What Should I Correlate? Peak Or Trough!

A. K. Das*, K. Dhandapani, P. B. Pandey
ONGC, Baroda

Summary

Acoustic velocity is not a criterion to distinguish among the various rock types. It has been attempted to show that the manifestation of the seismo-geological response of acoustic waves on the zero-offset seismic section as either peak or a trough is not appropriate to be concluded based on a normative way of thinking or a thumb rule. At any given well position, the reflectivity series is an absolute parameter which is not subject to any modification. But the peak or trough that is observed on the seismic section are variable as they are the product of the interaction of the embedded wavelet in the data and the reflectivity series i.e., as R.C series is definite, if wavelet character changes, the character of reflection as peak or trough also will change. Therefore, the synthetic seismogram to seismic section correlation must have the final say as to whether a peak or a trough has to be correlated in a seismic vintage for a particular litho marker.

Introduction

In an interpretation project report, whenever we see a team of synthetic seismogram and the correlated seismic sections we get tempted, inadvertently, to judge the accuracy of the correlation of a seismic horizon; the assessment being based on whether the acoustic wave is getting reflected from a lithological boundary between shale/sand or sand/shale. Furthermore, a concomitant consideration is done about the polarity conventions followed in the industry and as a result, if a horizon is correlated along a peak, we attempt a retrograde verification on the appropriate logs as to whether the horizon being correlated denotes the boundary between sand above and shale below or vice versa.

During interpretation of different 2D and 3D seismic data belonging to different vintages of Broach sub block of South Cambay basin, inconsistency in the development of peak or trough corresponding to the boundaries of layers was encountered which were overcome by generation of suitable matching synthetic seismograms. To understand the causative of these anomalies, geological models have been studied to obtain possible seismic responses with the help of GX-II modelling software; the same has been discussed with illustrations.

Importance of wavelet character

We visited the density and sonic logs of few wells in our study area and found that lithology interpreted as shale and sand from gamma ray, SP, resistivity and CDL/CNS log pairs had both positive and negative reflection coefficients along the well. Any particular sign, as a generalisation, was not assignable to the boundaries based on just the assessment of lithology from logs.

Often the simple but the critical diagram (Fig.1) depicting the relationship between seismic velocities and the rock types is ignored while attempting to evaluate the seismological response of the rocks. Let us recapitulate its significance:

Fig.1.

It indicates that more than one rock type can have the same velocity. In other words, velocity cannot be a criterion to uniquely describe a rock type. One rock type, say, shale may have higher velocity than that of sandstone and vice versa; velocity being dependent upon many factors not just the nomenclature of the rock type in question.

Often interpreters feel that one must be clear about
the polarity convention adopted in the processed section before attempting any interpretation on it. This invokes a discussion as to “whether one should really bother about any polarity convention underlying a processed section? Does the polarity convention really matter at the end of processing sequence?” To some, the answer may be yes. The explanation may be that if acoustic wave travels from sand to shale, it encounters, say, a negative reflection coefficient (RC) and therefore, under SEG convention of polarity, a trough should be visible against the RC and under European polarity convention, a peak should be visible. In turn, if it encounters a positive reflection coefficient a peak will be visible against the RC under SEG convention and a trough under European convention. Whether a peak or a trough will be visible against a boundary is often assessed based on some presumptive impedance values of the layers concerned. This deals with some fundamental questions in the minds of interpreters dealing with seismic data for deriving useful and costly conclusions.

A processor expects acquisition personnel to specify in the field log about which traces are recorded with proper polarity adopted by the recording system. That is, whether the compression is a positive number or a negative number i.e. a peak or a trough on tape. Once the acquisition personnel specify that a trace is normal one, the processor will not need to bother much about the convention aspect of polarity. Processor accepts the data from the acquisition group as it is unless he notices that some traces are reverse and hence need to be corrected. At this point only, the processor corrects the trace for the sign and goes ahead with processing sequences and gives the interpreter an output ready to be interpreted.

It is known that the deconvolution, a step of processing attempts to compress the basic wavelet embedded in the data bringing it closer to a spike thereupon attempting to turn the look of a zero offset seismic section closer to a reflectivity series responsible for the generation of reflections observed on the seismic section. Though, ideally the seismic section is supposed to be a representative of the reflectivity series of the earth, it is truly not so due to the fact that various subsurface phenomena like spreading, absorption etc. have the effect of broadening the wavelet (Non-stationarity character) and consequently, the embedded wavelet in the final processed output is not a simple one. The wavelet, most of the time has an oscillatory appearance and has energy spread over a longer time period and is often of mixed phase. A negative reflection coefficient, in fact, may be associated with a peak or a trough depending upon the phase character of the wavelet embedded in the section. Rarely, a zero phase (symmetrical) wavelet of short duration may be embedded in the data when, the seismic section may be a near factual representation of the earth’s reflectivity series. That is to say, if the wavelet embedded in the seismic section is a zero phase wavelet, we can fairly correctly determine the
disposition of the reflectivity series or impedance boundaries.

In fact, we should invariably attempt to conclude anything only after generation of a synthetic seismogram at well positions when we should try various wavelets to generate the synthetic seismogram to match best with the processed seismic section in question.

If the synthetic wavelet is a symmetrical positive sided wavelet and the reflection coefficient is positive, then we shall get a peak in the synthetic seismogram against the reflection coefficient. And if this peak matches with a peak at the corresponding temporal position in the seismic section then we can conclude that wavelet embedded in the data is the same as the synthetic wavelet. Hence the data is having normal polarity. But if the synthetic seismogram has a peak but the section has a trough at the same time (of course, after conclusion of best match position) then we can say that the wavelet embedded in the processed data is having phase/polarity opposite to that of the synthetic wavelet. So, for a positive reflection coefficient, we have to start correlating trough though in synthetic seismogram, we get peak. Moreover, if we get peak in synthetic seismogram and also peak in seismic section we have to correlate by taking peak against the said reflection coefficient.

It means that by knowing the polarity convention, as interpreters we shouldn’t jump to a conclusion for correlating the seismic section (hence the full vintage). We must tie up the to-be interpreted section/vintage with the team of synthetic seismogram, RC series and the wavelet at a given well position. We must remember that whatever be the circumstances, on a mega scale, reflectivity series generated from sonic and density logs at the well location is common to both the seismic section and the synthetic seismogram. What, then, must have been at variance are the synthetic wavelet we use to create the synthetic seismogram and the unknown wavelet embedded in the processed section. (Noise component is assumed to be zero here).

Unless we try to match the synthetic seismograms with the seismic section, we should not conclude the nature of the wavelet embedded in the seismic section. And most importantly, we also cannot conclude: The peak observed on the seismic section is due to a positive reflection coefficient or negative reflection coefficient as the peak or trough observed on seismic section is function of both reflection coefficient and the embedded wavelet. And to know concretely about all these parameters, we as interpreters have to resort to the method of elimination of uncertainties by preparation of synthetic seismograms wherein, we have the relatively unambiguous parameter i.e. reflectivity series generated from sonic and density logs. Apparent assumption in the course of this discussion is that the checkshot in the well used to calibrate the sonic logs is correct one and also that sonic log is correctly calibrated.

**Practical aspects**

In the light of the above, in the course of interpretation of seismic data in one particular area, one interpreter may correlate peak and another may correlate trough for the same litho marker. This may be the case under the following circumstances:

If seismic volumes belong to different vintages of acquisition and are not wavelet processed i.e., if the nature of seismic volume (i.e. raw stack, final stack, dmo stack, migrated stack etc) are different for each of the interpreters. Each seismic volume is unique in its own way. If the two seismic data volumes have two different embedded wavelets, the synthetic to seismic correlation will be different.

We emphasise that while deciding whether to correlate a peak or a trough for a particular reflector, it is not the polarity convention that plays a role rather it is the wavelet (its amplitude/phase spectra) embedded in the final processed section that plays a vital role.

**Therefore to conclude**

1) Supposing a litho marker is a boundary between shale above and sand below. By no logic, an interpreter can conclude that incident wave will encounter a positive or a negative reflection coefficient at the boundary by knowing the lithology above and below the boundary. As discussed above, just the nomenclature of a lithology is not enough to attribute it to high or low impedance. This must be ascertained only through the generation of reflectivity series (product of sonic and density logs) and by no other means and more so, never by a normative/thumb rule way of assertions. It is recommended that data should be deterministically wavelet processed for a better symmetry of the embedded wavelet and, therefore, for a better synthetic seismogram to seismic correlation towards a better definition of a layer boundary as a peak or a trough.

2) Different vintages of processed seismic data, logically, will have different embedded wavelets. Therefore, at a given well location, where the reflectivity series is only definite, for N number of seismic data volumes having
N different embedded wavelets we shall get N different degrees of synthetic to seismic correlation.

Some synthetics may possess a peak reflection for the same reflection coefficient and some others may possess a trough reflection for the same RC position and still some others may not possess a peak or a trough at all but something in between a peak or a trough i.e. a zero crossing or slightly above or below zero crossing.

As shown in Fig.2 & 3, with variation in the embedded wavelets in the data, various layer boundaries are manifested in the seismic sections either as peak or trough or zero crossing or some phase between peak and trough. This is conspicuously observable at the layer boundaries where the layers are well above the resolution limit of the embedded wavelet. Under such circumstances, it is advisable to first analyse the synthetic seismogram at the known well positions before deciding on whether to correlate a reflector as a peak or trough or a zero crossing. Knowledge of lithology is not enough to dictate the correlation of seismic reflectors. Synthetic seismogram vs. seismic section match must have the last say.

But the problem becomes complex when the layers are below the resolution limit of the embedded wavelet. This problem adds another dimension to the issue of seismic correlation and has been elicited in Fig 4. Here, the modelling has been done for six thin layers of 7 to 12 m thickness having velocity increasing with depth. All these layers have clear manifestation as peaks in the zero-offset seismic section generated with Ricker wavelet of 100 Hz peak frequency. With decreased peak frequency (i.e. 40HZ) of Ricker wavelet, the definition of layer boundaries gets obscured. It gets further complicated with band pass filters of varying pass bands and varying phases. The layer boundaries observed/resolved in the seismic section with 100Hz Ricker wavelet (Fig.4A) are transferred onto these sections. We find that all the layers are contained within two peaks and a trough. Assigning a particular peak/trough to any particular thin layer is not possible in this case. In such a case, correlating a peak or a trough doesn’t clearly correspond to any particular layer boundary. The thin beds alternations having more than one boundary are represented mostly within composite seismic response of peak or trough. Vertico-lateral extension and stratigraphic interpretation of these thin beds warrants careful interpretive approach.

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( The opinions expressed in this paper are only of authors)

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