SEISDIP™: Dip and Azimuths from 3 Component Vertical Seismic Profiles (3C-VSP)

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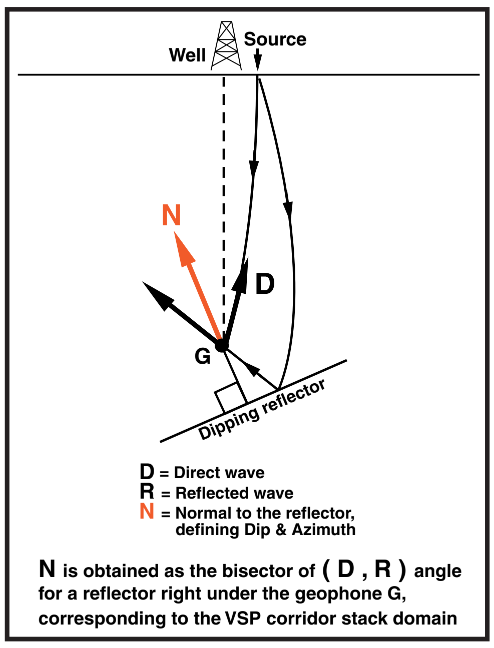
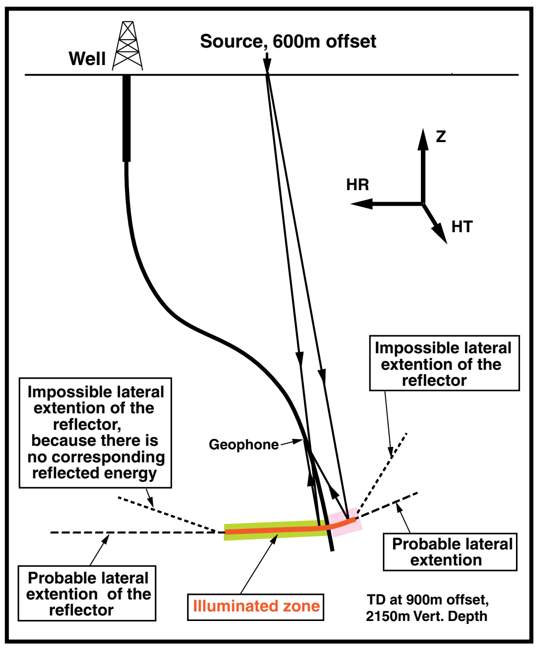
Principle of the method

- **3C oriented with a hardwave device and 3C isotropic recording processing**
- **P-wave polarization measurement and application of the Snell-Descartes law**

Application of Snell-Descartes law

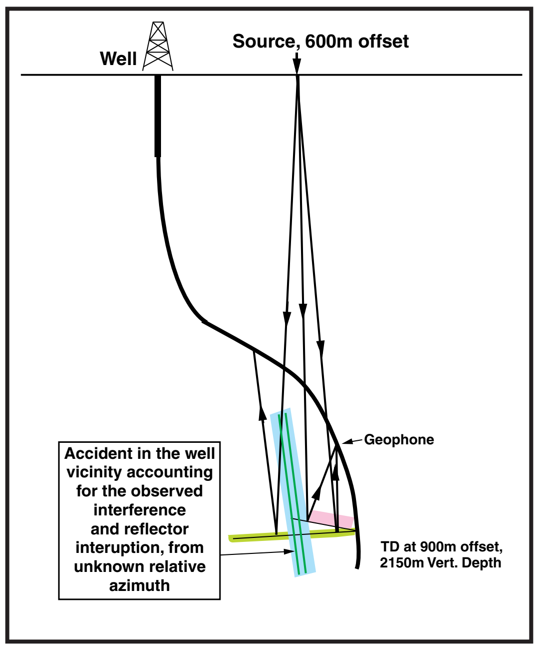


VSP imaging in deviated well



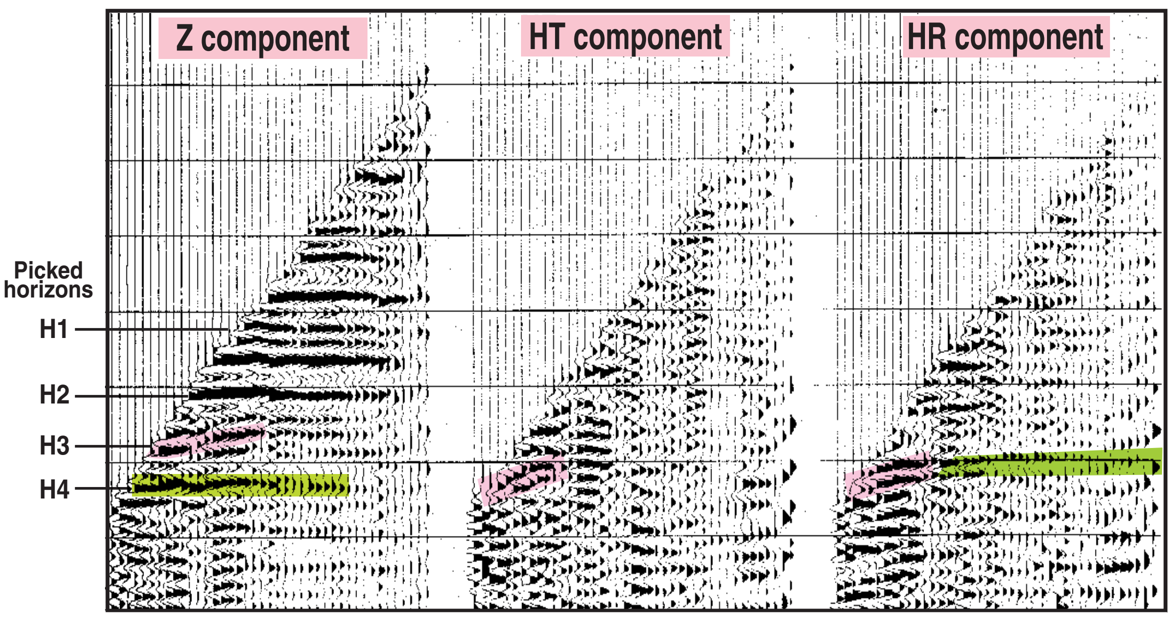
Sketch of geological flexure
Vertical plane of well deviation

Uncorrect VSP interpretation



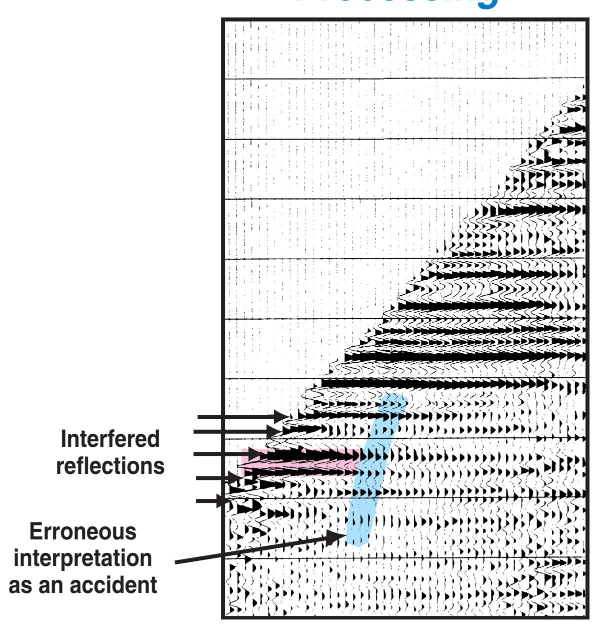
Conventional VSP-CDP stack built from monocomponent processing and monoclinal interface modelling of the well vicinity

P-wave 3C - ISOTROPIC reflected wavefield



When source is above VSP tool,
energy on HR or HT denotes strong dips

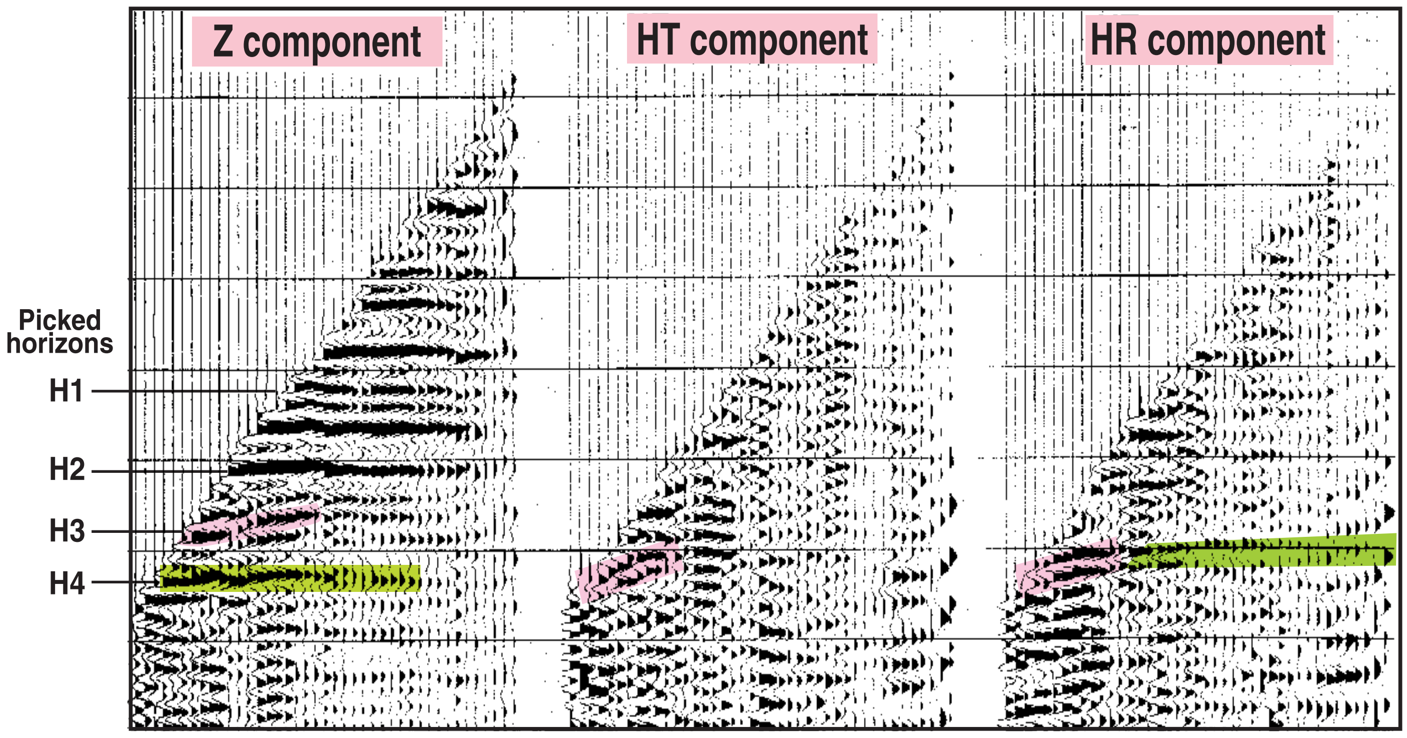
Monocomponent Standard Processing



SEISDIP™ : IFPEN trademark

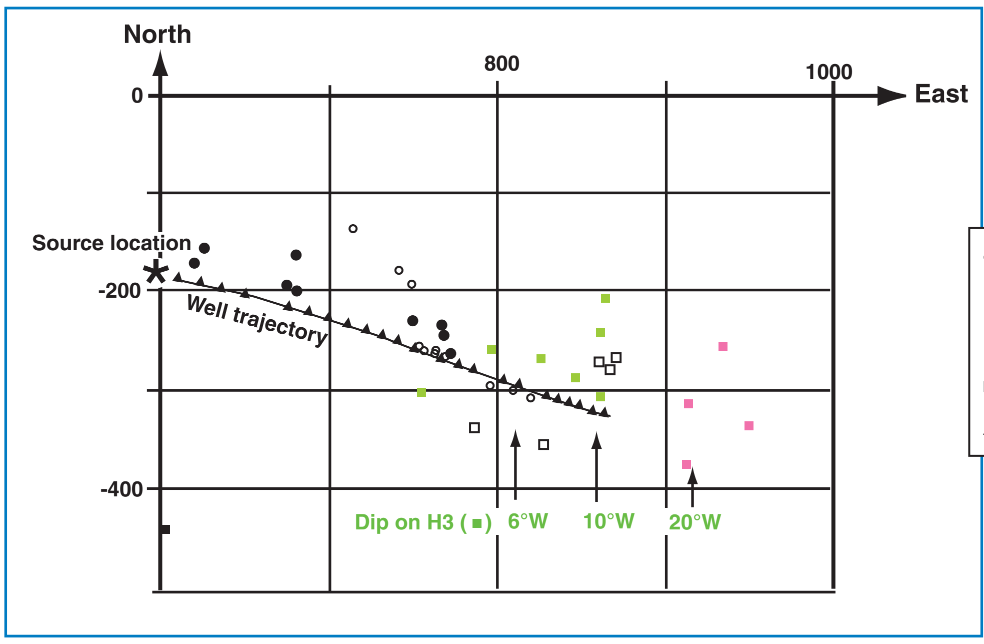
Application 1
Dip determination on 4 key reflectors by inversion of time and polarization

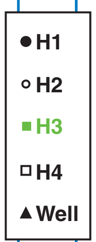
P-wave 3C-ISOTROPIC reflected wavefield



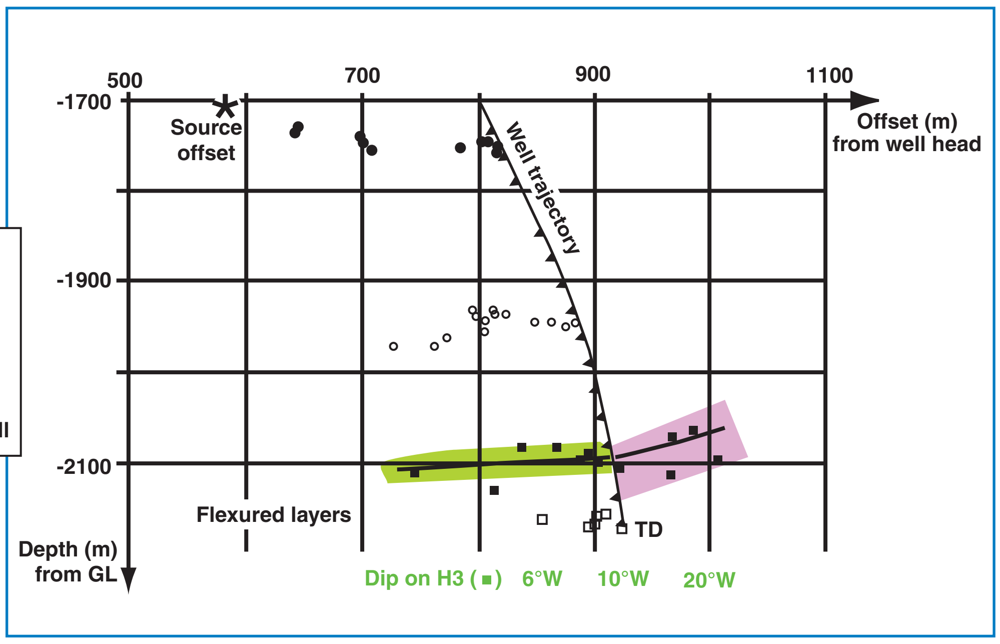
When source is above VSP tool, energy on HR or HT denotes strong dips

Mirror point location in horizontal plane

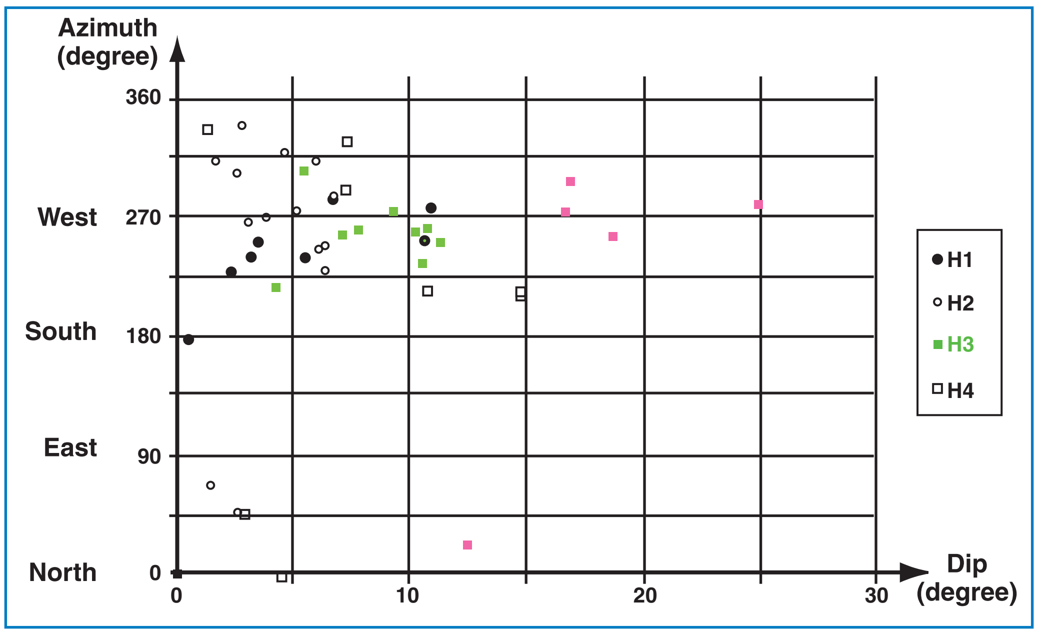




Mirror point location in vertical plane of deviation



DIP/Azimuth Crossplot

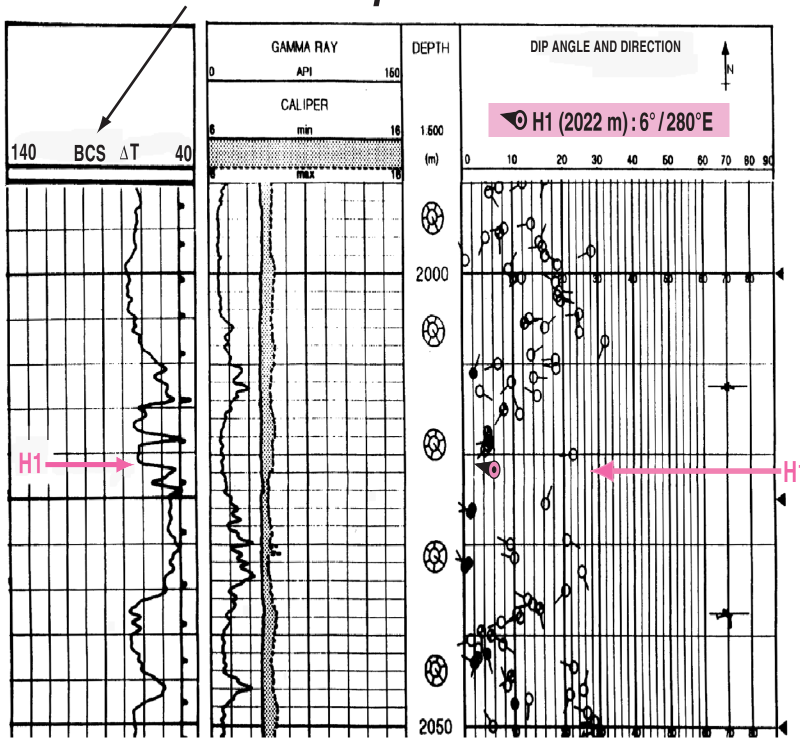


Application 2

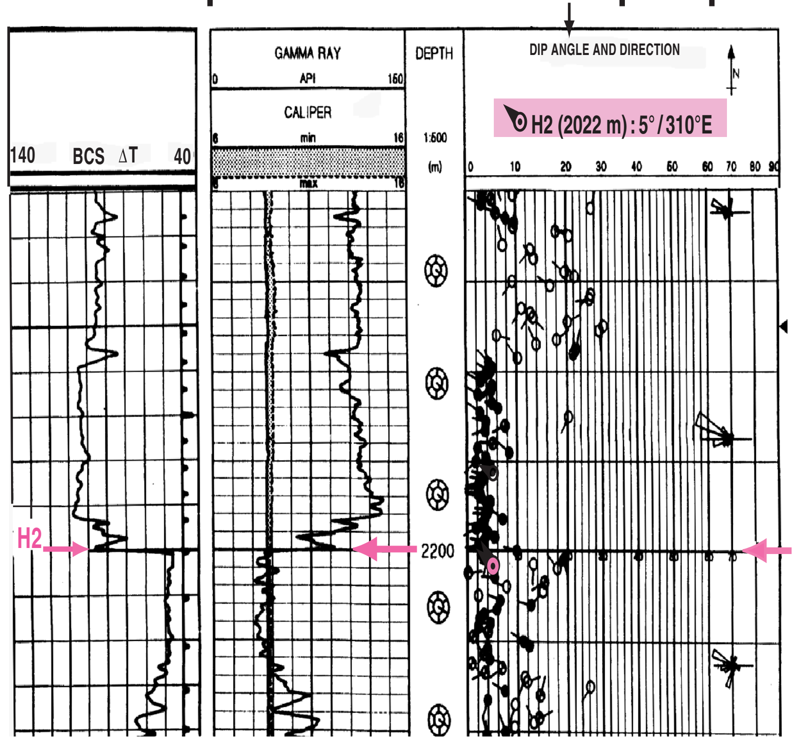
Dip determination along the borehole by polarization inversion in the VSP corridor stack domain

VSP dipmeter" results ( ) compared with conventional microresistivity Dipmeter log ( )

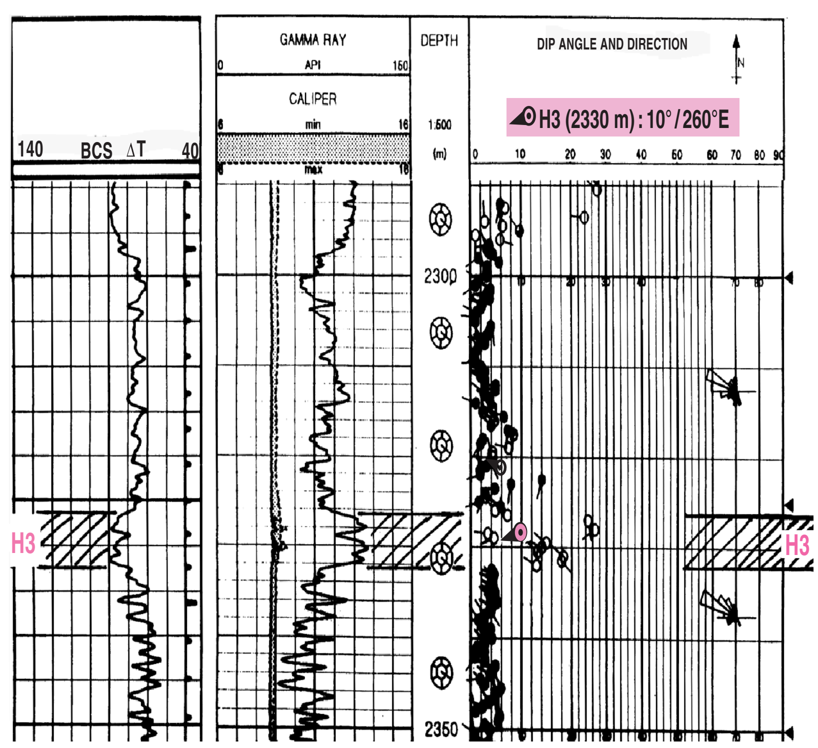
BCS : *Borehole Compensated Sonic*

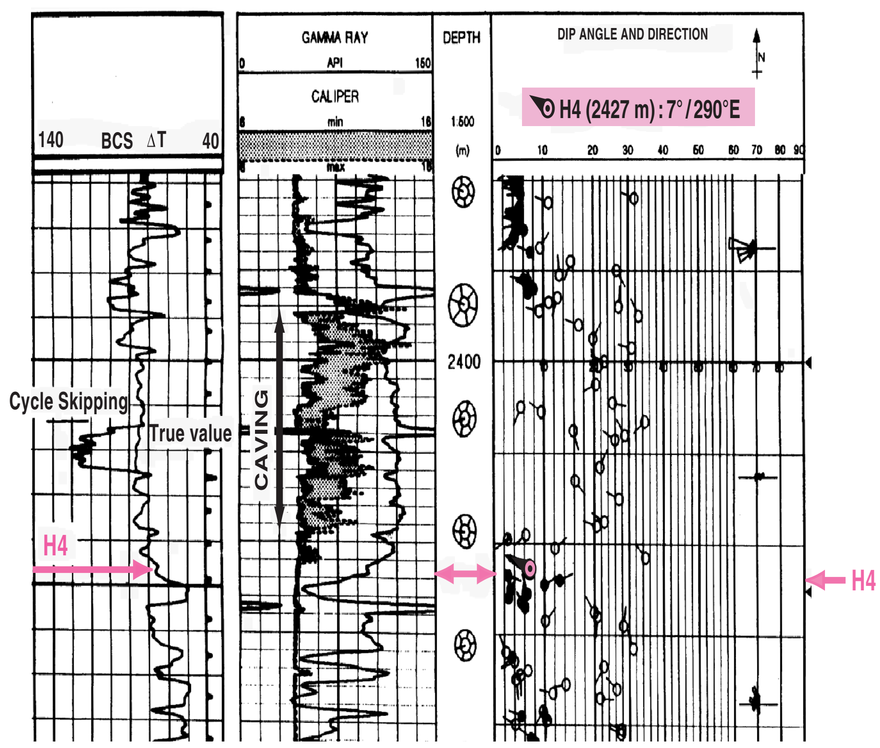


6 arm Dipmeter results on Tad pole plot



Courtesy of PETROREP, France





☐ ***The VSP "dipmeter"***

- **yields to the structural dip of seismic interfaces in the well vicinity**
- **is unsensitive to caves, OBM, casing**
- **can see below the well bottom**

☐ ***The microresistivity dipmeter***

- **restitutes the dip at high vertical resolution, locally on the borehole wall only**
- **works in open hole only, with good borehole conditions**

Suggestions
for the orientation of 3 Component VSP data

- Orientation using the direct P-wave arrival polarization at processing stage is cumbersome, time consuming, often unreliable, sometimes impossible in case of interfered direct arrival

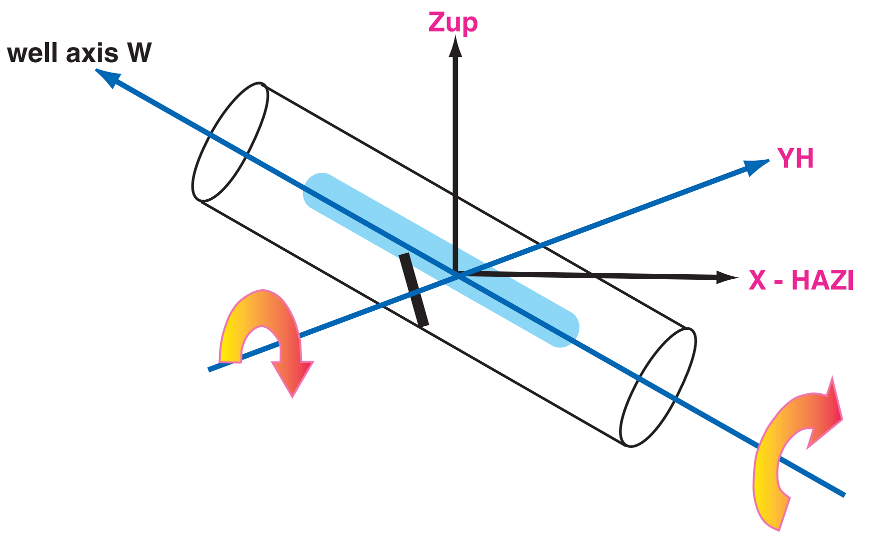
- Thus a hardware orientation device is systematically recommended in combination with the VSP tool at acquisition stage :

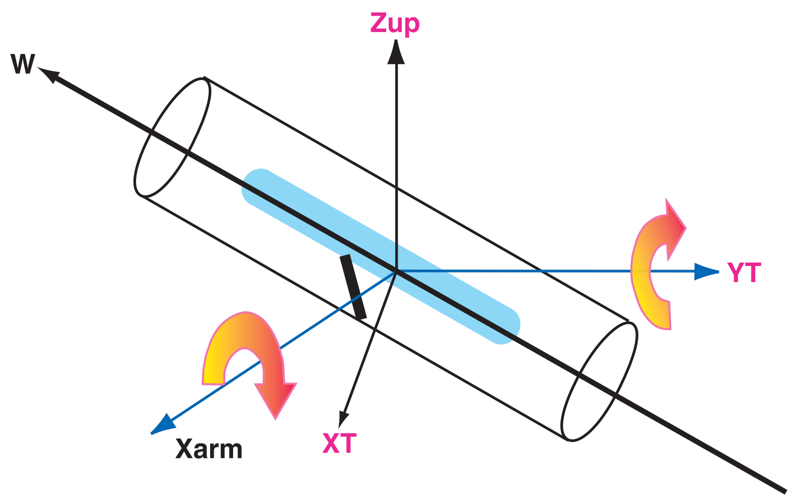
  - ***in deviated well* (vertical deviation angle DEV > 8°)** cased or open hole, double Gimbal mounted geophones with **Trunnion** setting, complemented with knowledge of the well trajectory, allow for unequivocal orientation of the 3 Components
    The **Binnacle** double gimbal setting does not allow for complete knowledge of the 3C orientation as the Relative Bearing (RB) angle of the VSP tool is needed, **thus the Binnacle setting is not recommended**

Description of the gimbal mounted geophone settings :

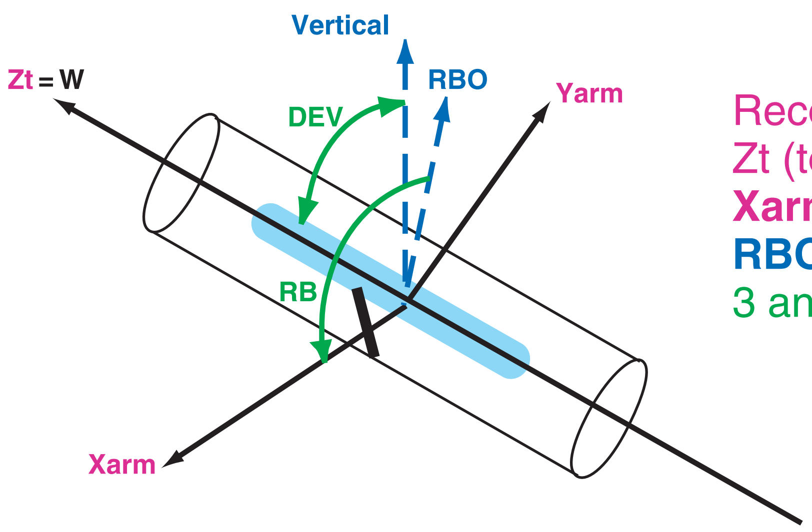
In the **TRUNNION setting,** one gimbal is free to rotate around the VSP tool axis (W), the other gimbal is free to rotate around the horizontal axis (YH) orthogonal to the well deviation vertical plane. X-HAZI is oriented toward Hole AZimuth direction (± 360°).
Recorded orthogonal components :
Zup (vertical), X-HAZI, YH (horizontal)

In the **BINNACLE setting,** one gimbal is free to rotate around the (Xarm) axis orthogonal to the tool axis (W) in the plane of arm opening, but with an unknown orientation; the other gimbal is free to rotate around the horizontal axis (YT).
Recorded orthogonal components :
Zup (vertical), XT, YT (horizontal)





- ***in near vertical well (DEV < 8°)***, an orientation accessory such as a gyroscope or a inclinometer / magnetometer has to be combined with the VSP tool, without deteriorating the mechanical VSP tool coupling to the formation or generating unwanted power induced seismic noise on the tool geophones. Commercial inclinometer / magnetometers are widely used in wireline logging, and are efficient down to very small well deviations (DEV < 1°- 2°) in cased hole



Recorded orthogonal components are fixed in the tool :
Zt (tool axis), Xarm, Yarm. Receivers are omnitilt.
Xarm orthogonal to well axis W in the plane of arm opening.
RBO is in the vertical plane and orthogonal to tool axis W.
3 angles are needed to orientate the 3C data :
- **RB** Relative Bearing (± 360°)
- **DEV** well DEViation (0° - 90°)
- **HAZI** Hole AZImuth (± 360°)

Conclusion

- The SEISDIP technique represents an **independent** and **reliable method** to obtain the structural dip/azimuth in the well vicinity, potentially up to a distance of a few hundred meters away from the well and below Total Depth, based on **oriented 3C VSP** data and **isotropic processing**

- The "VSP dipmeter" SEISDIP method **complements** the dip results obtained by other methods, such as surface seismic and wireline microresistivity dipmeter log

- The "VSP dipmeter" SEISDIP method **offers** an **alternative solution** to attain the dip when the other methods fail

Recommendations for the **application** of the **SEISDIP** method

Where ?

High cost wells in areas where the results from conventional methods are unsatisfactory due to :

- surface seismic image blurred at target level, not necessarily at large depth
- difficult borehole conditions affecting the acquisition of wireline logs or the quality of their measurement : logging tool sticking to the borehole wall, irregular logging speed, caving, OBM, etc ...

How ?

By combining a hardware orientation device to the VSP tool for acquisition of single run / single rig source VSP's in vertical/deviated well, especially if the well is vertical over and above the target depth interval

If gimbal mounted geophones are to be used in deviated wells (DEV > 8°), gimbal geophones need to be mounted on a Trunnion setting in the VSP tool

Warning

If a inclinometer / magnetometer tool or a Gyroscope has to be combined with a VSP tool, it is highly recommended to **contact your VSP contractor 15 days prior to VSP acquisition** in order to insure that the tool combination is correctly implemented