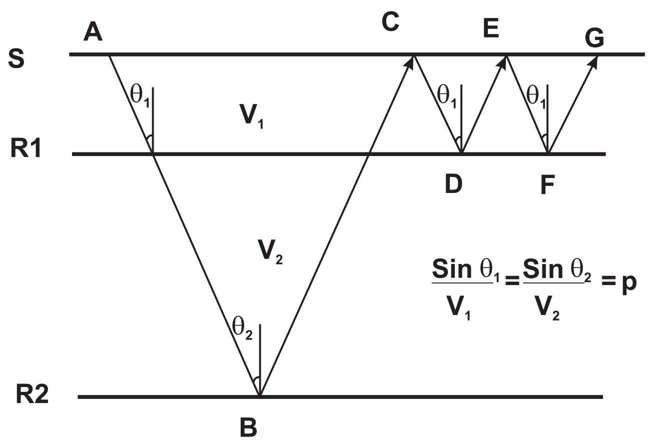
Points-to-ponder-I *(Continued from page –17)*

1. Suppression of multiples by predictive deconvolution of a trace is best achieved when the multiples in that trace are periodic in time. That this is so in a tau - p domain for any p-trace can be easily seen from the diagram below.



The primary ABC & its multiples, CDE and EFG have the same 'p' value, but different offsets.

By Snell's law, the ray ABCDEFG has a common ray parameter, $p = \sin(\theta_1) / V_1 = \sin(\theta_2) / V_2$. Consequently, the primary arrival corresponding to ray ABC as well as the associated peg-leg multiple arrivals corresponding to ray paths ABCDE and ABCDEFG belong to the same p-trace. Furthermore, the ray paths such as CDE, EFG, and for higher order multiples are equal i.e. e, the multiples have periodicity in p-domain. On the other hand, as is clear from the diagram, the multiples and primary arrive at different offsets and, therefore, cannot be predicted from the trace corresponding to offset AC containing the primary arrival ABC. (For that, one requires 2-D or 3-D prediction technique such as Surface Related Multiple Attenuation or Wave Equation based multiple prediction).

2. False. The so-called "Bright spot" on a seismic section can arise from any interface with a strong litho-contrast. Similarly, any interface with a contrast in the Poisson's ratio has an AVO effect of one class or another associated with it. A low impedance gas-charged sand capped by higher impedance shale and water sands below is just one instance leading to bright spot with AVO (in this case, class III). But that is not the only situation where a high amplitude and AVO effect are manifested.

   Different shale litho-types vary significantly in their rock properties. For instance, in one study of rock properties of Lewis shale in SE Wyoming, ["Sedimentology and Petrophysical Character of Cretaceous Marine Shale Sequences, Foreland Basins: Seismic Response of Seals Horizons" Wm. C. Dawson et.al, Search and Discovery Article #40089 (2003)]. It was found that High Stand Shale (HST) generally has a lower P-wave velocity, lower density, and higher Poisson's ratio than a Transgressive Shale (TST). Consequently, a shale-shale interface of HST shale immediately above a TST shale was expected to generate a strong reflection with AVA similar to that for a model with shale above and hydrocarbon-saturated sandstone below. Drilling results confirmed the absence of sandstone (and hydrocarbons). Similarly, a shale-limestone interface can generate a bright amplitude and AVO because of impedance and Poisson's ratio contrasts.

3. Correct – but the proposition requires qualification. Gas-charged sands typically have low Poisson's ratio between 0.1to 0.2. Thus when the reservoir is a gas-sand, we invariably get a strong Poisson's ratio contrast both above and below the sands leading to an AVO anomaly. The anomaly would be of Class III if the bounding formations (shale above, water sands below, for instance) have lower impedance. The anomaly would be of class II if the sands are of low impedance to start with thus reducing the normal incidence reflectivity close to zero. Thus, assuming that the data are processed properly, *absence of an AVO anomaly rules out the presence of gaseous hydrocarbons in a clastic set up*.

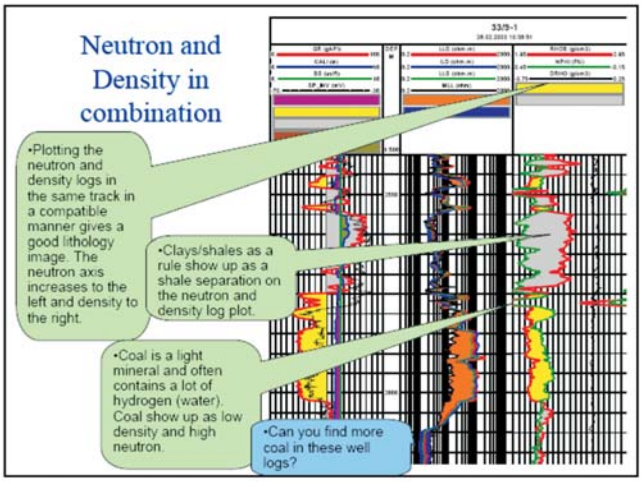
   However, one cannot make a similar a-priori statement on the necessity of AVO anomaly for presence of hydrocarbons in a carbonate reservoir or for liquid hydrocarbons since frequently such set-ups are associated with very weak contrast in impedance and Poisson's ratio across an interface making it difficult to see an AVO anomaly.

4. Tools for measuring neutron porosity essentially consist of a radioactive source emitting neutrons and receivers which detect neutrons. Neutrons loose their energy – mostly, through elastic scattering from hydrogen atoms in the formation, but also through scattering from other nuclei of the formation – until they are slow enough to be absorbed by the nuclei in the formation. Greater the concentration of hydrogen atoms, higher is the energy loss and, hence, lesser is the number of neutrons reaching the detectors. The neutron count is converted to porosity using calibration from laboratory data for a specific type of rock (normally limestone) and is displayed with porosity increasing to the left.

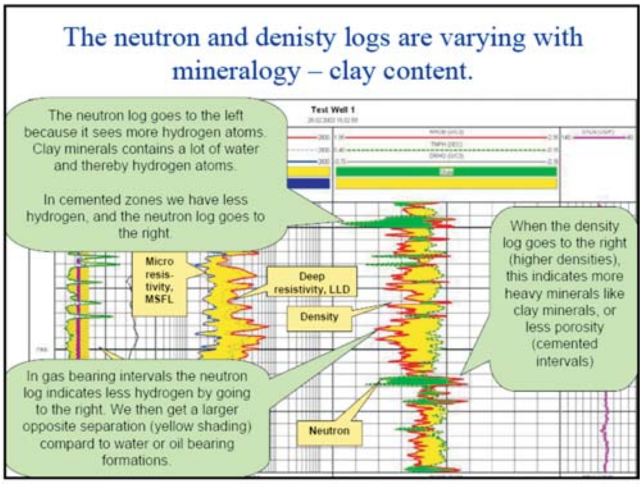
   In clays, the hydrogen index is higher because of the associated water and leads to increased value on a neutron log, i.e, the log swings to the left. Density logs- displayed with increasing value to the right - measure effectively the electron density in a formation which increases with higher density formation. Presence of heavy clay minerals swings the density log to the right. Because shale is rich in clay content, it becomes visible on a neutron porosity log plotted side by side, and on the left of a density log, as a separation between these two log curves. This is called as "shale effect" or a "neutron porosity – density separation".

On the other hand, gas sands normally show decrease in density and also lower neutron porosity due to low hydrogen index (compared to water or oil). Thus, we expect opposite effect, i.e., density curve swinging to the left and neutron porosity curve swinging to the right, thus leading to what is called as "neutron porosity – density crossover". These concepts are illustrated in the figures below taken from Helge Langeland, "Sedimentology from logs", www.knowledge-reservoir.com.

However, if we have gas charged sands with heavy minerals, such as feldspar and pyrites (as was actually the case in this example), the density increases in spite of the presence of gas swinging the density curve to the right. Higher formation density also leads to slight increase in neutron scattering and therefore lower neutron porosity. Thus, instead of getting a cross over, we get separation



(Courtsey, Helge Langeland, knowledge-reservoir.com)



(Courtsey, Helge Langeland, knowledge-reservoir.com)

between the two logs. Radioactive minerals like mica (which were present in this case) would give rise to high gamma. Conducting minerals (feldspar) would lower the resistivity. Thus, "shale effect" on electo-logs can appear even in a sandy gas-charged formation.

5. Snell's law states that when a ray travels between two points in a variable velocity medium, the ray path changes its direction depending upon angle of the ray and velocities in the media. The Fermat's principle states that the ray path between any two given points follows the least-time path. However, at any given point it is enough to satisfy any one of these laws. If the ray path follows Snell's law then it will be the least time path. If the ray path is the least-time path, then it will automatically satisfy Snell's law. This can be proved, first for an interface of two isotropic homogenous media, by differentiating the total travel time between two points with respect to the angle of refraction and setting the result to zero (so that the travel time becomes a local minimum). The proof then can be extended to media with variable velocities by partitioning the grid into cells such that within each cell the velocity can be regarded as constant.