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Seismic window

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Time to depth conversion

One of the arts of geophysics is converting seismic times to depth, and dealing with the uncertainty. Today we can convert entire datasets to depth using ‘seismic velocities’ and co-krigging with well depths. It was not always so easy. To calculate the depth to various objectives in a well, a number of hand calculations were required. The easiest step in this process was selecting the velocity functions nearest the well location because they were printed at the top of the section (Figure 1). Today velocities come as separate files and there are a number of versions – migration velocities, smoothed velocities, velocities in depth or time, velocities corrected for anisotropy etc. But, the ‘velocity boxes’ had a choice of only two types of velocity – average and interval. Although the average velocities were easier to use, it was the interval velocities that gave the best results. Figure 2 shows the supplied velocity information on the left, and the series of calculations that led to depth estimates on the right. The far right column is the calculated average velocity and it differs from the average velocity supplied on the section.

Depth prognoses are special cases and require more care than simply converting a map from time to depth. To produce depth maps there is a variety of methods and techniques that can be employed ranging from a single time-depth formula from a well to quite complex 3D functions. One technique I have used is the Vo-K method. Unfortunately I have rarely had much luck with Vo-K and I’m not a fan. My preference is to analyse the available data for trends and identify a time – depth relationship. For example, I had good success in the Exmouth sub-basin using the ‘Dempsey formula’, where the primary objective in three exploration wells was found to be in error by just –1, 0 and 1 m. This method used a simple formula (Figure 3) derived from well control to estimate the depth to the top Barrow Group, and contained two terms – a water layer term and a rock

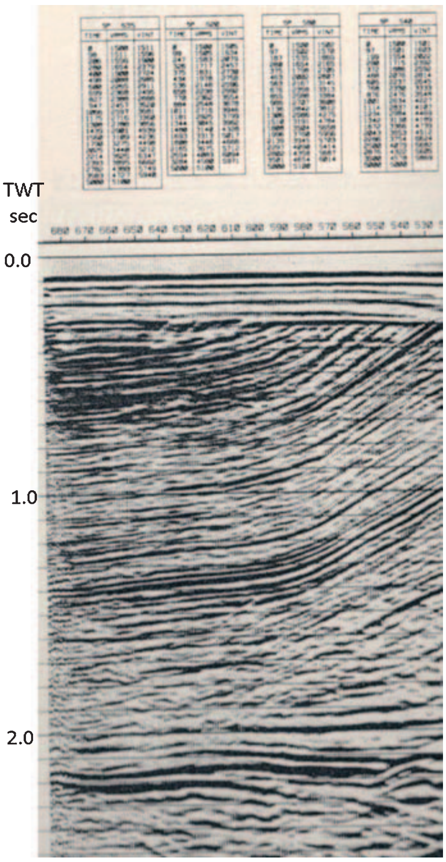

Figure 1. *Seismic section with ‘velocity boxes’ in the header. Details of the second from the left are reproduced in Figure 2.*

TWT (ms)	Vav (m/s)	Vint (m/s)	TWT interval	OWT interval	Thickness (m)	Depth (m)	Vav * (m/s)
0	1500	1505	99	50	74	0	
99	1505	1634	148	74	121	74	1505
247	1583	2079	79	40	82	195	1582
326	1717	2457	49	25	60	278	1703
375	1831	2730	59	30	81	338	1801
434	1978	2758	102	51	141	418	1927
536	2148	2596	122	61	158	559	2086
658	2258	2992	112	56	168	717	2180
770	2362	3554	114	57	203	885	2298
884	2518	3678	127	64	234	1087	2460
1011	2716	3946	170	85	335	1321	2613
1181	2925	3799	163	82	310	1656	2805
1344	3045	3962	136	68	269	1966	2926
1480	3140	4320	213	107	460	2235	3021
1693	3313	5017	115	58	288	2695	3184
1808	3446	4666	357	179	833	2984	3301
2165	3575	5712	429	215	1225	3817	3526
2594	4203	6094	690	345	2102	5042	3887
3284	4500	5971				7144	4351

Figure 2. *Example of calculations used to prognose depths from stacking velocities. The three left hand columns are taken from the seismic section shown in Figure 1. A hand calculator was used to calculate the depth to each velocity point. Note how the average velocity in the right hand column differs from the value printed on the section.*

"Dempsey Formula" for Water Bottom (WB) to Top Barrow (IH) Depth Conversion
$Thickness_{WB-IH} = TWT_{WB-IH}/2000*(2698-1017.8*(TWT_{WB}/2000+0.5*(TWT_{WB-IH}/2000)))$

Figure 3. *A simple formula used to calculate depth to the Top Barrow Group in the Exmouth Basin. This formula, developed by Craig Dempsey of BHP, calculates the thickness of sediments below the water bottom.*

layer term. When broken down this formula has some aspects of the Vo-K method.

Variations in water depth can distort the actual structural configuration below, and hide prospective structures. A visual technique I commonly use to apply a rudimentary correction to minimise the effects of a varying water depth is to flatten seismic sections on a surface equal to 0.6 times the water depth (Figure 4). This is basically a static correction.

No matter which method is used, it is unlikely to tie to the available well control so a depth adjustment map is created by contouring or gridding the error values at wells. Creating a depth adjustment map is where the art sneaks into depth conversion, but it is a requirement to produce maps that tie to well control.

It seems we haven't progressed far. Where we once used interval velocities and tied to wells with an adjustment map, we now use detailed seismic velocities co-krigged with well data. Overall the only difference seems to be the speed of the calculations.

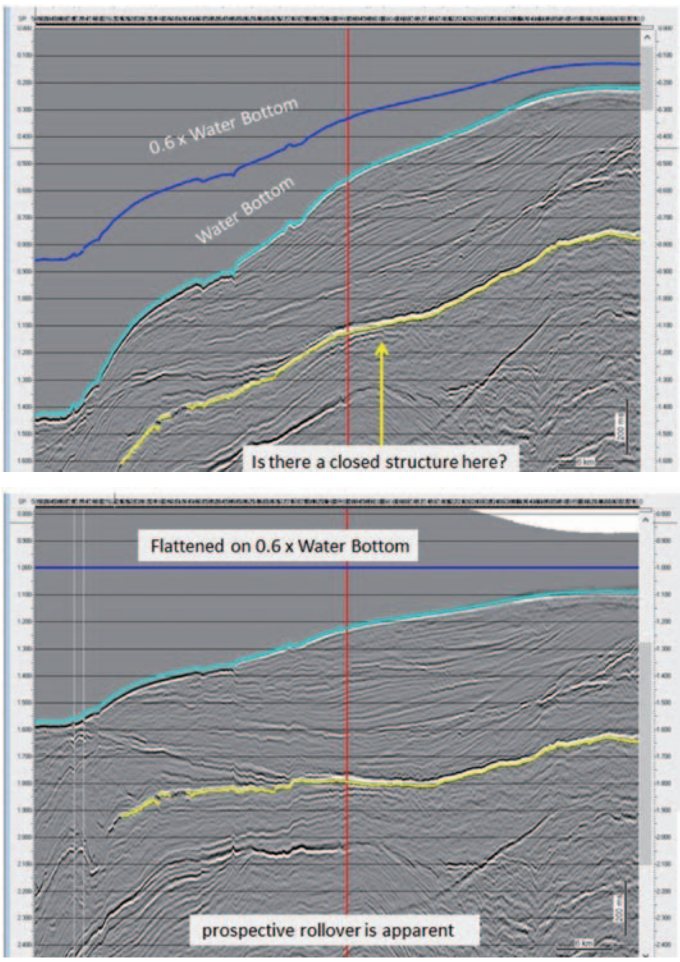

Figure 4. *Example of quick approximation to remove distortion of structure beneath a varying water depth. The yellow horizon has no rollover in the time section (top). After flattening on 0.6 × water bottom a rollover can be seen (bottom).*