Seismic Window

Michael Micenko
Associate Editor for Petroleum Geophysics
micenko@bigpond.com

4D and the war on noise (and other geophysical warfare)

I'm led to believe that during the cold war there were some interesting ideas developed that enlisted geophysics to build weapons to attack the west. However, the real geophysical war conducted daily is the war on seismic noise. This is particularly important in 4D seismic where subtle changes are often difficult to see because the changes are of similar magnitude to the seismic noise.

4D seismic or time lapse 3D is used to monitor fluid movements in a producing hydrocarbon field. The process involves recording a base 3D survey before production starts (or shortly after) and also one or more monitor 3D surveys sometime later – time is the fourth dimension.

As hydrocarbons are produced the reservoir properties change. For instance, pressure may decrease near producing wells and increase around injector wells, or oil may replace gas or water saturation may change. These changes result in small changes to the seismic response that can be observed as time and amplitude differences between the base and monitor surveys. The example in Figure 1 is from the Enfield oil field in Western Australia's Exmouth sub-basin. There are many other examples of the successful application of 4D seismic providing valuable information that resulted in better reservoir management but I find there is still reluctance to try the method in some quarters. The problem is noise which may affect the repeatability of the seismic data.

Seismic processing has many tools and perhaps the most powerful weapon in the war on noise is stacking. The modelled example of Figure 2 illustrates how a small change in seismic amplitude is difficult to see in the presence of seismic noise of similar magnitude. But, after the application of a stacking process, the noise is reduced and the 3% difference between base and monitor surveys is now apparent (Figure 3). This illustration may over-simplify the problem but it does show that even in the presence of strong noise a relatively small change in the seismic response (3%) can be detected and there is no need for a pessimistic approach if appropriate processing is applied.

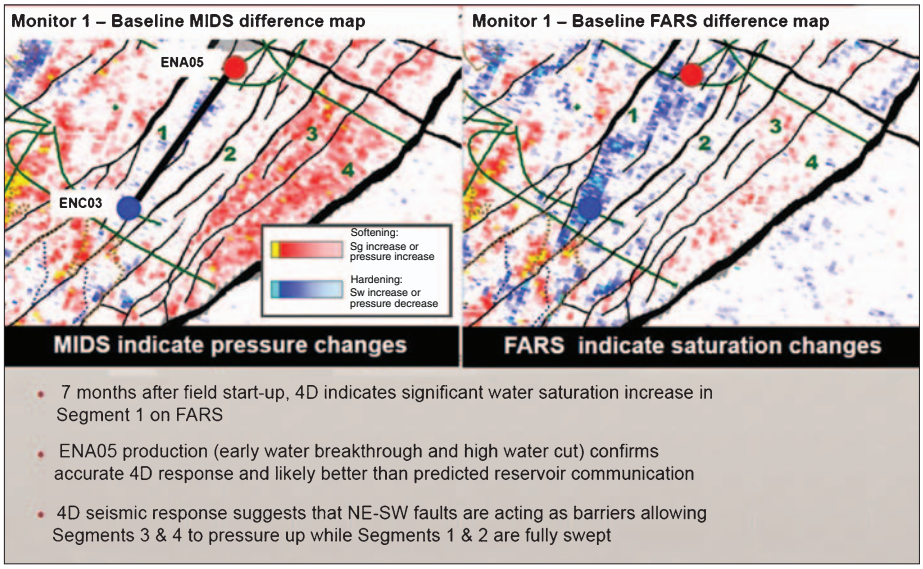

Figure 1. *Example of 4D seismic response caused by changes in the reservoir as a result of production. In the centre of the maps, blue area on FARS (far angle stack) indicates increase in water saturation while white area on MIDS (mid angle stack) suggests no change in pressure (from Hamson, 2012).*

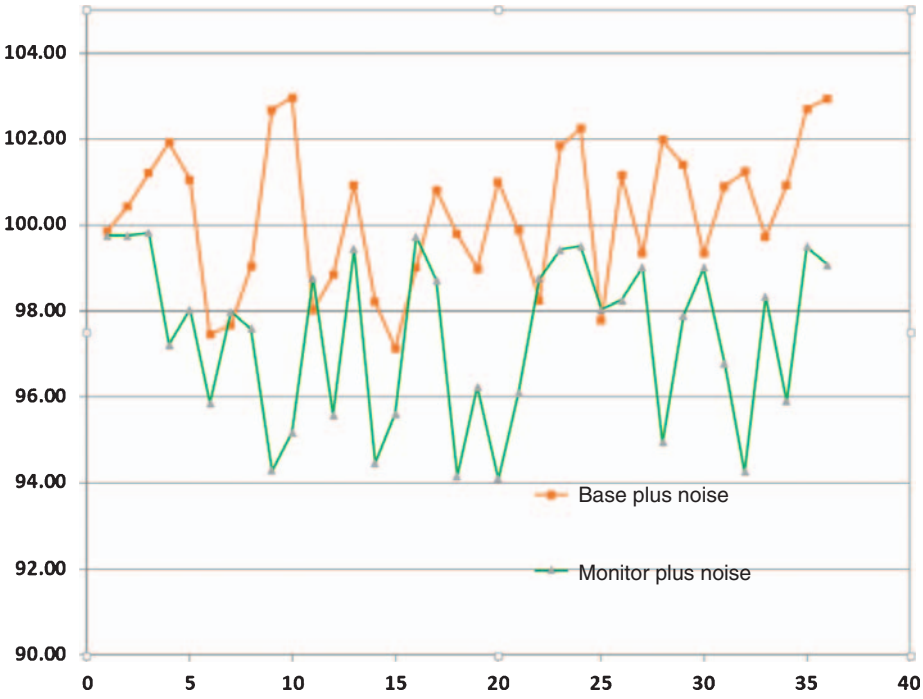

Figure 2. *Modelled amplitude of base survey and monitor survey in the presence of different random noise for each. Vertical axis is amplitude, horizontal axis represents CDP location. Original amplitudes are 100 for base and 97 for monitor which represents a 3% change. There is significant overlap between the two lines.*

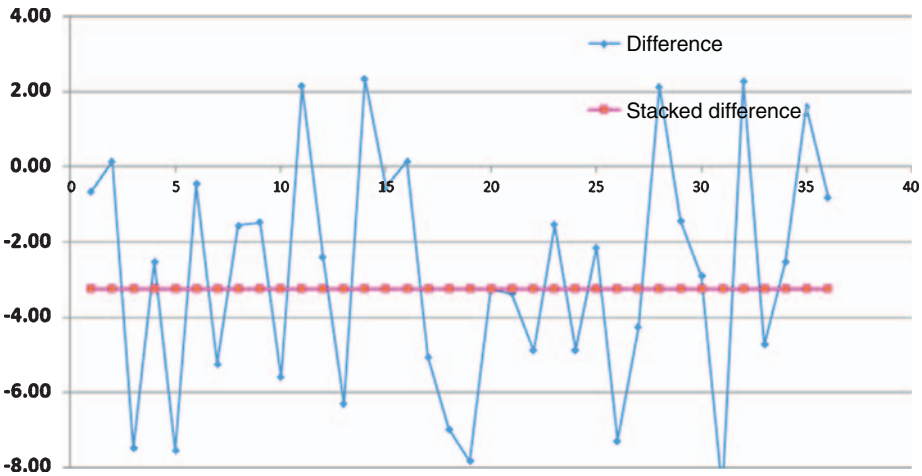

Figure 3. *The difference between monitor and base models of Figure 2 before and after stacking. The magnitude of the 4D response is difficult to discern on the raw data (blue) but after stacking (pink) it is similar to the actual value.*

Getting back to the cold war. I have never been to Eastern Europe but I know some people from the former eastern bloc who have described some more destructive applications of geophysics. The aim was to invoke a natural disaster in the targeted country without arousing suspicion or reprisals. They sound a bit Hollywood but I'm assured they were real avenues of research. Geophysical weapon A involved changing the course of small asteroids so that they landed in the targeted country and caused widespread damage. That sounds a bit hard to do, but geophysical weapon B is easier. The plan was to create an artificial earthquake in the Black Sea that would generate a tsunami which would travel west and flood Turkey. Why would anyone want to do that? At the time, Turkey had a large contingent of NATO forces which, it was hoped, would be rendered useless.

Reference

Hamson, G., 2012, Leveraging 4D seismic and production data to advance the geological model of the Enfield oil field, Western Australia. Search and Discovery Article #20172, AAPG.

Letter to the Associate Editor Petroleum Geophysics

Associate Editors' Note: I'd like to thank Doug Morrison for this response to last month's article. As well as providing some solutions, Doug also highlights another problem faced by explorers – the lack of data. We always want to have just one more data point or line or well!

Dear Michael,

I liked your short article in *Preview* on visualisation and hand contouring – with hand contouring a lost art form and redundant nowadays. I couldn't resist having a go at your exercise. The classic 'insufficient information' – just one data point somewhere in the middle would be enough. Although I am now retired and don't need to be concerned you have hit on some points I was harping on for years. The data point locations or, in aeromagnetics for instance, the flight lines, should be the first overlay produced in any image processed gridded data.

Anyway, I couldn't resist having a go at your exercise with a series alternatives – the first hand contouring I have attempted for 25 years (Figure 1). I would have sent people back into the field to finish the survey. A nice test and a bit of fun.

My first attempt at hand contouring was on the Bass Strait aeromagnetic survey in 1961–62 for my then employer Aero Service Corp for BHP/Hematite Petroleum – interestingly it was a survey I recompiled (from original analog data) and image processed for Geoterrex and the Victorian Government in 1993. Nice memories.

For your interest - hand contouring as art does happen. See attached example (Figure 2). These aeromagnetic contours are of some radiating dykes in Queensland – probably about 500 km of acquired data in this image. The reproduction here is not all that good as it is from a hand-held photo. I drew and had this framed sometime in the early 1980s and it is in my shed somewhere if it hasn't faded away. There were gridded computer contours produced for this survey and they were in places a mess and I took on the task to fix it – the varying strike directions and narrowness of the dykes couldn't be handled all that well when gridded and contoured. I must admit the computer generated images didn't look too bad as greyscale (sun angled) and full spectrum colour images although some of the dykes were just a series of bulls eyes.

Regards

Doug Morrison
ASEG Member

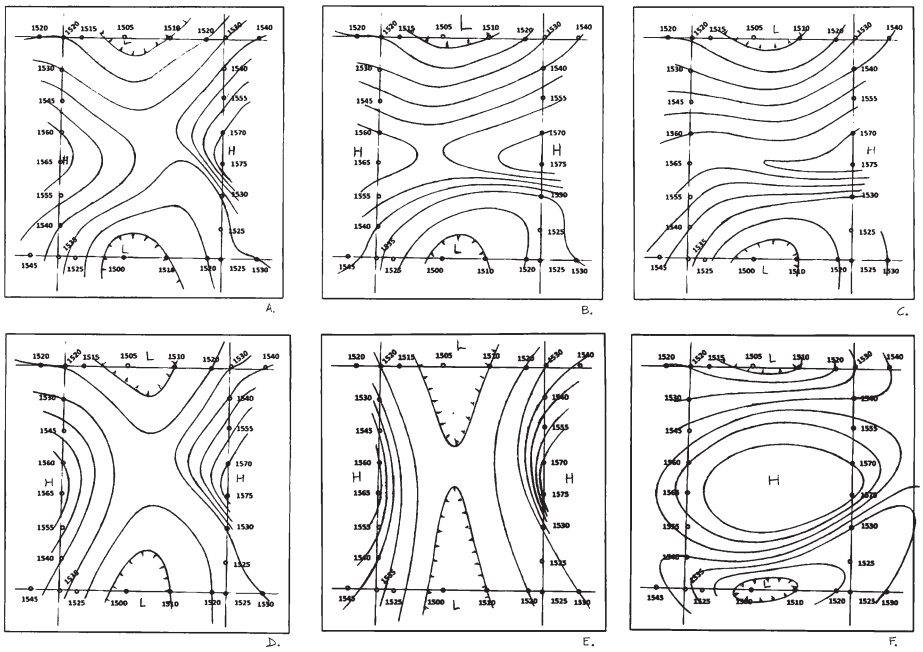

Figure 1. *A series of solutions to the hand contouring exercise published in the October 2015 issue of* Preview *(drawn by Doug Morrison).*

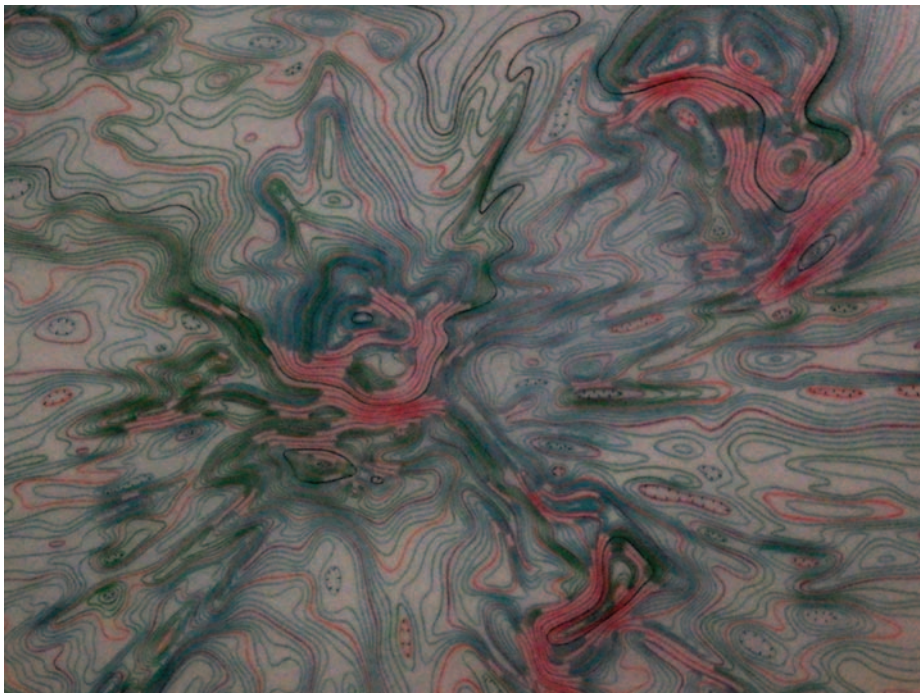

Figure 2. *Geophysics as art.*