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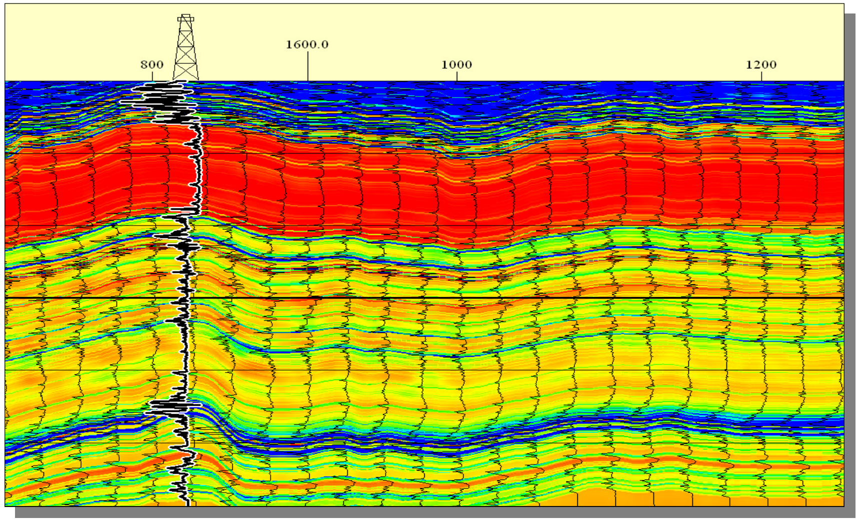

WELL LOG EXTRAPOLATION

Investigating a Triassic sandstone reservoir

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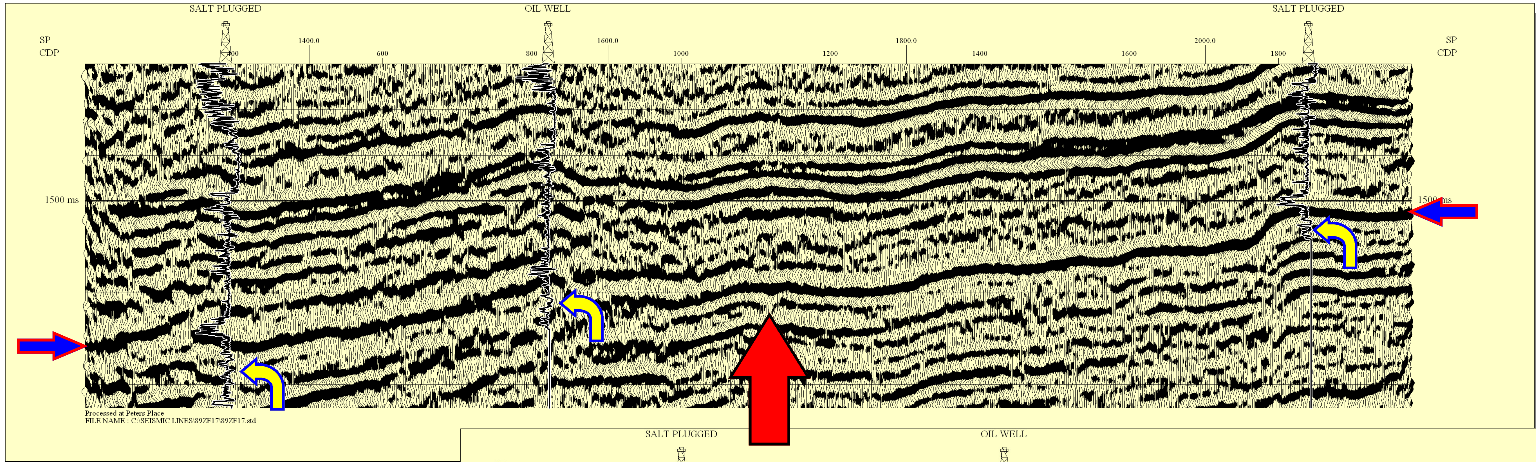
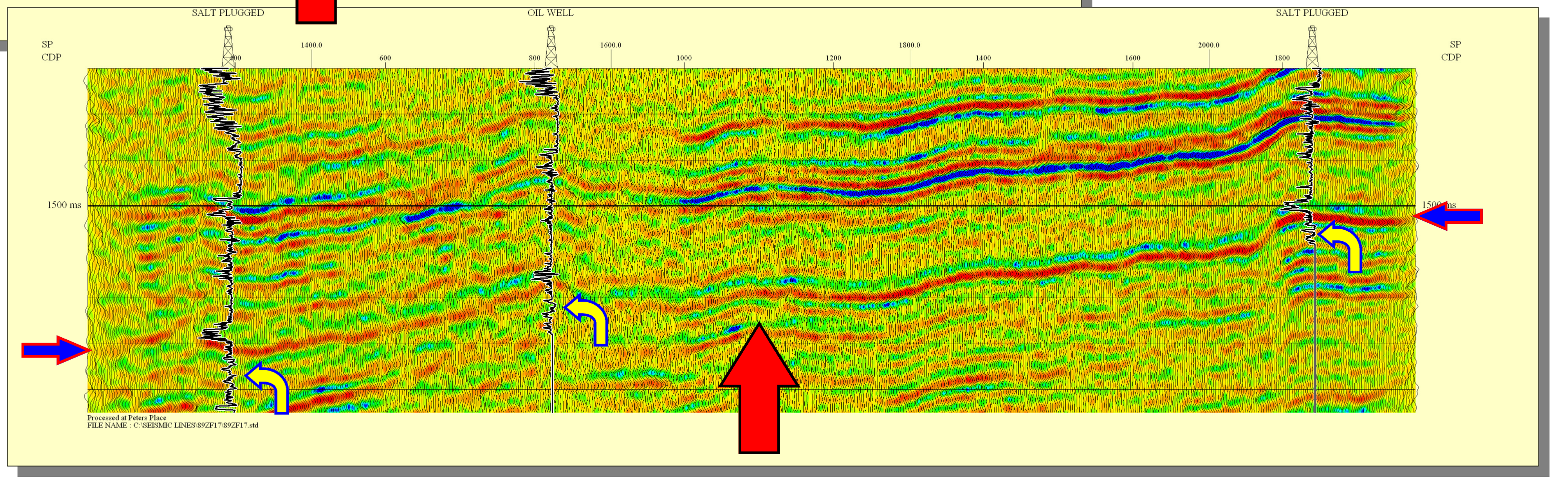
The pictured seismic line connects three wells. Two of them are dry holes, but the central one is a good oil producer. The two dry holes were drilled in the early eighties, the oil well in 1992, based on the pictured seismic.

The reservoir is a Triassic sandstone layer, with an average porosity of 15-18%. This sounds pretty high in the area, especially considering the depth of 2500-3000 meter. In the two dry holes the pores of the reservoir are fully plugged by salt.

The top of the sandstone is an eroded, unconformity surface. This was covered first by shale, then, at the end of the Triassic by salt. The Jurassic starts with a thick shale sequence. The blue arrows point to the top of the Triassic salt, which is called in the area as "S4" salt. It is covering the whole Triassic basin and it is very easy to correlate on the seismic time sections. The yellow arrows show the locations, where the three wells encountered the sandstone, which is called in the area as "A" sand. There is no specific seismic reflection related to this sand body. The usual way of interpretation is to follow the top of the salt and later on add the difference between the top of the salt and the top of the sandstone, measured in the existing wells.

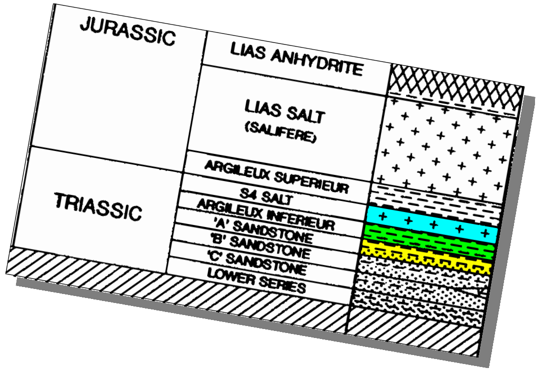
Since the top of the sand is an unconformity surface and the flexible salt equalizes everything, this is not always the best solution.

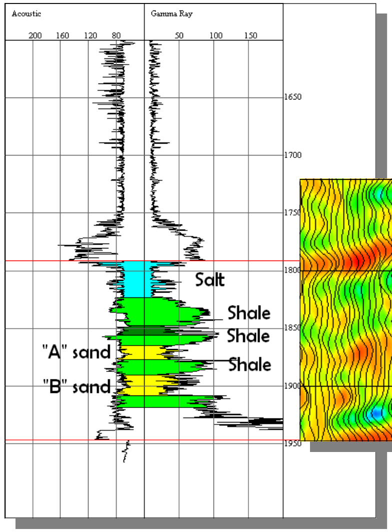


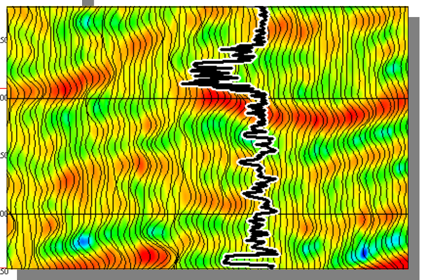


The second picture shows the same data, as the first one, only in colors.

The seducing feature on the seismic is marked by red arrows. It is a good size of closure, only we want to make clear, where is the "A" sand and we want to have an estimation, weather it might contain oil, or not.







The next figures show one by one the three wells with the corresponding seismic sections. The thick curves on the seismic sections are the time converted acoustic logs.

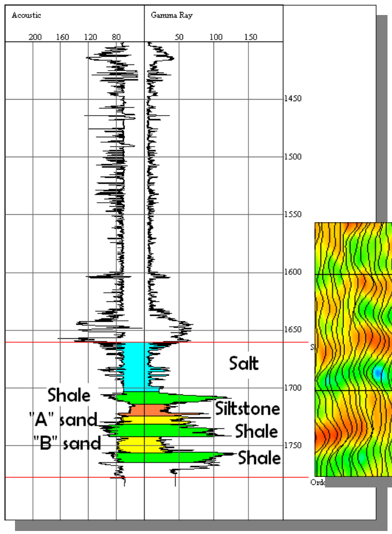
First, here to the left, there is the dry hole from the left end of the seismic section. As one can see on the seismic sections (previous page), this well seems to be misplaced. It was drilled on some older seismic interpretation. Probably the non migrated diffractions distracted the eye of the interpreters.

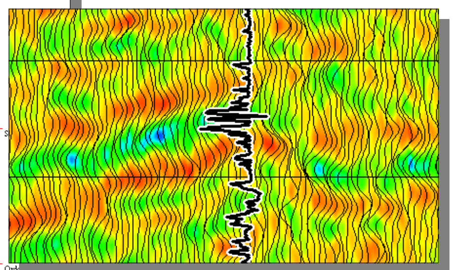
Anyway, the problem with this well is not only the position, but the total salt cementation of the reservoir.

The next well (see below left) is the central one on the seismic section. It has a reasonably good production rate, the DST tested within the range of 560 to 780 barrels per day of good quality light oil production (depending on the choke size).

It is easy to locate the different layers on the time converted logs, just one has to line them to the acoustic and gamma ray curves on the left side. There the layer boundaries were set by the time converted tops of the log interpretation.

The big jumps are related to the Jurassic cover shale, called as "argileux superieur" in the area. Below that there is the Triassic salt, called as "S4". At the bottom of the salt, the left kick (slower velocity) is the result of the covering Triassic shale sequence, named as "argileux inferieur". Under the shale, there is our sandstone reservoir, called as "A" sand.



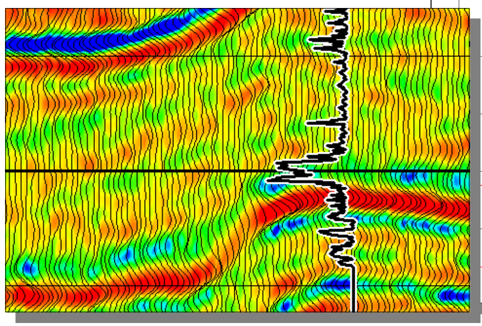


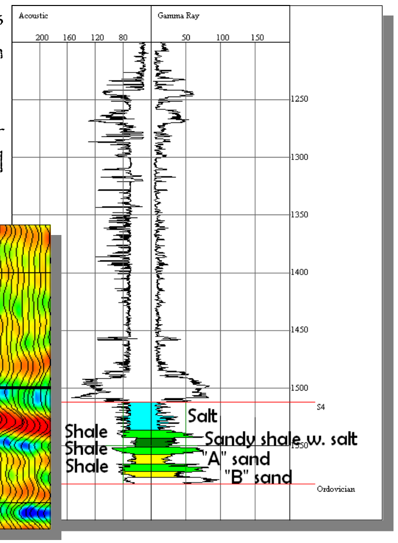
In the oil well the top zone of the "A" sand is siltstone, with very low porosity. This results higher velocities on the acoustic log (kicking to the right). Just below the siltstone comes the clean sand, filled with oil. Then again there is a shale sequence, separating the "B" sand, which contains over pressured water.

Finally, the third well is the rightmost dry hole. Here, inside the covering shale body, there is a higher velocity (and smaller gamma ray) zone, related to sandy shale, where all remaining pores are filled by salt.

Also, the "A" sand is totally plugged by salt.

On the seismic section one can see a reasonable size of fault nearby. It was supposed that the leakage through this fault caused most of the troubles in this part of the reservoir.





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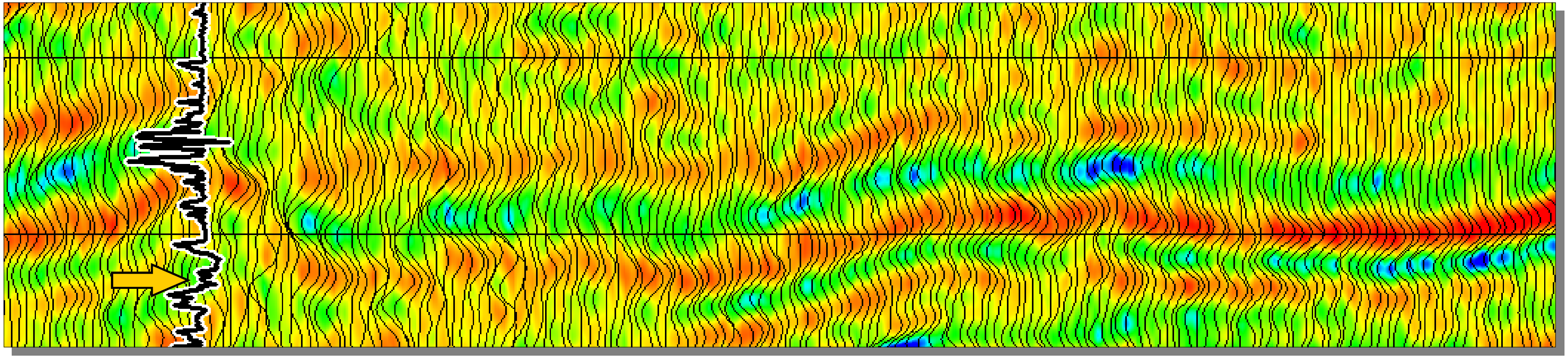
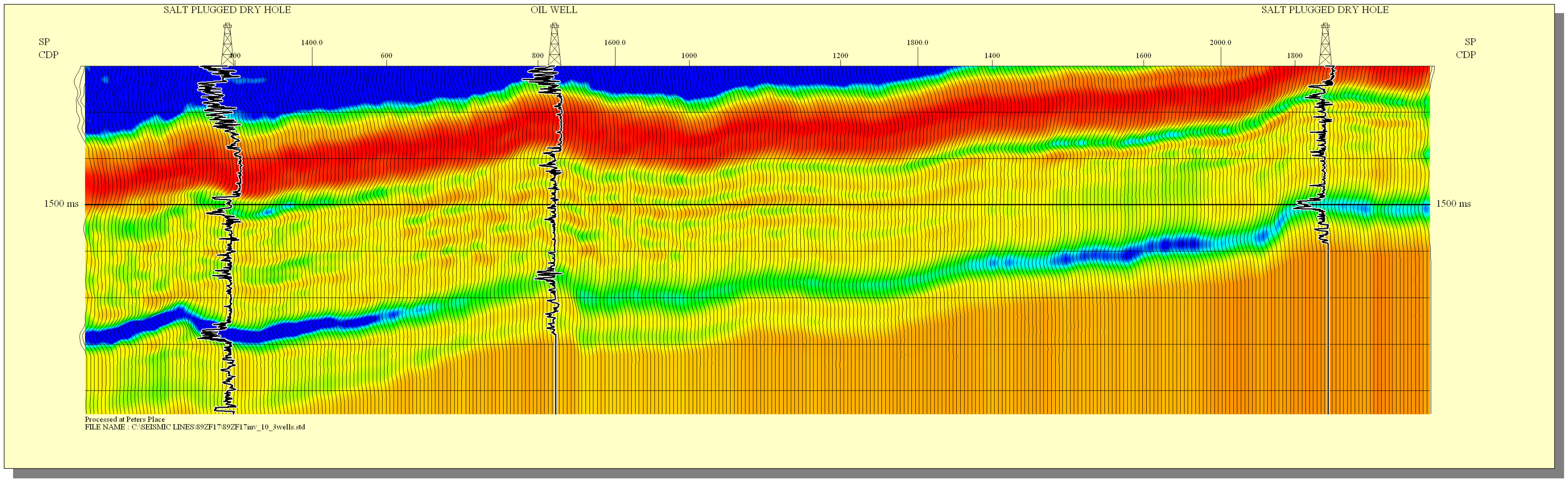
Now, the question is, where is the "A" sand in our new prospect area, and further more, how could one guess, what is filling the pores ?

Looking at the conventional seismic section, either in the normal way, or in the colored form, seriously, no one could answer these questions. Especially, there is nothing characteristic to see on the seismic sections, what could give any hint of what is filling the fabulous "A" sand reservoir.

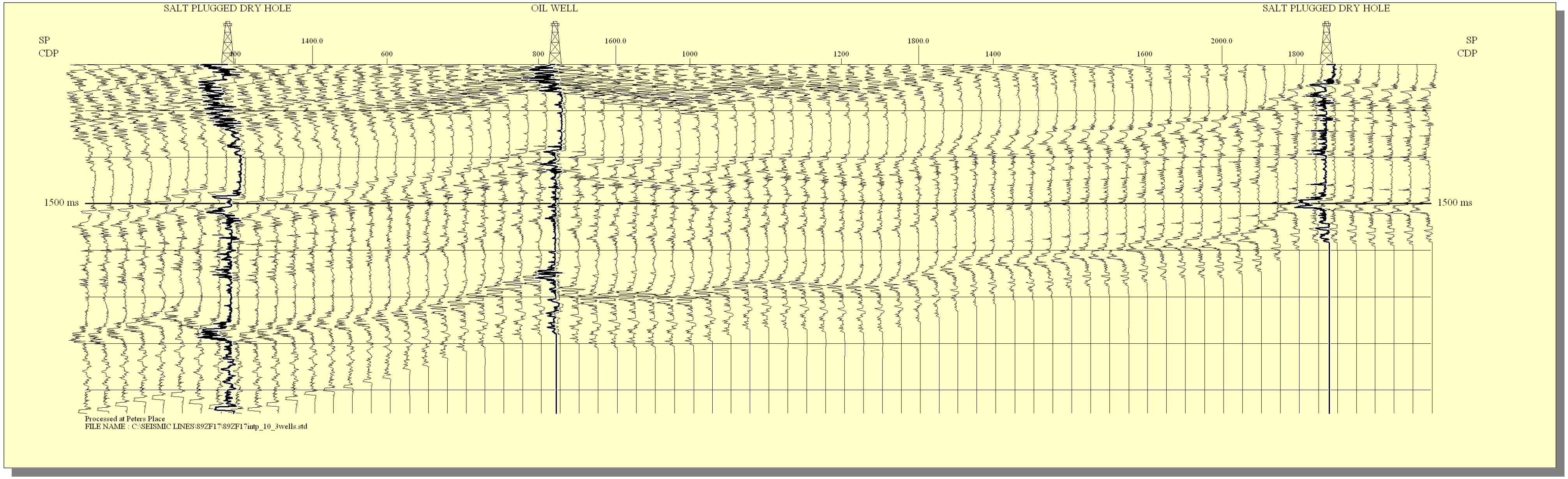


The picture below is a piece from the "inverted" seismic section. Here the same applies, as above, the frequency range, which is limited by the seismic frequencies doesn't allow to go into small details.



The solution is : Log Extrapolation.

The name "Log Extrapolation" comes from the past, when BELVEDERE MAORPET tried to extend log curves horizontally, to the close neighborhood of wells. As the result of later developments, BELVEDERE MAORPET's method became more an interpolation, than extrapolation, where the interpolator function is the seismic time section itself. One has to place the time converted logs on the seismic and the waves will carry away the logs horizontally, filling the gaps between the wells. The method works well with the acoustic logs. Sometimes resistivity type logs can be used as well. Unfortunately the method does not work with gamma ray logs. BELVEDERE MAORPET still puts efforts in further developments, but one has to understand, the acoustic log is the only one, which is some kind of a "relative" of the seismic section.



So we might expect, that the seismic wave knows, how should the acoustic log behave, but it has little idea about other types, such as the gamma ray, or neutron logs.

The picture above shows the acoustic log section, plotted every 25th curves. Since the section is heavily compressed in the horizontal direction, it is difficult to correlate between the curves. Here helps the color display, pictured on the next page.

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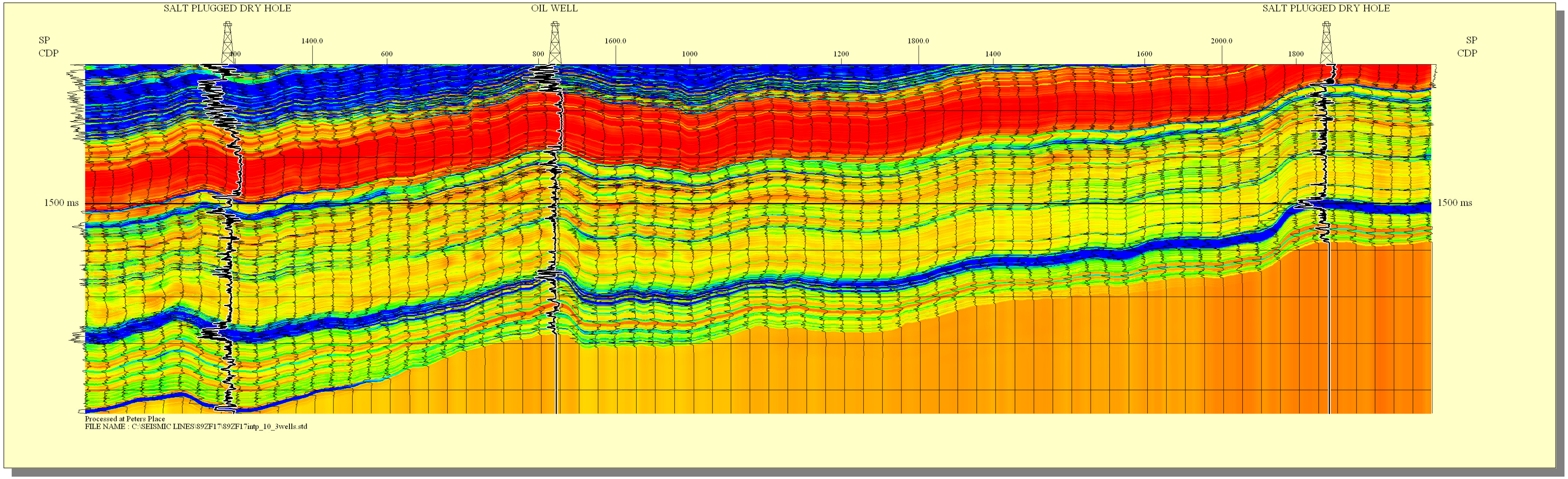
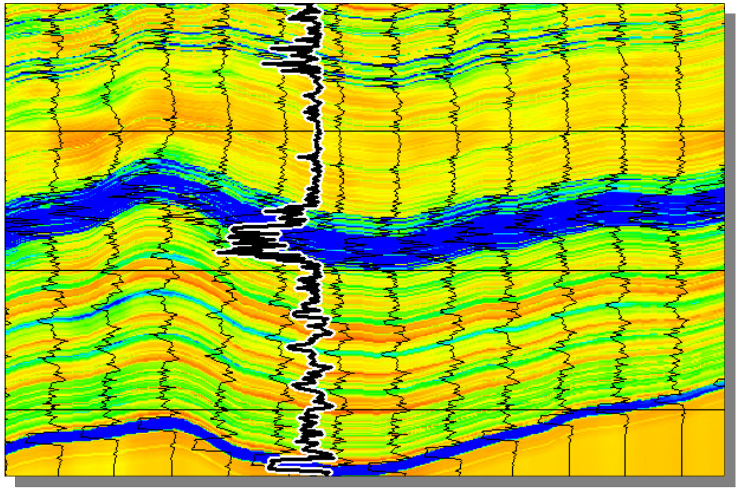
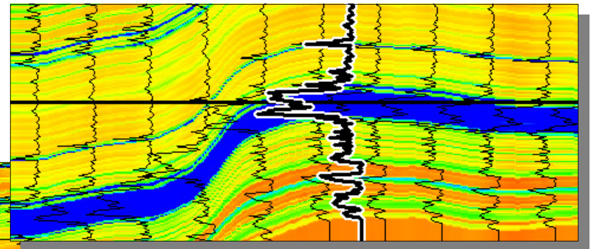
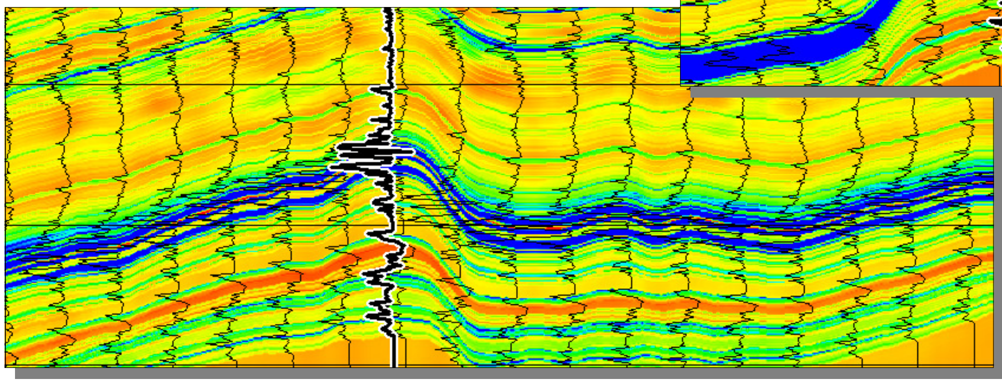


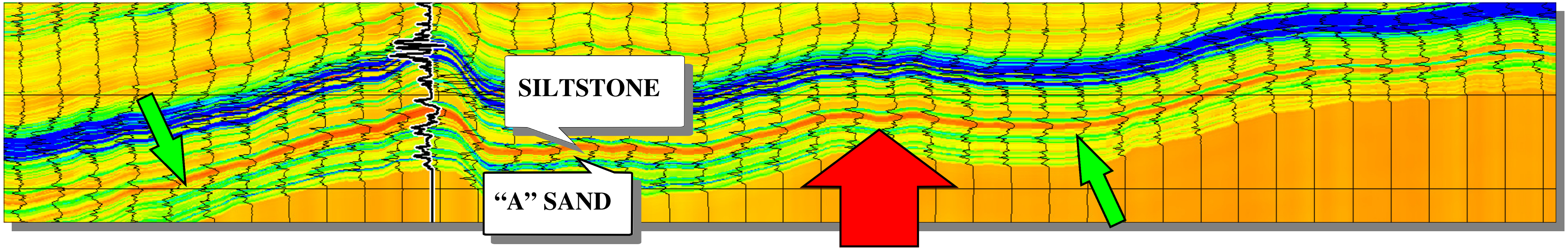


The colors give continuity to the picture, so one can easily recognize and correlate the layers, discussed on the previous pages.





Using the acoustic log extrapolation the first question could be answered. It is easy to follow the siltstone body and to recognize the "A" sand, just below it. Anyhow, the



clear character of the siltstone-sandstone duplex seen in the central oil well fades out after a distance (green arrows). These limits might be the limits of the salt-free "A" sand, out of that salt can be expected in the reservoir.

Why ?

Just because we do know, that in the left and right wells the reservoir is plugged by the salt and this little character change is the only small, detectable difference between the salt plugged and the oil bearing reservoir. This might sound strange, but there must be a point, where one has to detach from the clear physics and has to move to the fields of skill and geological experience.

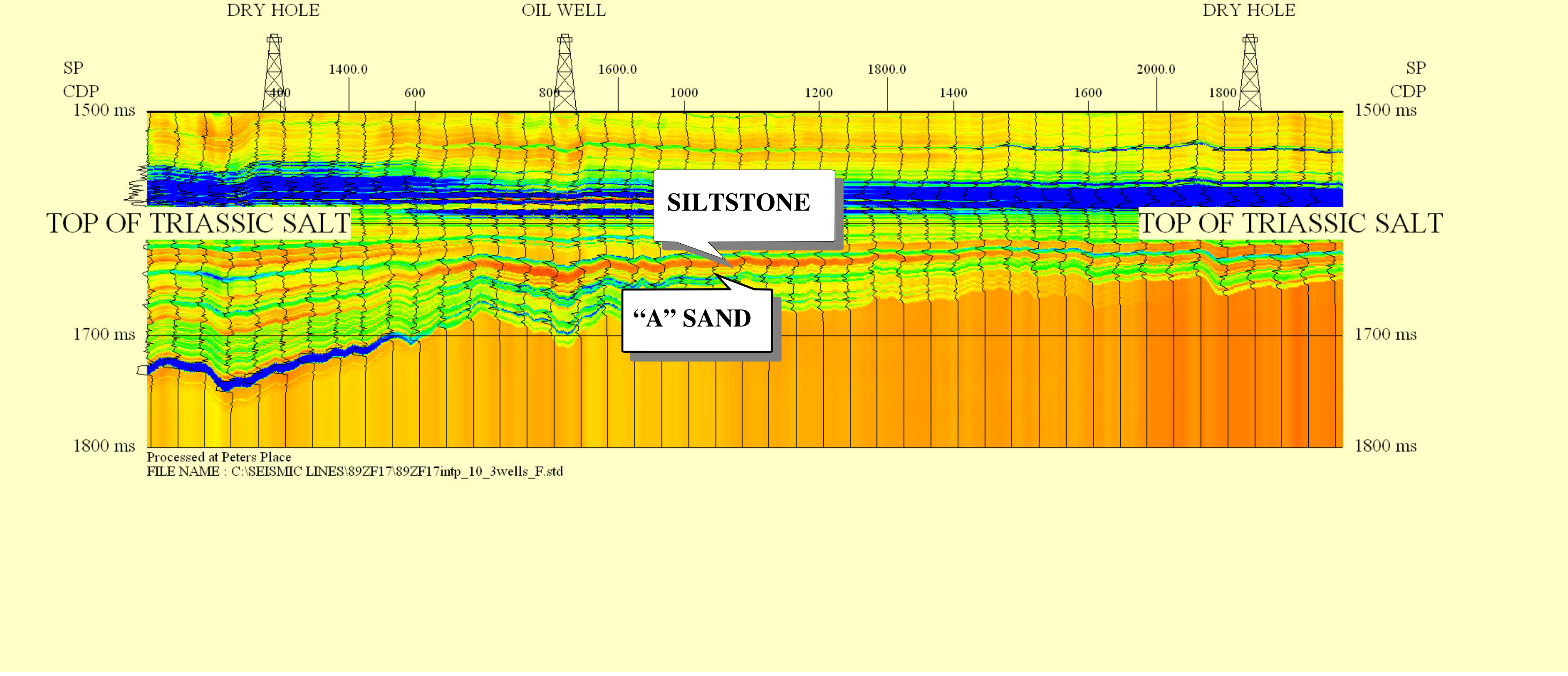
Here you see now, there is indeed a reasonable good reservoir available at the potential prospect location (red arrow). Also, there is a good chance that it is not plugged by salt. The only question remains, what is filling the pores, valuable oil, or simple water ?

To answer the question, you must be familiar with the "secret". There had been several former studies in the area, which have proved that the oil migration took place during the Jurassic time at the "Lias" period.

So, we have to investigate, what was the shape of our reservoir during that specific period. We have to examine, if there had been a chance to trap hydrocarbons at the time of the oil migration.

Also, there is a weak chance to fill a younger reservoir by secondary migration. At later times, especially during the Alpine movements many of the "old" structures opened and the hydrocarbon content migrated away. Unfortunately it is hard to chase, where could those $ valued drops flow away, because a lot of possible migrating ways had already been barred by the salt at that time. It is not hopeless, but it needs further studies. For our "prospect" area, let's stay at the first question : was there a chance for the reservoir to be filled by petrol during the first, genuine oil migration, or not ?

The geologist's best tool is the "flattening". This is what we used to do on the conventional geological cross sections, so why don't we apply it now ? "Flattening" on one specific geological period shows, what was the shape of the already existing layers at that selected time.



First, here is the simplest case. The "top" of the Triassic salt (which is, as a matter of fact the end of the Triassic period) is a well defined phenomena. Let's flatten on this time first.

Here you see the real shape of the "A" sand body. You see the siltstone here as well, but don't forget, the upper part of the sand became silted most probably later on. At the end of the Triassic period, it had to be all sandstone. Of course, you see, it was an eroded, faulted surface, as the result of the end of a dry period. The holes had been filled by shale and later by salt, to arrive to an equalized, flat surface, where the Jurassic period started

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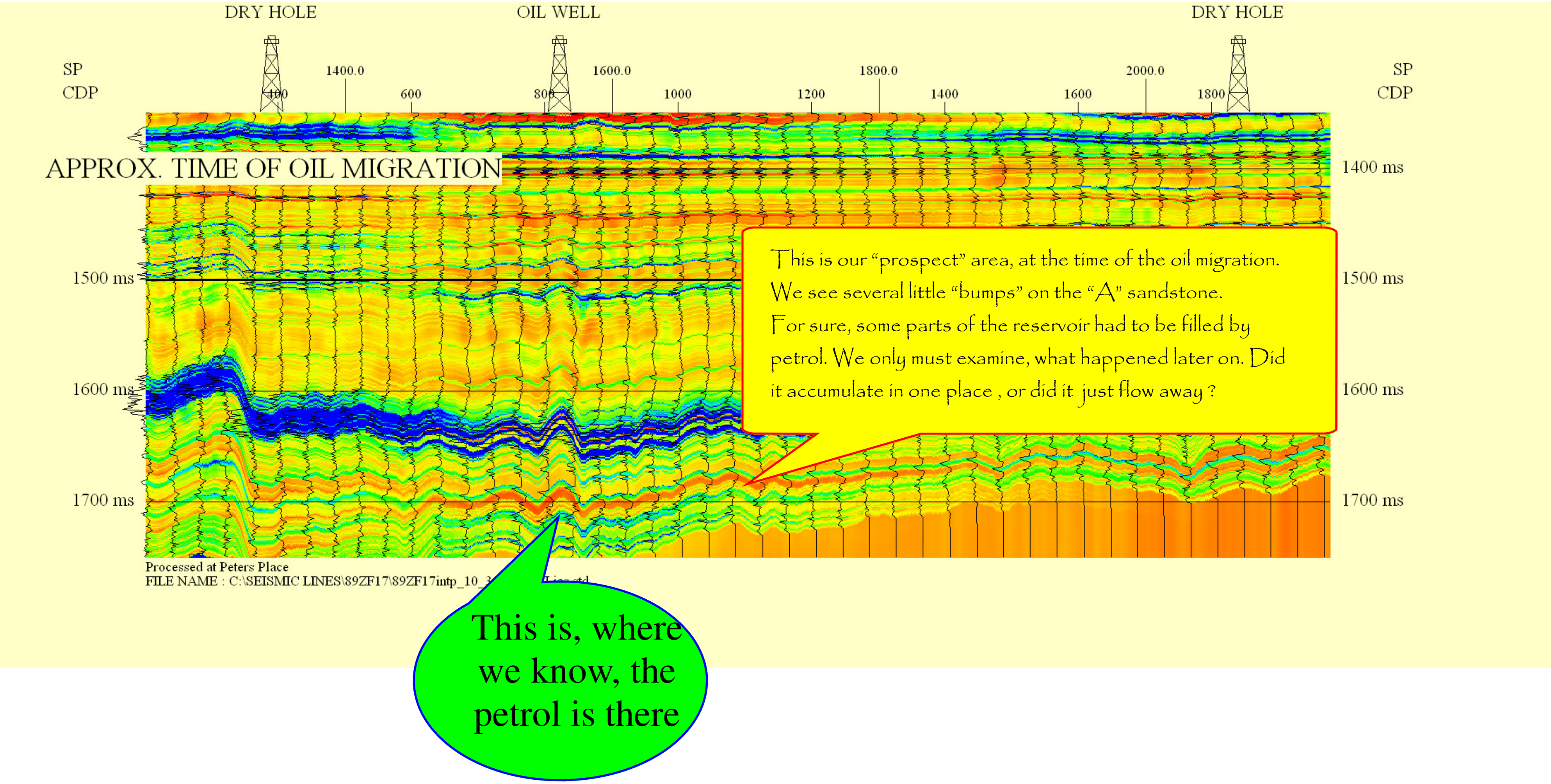
Let's see now the most important : the shape of our reservoir during the oil migration, which had happened somewhere at the "Lias" period. Fortunately, during the "Lias" there was a moment, when strong , regional dolomite sediment was deposited on the top of an anhydrite sequence, giving a nice, recognizable event. Let's flatten on this time now. This is the approximate time of the oil migration.

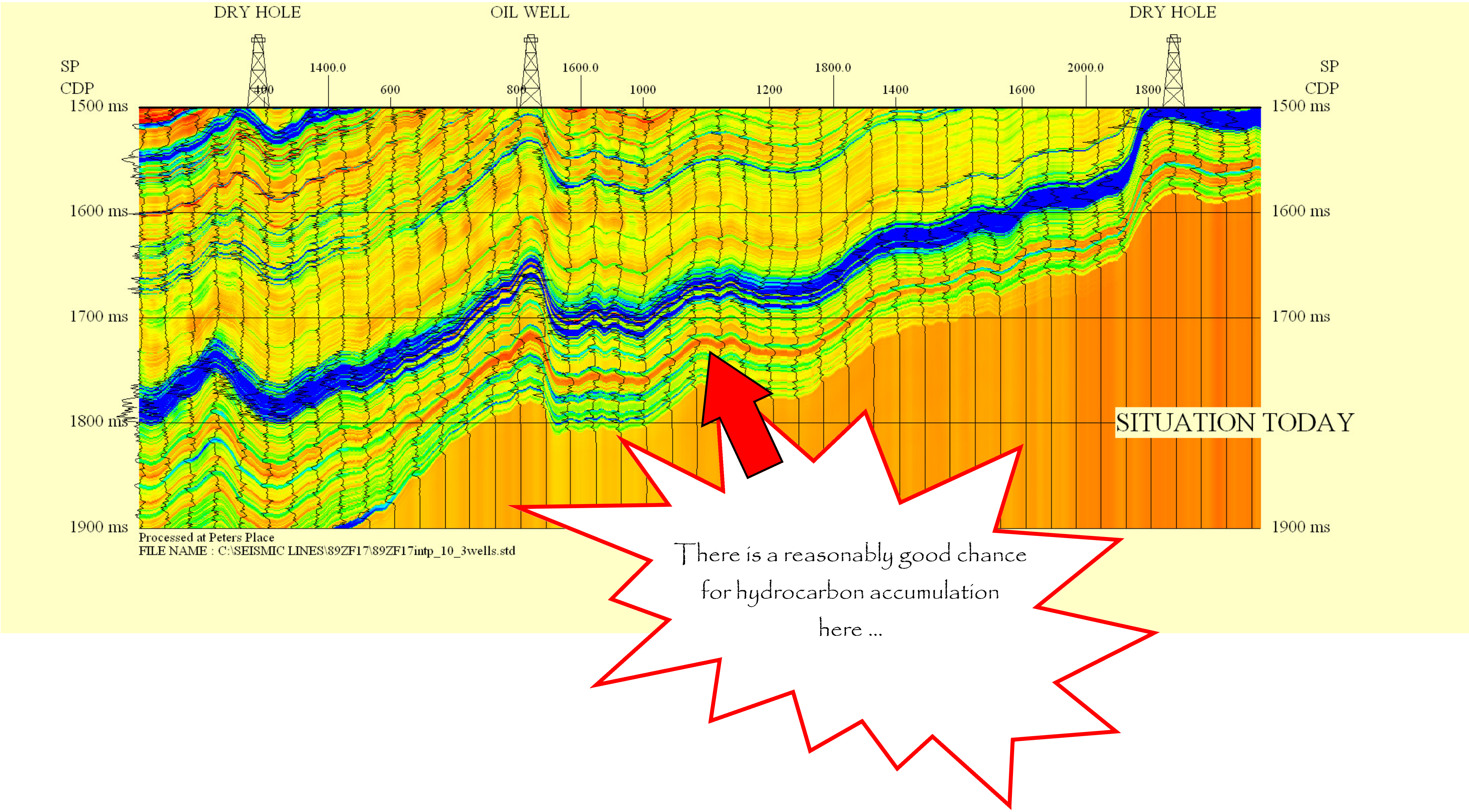
To complete the picture, you also have to know, where did the petrol come from ? This was the deeper part, the Silurian "hot" shale sequence.

So the oil came from the deep part and its migration might had been stopped first by the Triassic shale, but definitely by the Triassic salt, covering everything. It filled all possible bumps of the non plugged "A" sandstone.



Present situation.

As you see here, there was indeed a chance, that the petrol, trapped in the small "bumps", later on accumulated in one big pool. It must be in place, even today.



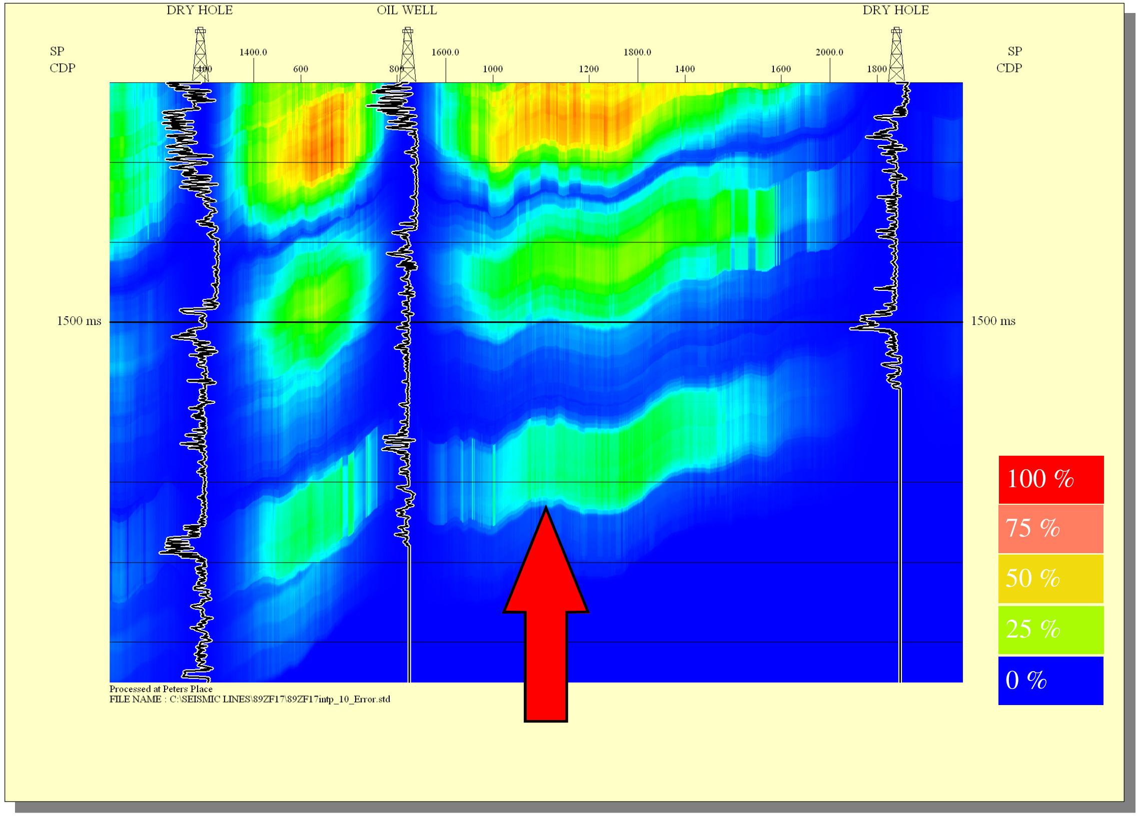
Error estimation, risk factors.

The "Log Extrapolation" method, presented in the former pages might sound like a "hocus-pocus" magic. Nobody can prove that the seismic wave might really "know", how the acoustic log behaves.

Also, there are other risk factors, what must be analyzed. These are for example the presence of multiple type reflections, or diffracted waves, which have really nothing to do with the behavior of the log curves. Also the stability, the noisiness of the section should be examined.

To simplify the possible factors, we will separate two cases.

The first case is, when there is only one well, or maximum two wells available for log extrapolation. This case there is not much to study, since we don't have a reference to check the accuracy of the extrapolated logs. In this case BELVEDERE MAORPET can offer only the accumulated "knowledge" to guess in such and so situations what used to be the expected error.



The second case is, when there are at least three, or more wells available. They don't have to lay along the same seismic line, but there must be enough, similar quality seismic to connect them by a "combined" seismic time section. This case we can exclude one-by one the wells and repeat the extrapolation process along the connecting (combined) seismic line. The accumulated discrepancies will show the validity and "goodness" of the extrapolation.

On this figure the color coding goes from blue to red, blue means no errors, red means 100% expected error. The blue-green patches on the figure correspond to approx. 10-20% expected discrepancy.

The zone of the reservoir at the prospect area (red arrow) is still in the acceptable error range (light blue, approx. 5%), so we can hope, our conclusions are correct.

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