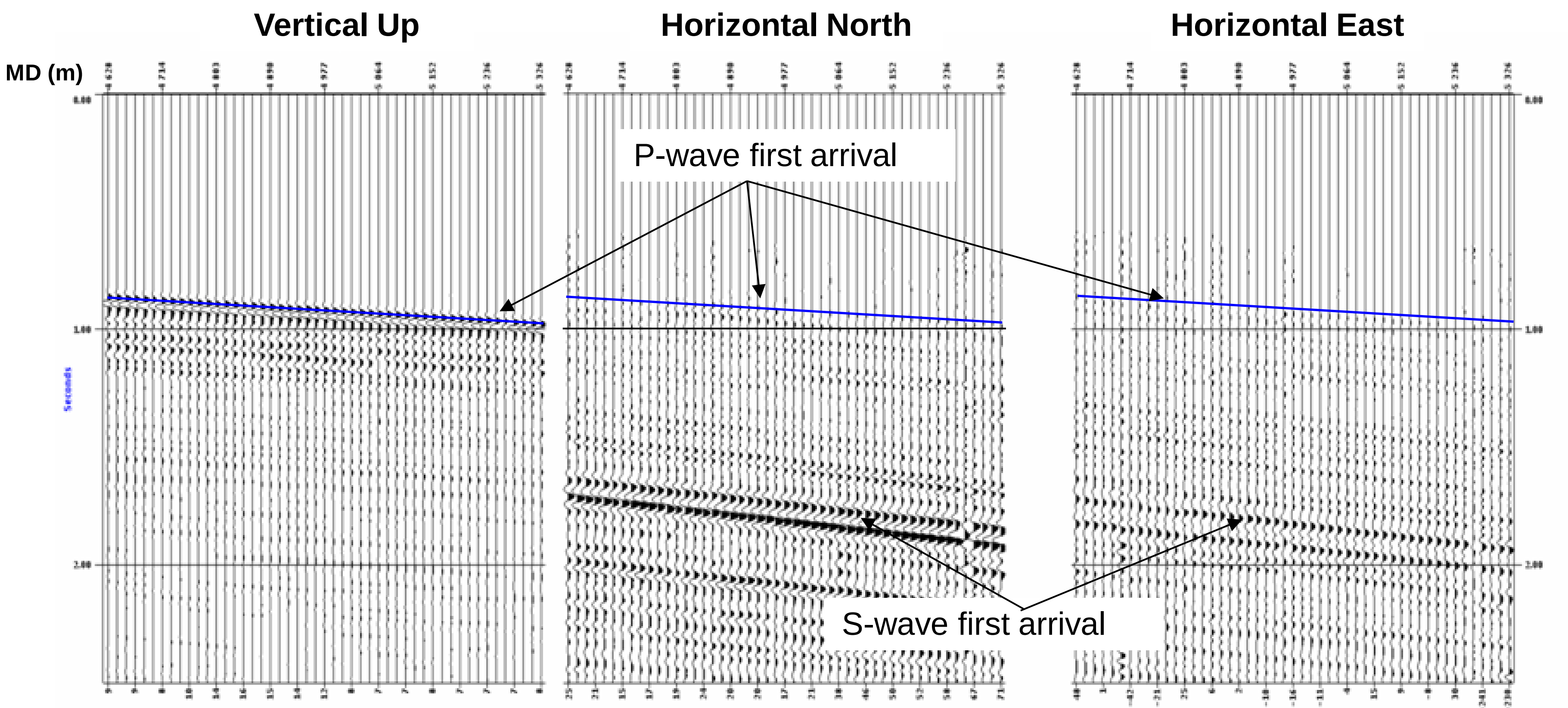
Courtesy of NIOC, IRAN

Raw 3C data Isotropic display 3 components



Courtesy of NIOC, IRAN

Oriented 3C data Isotropic display 3 components



P-wave direct arrival on Vertical component only,

S-wave direct arrival on horizontal components only

Courtesy of NIOC, IRAN