What's the Datum

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Summary

Datum and replacement velocity are terms used in seismic processing but are often not completely understood with respect to the impact they can have on the data. This talk will attempt to define what various datums are as they pertain to seismic data as well as the affect that replacement velocity can have on structural reliability of the processed data. Real data examples will show the effect of various datum and replacement velocities applied to the data.

Theory / Method / Workflow

One of the first questions that arises in the processing of data is "What is the datum and replacement velocity"? The normal answer is typically arrived at by looking at what has been used in other data in the area in the past and then using the same values. Most of the time referencing past projects is a pretty safe thing to do, the assumption being that someone had taken the time to look at the data and actually figure out what the best datum and replacement velocity were for the data. But what do those numbers mean, and how can they impact the data? After all, isn't it just a bulk shift to move the whole section up or down in time? Why do we even need to worry about it anyways, couldn't we process from the surface and then load the data up in the workstation and bulk shift it to tie the rest of the data in the project?

As with most things that seem very simple, datum and replacement velocity is not quite as simple as it appears. Even considering a simple elevation correction where we correct the data to a flat datum from the surface, we can introduce long wave static issues into the section if we use an incorrect replacement velocity.

First we will define several different frequently used terms. After going through an entire shelf of geophysical texts I realized that not one single text had an entry in the index for datum. I may have chosen poorly in the shelf I selected, but it did have a lot of large imposing looking volumes. Merriam Webster[1] gives datum (plural datums) with a mathematical definition of "something used as a basis for calculating or measuring". That seems rather exact but at the same time ambiguous. As it pertains to seismic data, we have more to consider.

I will suggest for a practical definition of datum: an elevation that is used as a reference surface for our data. I will also suggest that we need to consider several different types of datums to make sense of what we ultimately consider the datum. Since a datum is defined essentially as a reference for measurement, we will have to consider the various stages of a rudimentary processing sequence and the impact of datuming on the seismic data.

In a conventional processing sequence, raw field data is converted into a stack section, or gathers for use in subsequent analysis, all the while passing through several different adjustments for various datums. We will consider a few key points where datum is particularly relevant.

Seismic data recorded in the field, with a few exceptions, is recorded to a datum of topography. We can somewhat safely assume that the individual traces in a shot record are referenced in time to the surface elevation at that particular receiver. Similarly for our source points with the caveat that for dynamite data, we must also consider the shot hole depth. In modern continuous recording systems, when shot data is extracted from the continuously recorded volume it is generally assumed that this assumption holds.

In an area with no topographic variation, we can hypothesize that our imaginary shot records do not contain any variation from perfect hyperbolas in their reflected events due to changes in surface elevation. This immediately leads us to the next troublesome consideration of a very rugose near surface where our imaginary shot records are contaminated with up and down shifts trace to trace due to these elevation changes.

This is the point at which we will consider adjusting our recorded time to correct our actual elevations to a constant datum elevation. By using a constant planar elevation as the datum we compensate for the trace by trace (station by station or shot by shot) variation in the actual surface elevation. We will call this "client datum". This is what is often referred to as the elevation correction.

It is entirely possible to perform the processing from this datum, residual statics and NMO will both work using a constant datum, as well as migration. However, there can be some issues with NMO and migration when the datum is different than the elevation. This is due to the fact that the actual velocity recorded in the data is different than that defined by the NMO equation when the actual start time is different. Recall the NMO equation:

$$T^2 = T_0^2 + X^2/V^2$$

The adjusted time T is related to the zero offset time T_0 and the offset X as well as the NMO velocity V. That is the correct moveout time at any particular offset is not only dependent on the offset and velocity, but also the zero offset time. If we alter the zero offset time with a static shift to apply a datum correction we are impeding the ability of the NMO to do its job properly. When we have shifted the recorded data in time to correct to our client datum, we have effectively changed the T_0 value but not altered the actual physical response of the recorded data to compensate for the altered hyperbolic curve. This leads to a couple different concepts I will call "processing datum". Processing datum will be simply: a datum used to perform processing steps from. For example, to perform NMO we might shift our data from a flat client datum to a processing datum, and after NMO is applied shift back to the client datum. One possible

processing datum is using the actual topography as the datum for NMO calculation and correction. Another common processing datum is to use a smoothed surface through the actual topography which is referred to as "floating datum".

Recalling that the goal of the processing is to generate a stack volume or a set of moveout corrected gathers, we have now dealt with several issues that could cause issues with the stack response. By correcting for the elevation differences and shifting the traces to a flat datum we have removed the up and down shifts (or chatter) due to the variability in elevation hopefully allowing the traces in the gather to fit on a nice hyperbolic curve defined by the NMO equation. By using a floating datum or other methods, we have shifted our NMO T_0 time to fit the observed hyperbolic curve of the data better.

Unfortunately, this is not quite enough in the event that we have "statics" in our data. While it is beyond the scope of this talk to explain the concept of statics, a rudimentary explanation is required. Suppose that we have a near surface layer of varying thickness and consolidation, some areas of relatively low velocity and others of high velocity, in other words we have a weathered layer in the near surface. A quick thought experiment suggests that this will give rise to time delays as the downgoing source wave and upgoing recorded wave pass through it, further these delays will be observed in the recorded times at our receivers. This will introduce additional up and down time shifts trace to trace in our gathers and is the weathering we attempt to solve for with refraction or tomographic statics. In essence we attempt to measure the thickness and velocity of the near surface material and replace the so called low velocity layer with an imaginary layer at the "replacement velocity".

The replacement velocity is a best estimate of the vertical velocity in the consolidated material below the near surface low velocity layer. By using the replacement velocity to replace our low velocity layer we are attempting to remove velocity heterogeneity in this unconsolidated weathering layer. There will generally be a limited range of values that work well for replacement velocity, but excessive variation from this can lead to undesirable consequences. When we are calculating the statics for replacement we simply need to consider that the time shift is given by

$T = D/V$

This tells us that our static correction T is directly proportional to the thickness of what we are replacing D, but inversely proportional to the velocity we are using to replace with V. A very low replacement velocity will give us a large static, and a very high replacement velocity will give us a small static. Considering that we are effectively removing a lower velocity layer and replacing it with a higher velocity layer the math tells us we are converting large time shifts into smaller time shifts.

A further approach sometimes used in refraction statics methods allows for the use of an "intermediate datum". Once the low velocity layers have been stripped away (statically compensated for) the data can be corrected to the base in time of the low velocity layer. Essentially the weathering layer is removed but not replaced when correction is performed to the intermediate datum. In principle, with this intermediate datum known, later in the processing flow the choice of final or client datum and replacement velocity can be changed.

Results, Observations, Conclusions
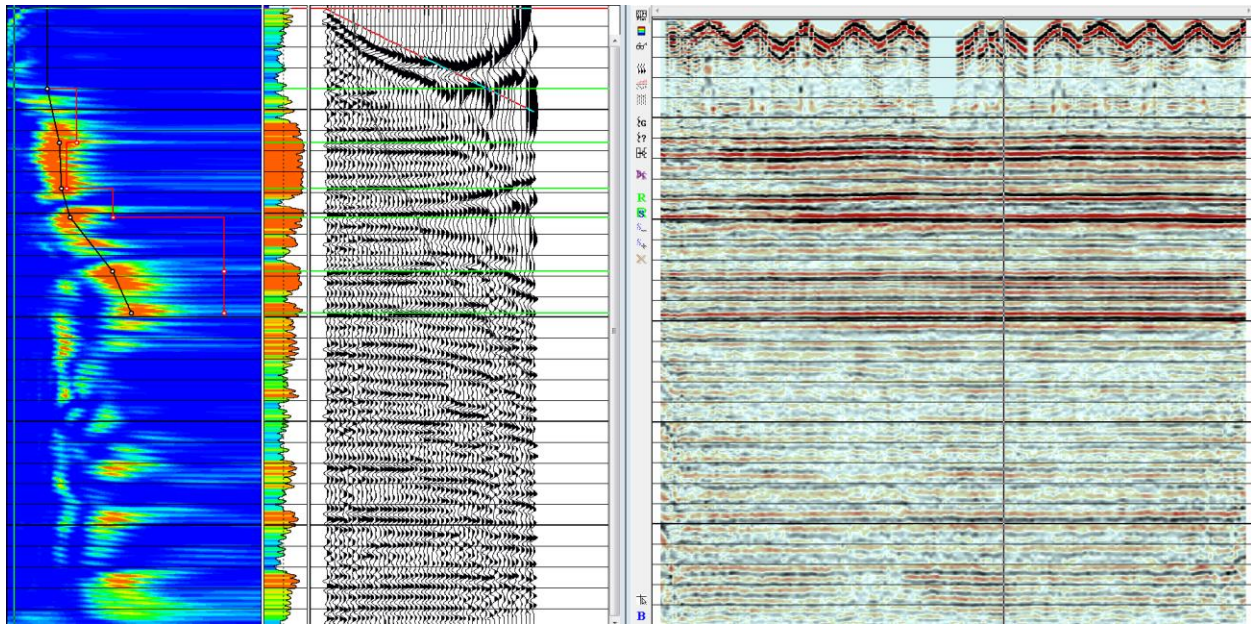
Figure 1: Velocity semblance display, common offset gather and stack line with data at field datum
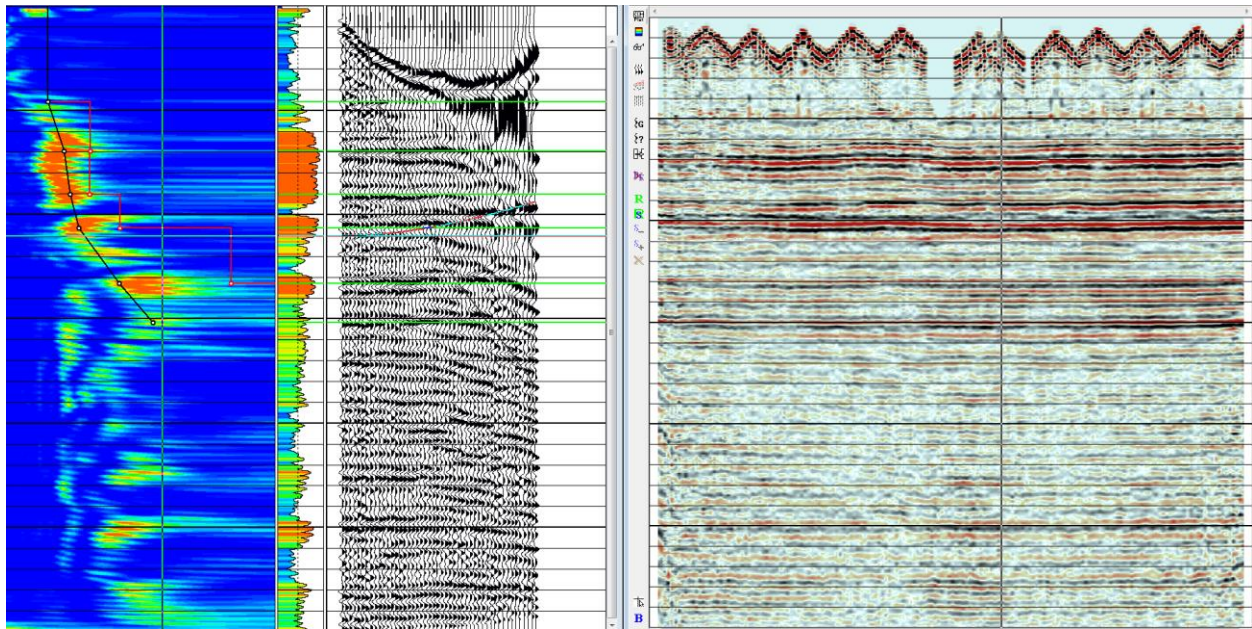
Figure 2: Velocity semblance display, common offset gather and stack line with data corrected to flat datum using data derived datum and replacement velocity (elevation only correction)
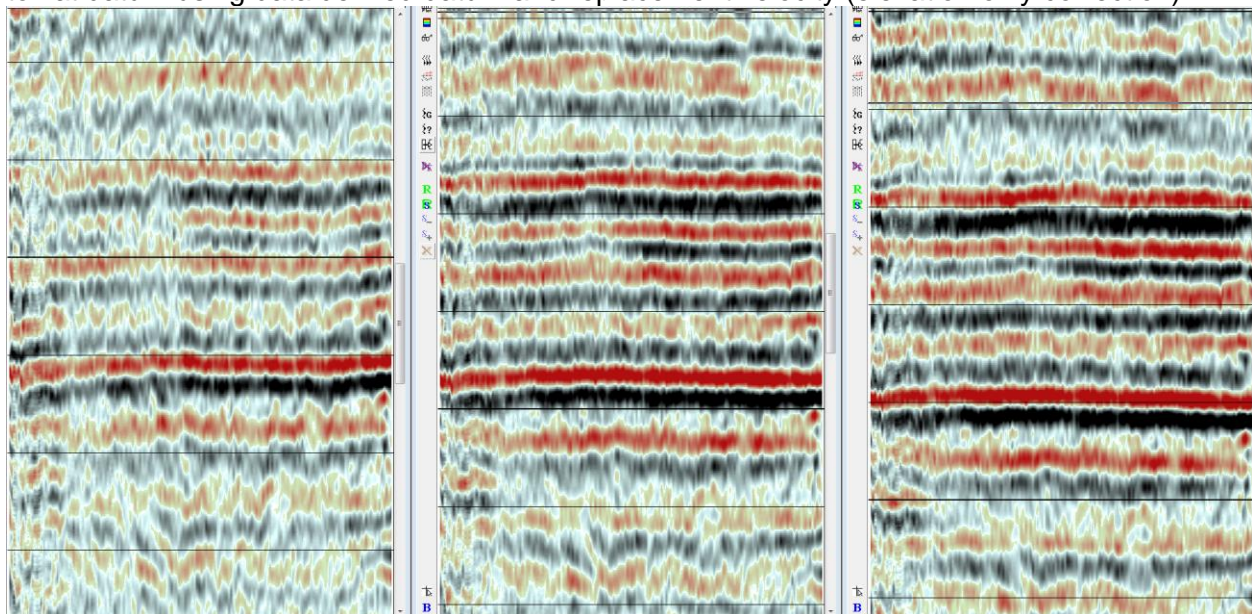

Figure 3: Stack with data corrected to flat datum using data derived datum and low replacement velocity (left), correct replacement velocity (middle) and high replacement velocity (right). Note the subtle change in structure, (elevation and refraction correction)
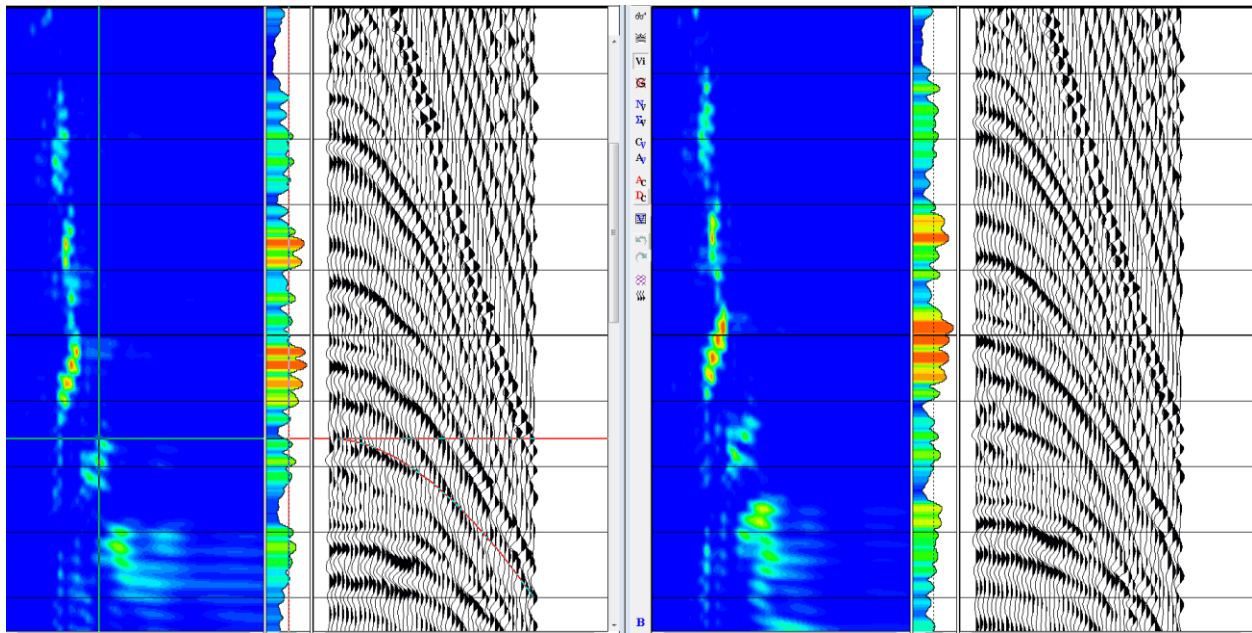
Figure 4: Velocity semblance and common offset gather with data corrected to flat datum (left) and with refraction statics applied (right). Note improvement in events with refraction statics applied.

Figure 5: Elevation profile for a line with rough topography showing the datum located above the highest elevation. This will prevent near surface data from being removed with the application of a datum correction.

Figure 6: Elevation profile for a line with rough topography showing the location of the floating datum, source points are shown by red, receiver points in blue and the floating datum is the dashed blue line.

Novel/Additive Information

A question sometimes asked by clients is if they can simply undo the elevation correction on their loaded stack data and move it to a new datum and replacement velocity combination. The answer is, unfortunately, it's not quite that simple. At stack the trace header contains a cdp elevation which is the result of interpolation at some point in the processing flow. The cdp elevation can be a blended version of the source and receiver information and especially in 3D can be almost completely meaningless. Further, the start of the data on the section has had the influence of refraction and residual statics as well as possible bleeding from mutes, NMO, migration, noise attenuation, and many more cause it to not be the actual elevation. To properly "undo" the elevation correction would require being able to undo it at the shot and receiver, even in a 12 fold cdp that means 12 different combinations of shot and receiver.

Acknowledgements

References

1 Merriam-Webster's online dictionary