Introduction

During the last years, dramatic innovations have been achieved in onshore seismic processing like 5D interpolation, surface wave modelling, surface related multiple elimination, 3D deconvolution, etc. Most of these technologies take advantage of rich offset wide azimuth 3D datasets but are hard to transpose to 2D seismic.
Therefore, when 2D image did not help exploration, tendency is to jump to 3D acquisition, engaging a significant budget for seismic acquisition, sometime in a remote area with possible HSE exposure.
However, in some cases, considering a 2D reprocessing is worth the investment and could lead to a complete reassessment of a block potential.

This onshore block in Yemen is covered by a grid of 2D lines (cf. Fig.1) acquired in the 90's with typical surface issues like wadis, rocky plateau and a mix of both dynamite and vibroseis sources. Target horizons are heavily faulted with a poor imagery and seismic interpretation is poorly controlled with sparse well data.

Following recent good results from 2D reprocessing in a neighbouring concession, Total Yemen engaged a complete reprocessing of the 2D lines in 2014/15 with Geofizyka Torun. A thorough handling of noise, statics, velocity picking and use of CRS-like technique were expected to bring some uplift in the final image compared to the vintage processing.
This job was also done to understand any potential acquisition parameters optimisation for future seismic surveys.

Eventually, the reprocessing went much further than anticipated and shown unexpected results.

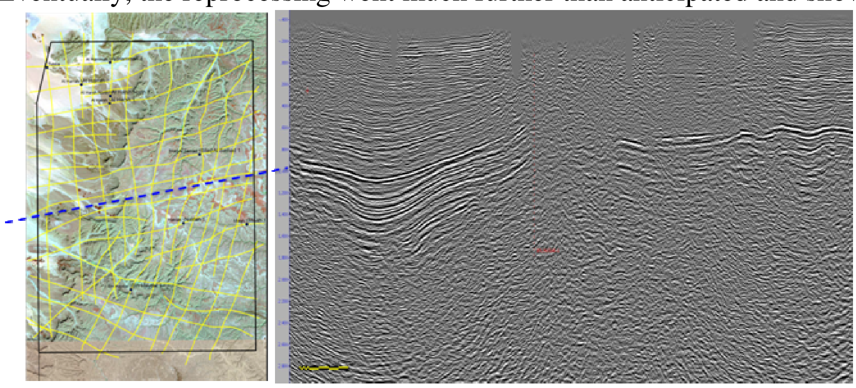

Fig.1: seismic lines location map onshore Yemen – structural framework

Data challenges

All the 2D lines from the survey shown in Fig.1, were acquired using the same spread parameters, sweep frequencies (excepting lines shot with dynamite source), instrument filters, etc. In general, the data is affected by low frequency surface waves and guided waves. Dynamite seismic records are characterized by a higher amount of background noise, which made first breaks difficult to identify and pick. Surface conditions had also a great impact on data quality: seismic acquired on high-elevated plateaus are less noisy, with broader frequency range, while records from valleys (wadis) are very noisy with large amount of low frequency. Previous reprocessing from 2008 was not considered as successful with some line with a very poor stack image (Cf Fig.2).
Identification of main data challenges led to list of several area-specific issues: (1) consistent acquisition geometry had to be reconstructed, (2) initial statics required special attention because of abrupt changes in shallow subsurface velocities, (3) surface and near-surface noise, especially guided waves, needed careful elimination with preservation of all wavefield pieces which can be used to compose final seismic image, (4) moderate stacking fold with gaps in shot gathers because of numerous missing data – not retrieved from archives – caused low S/N and increased ambiguity, (5)

lateral changes in wavelet spectrum because of various surface conditions – fairly hard surface crossed by wadies with a loose material – needed reconstruction of wavelet homogeneous wavelet.

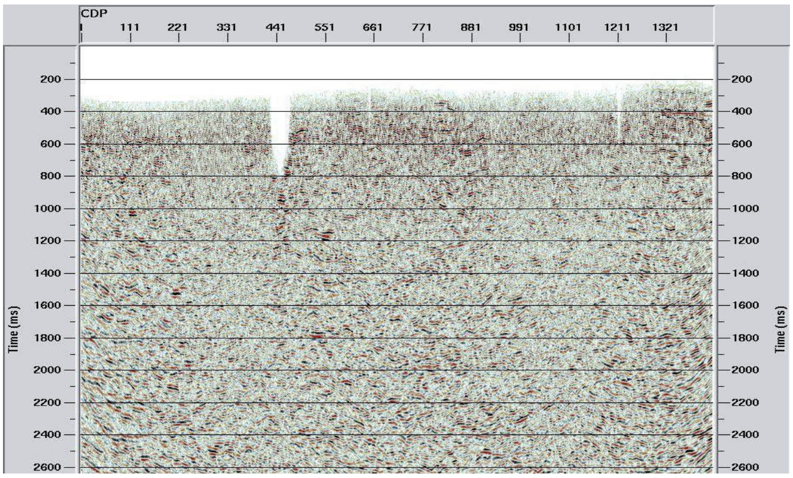

Fig.2. *Vintage seismic section: the worst line of the entire survey to be compared with reprocessing version in Fig.5*

Method used to maximize value of the seismic data

The processing workflow applied to meet challenges of such a project is coming beyond standard scheme, and is briefly described in Fig.4. This workflow is made of classical processing modules, but by using a global approach with multi-lines (ML) QCs, its implementation was optimized according to the data quality. To increase consistency of the final result of 2D multi-line processing, all the lines were processed in parallel, and processing moved to the next step only upon condition the result of ML Mistie Analysis for phase rotation, statics, amplitude, and velocity had been accepted. Let's follow steps and way of work within the workflow outlined in the Fig.4.

At the beginning, reference brute stack was produced with a linear flow similar to the one shown in Fig.4 with a standard residual statics and velocity loop. Result in Fig.3 looks similar to the vintage section (cf. Fig.2) confirming a correct starting point. The flow consisted of initial refraction statics, estimated from first breaks, with interactive (and interpretive) correction of large static errors, and correction for the long wavelength component of statics. De-noise procedure consisted of modelling noise followed by adaptive subtraction, and was charged to eliminate ground roll, guided waves, and preserve diffractions, steep wall reflections, and useful sometimes, the out-of-plane reflections, see [1] for more explanations.

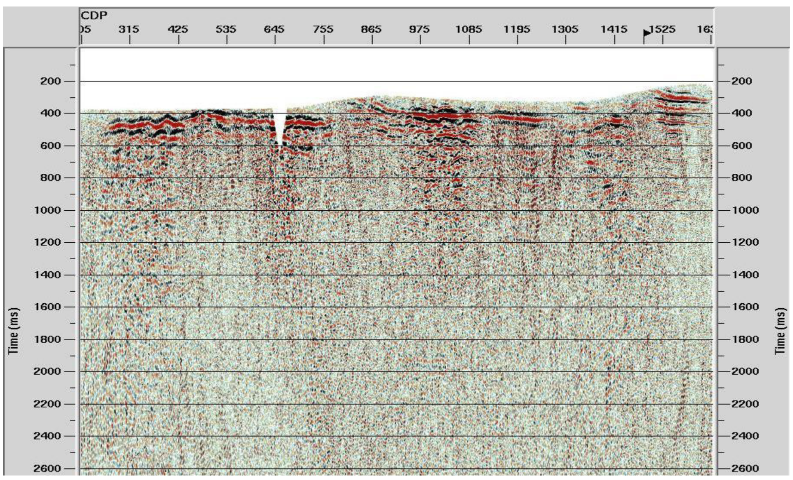

Fig.3. *Brute stack seismic section obtained at the beginning of reprocessing. Vintage result, seen in the Fig.2, is approximately reproduced, and the new brute stack shows superior initial statics.*

A key aspect of 2D land seismic processing in challenging geology is iterative separation of statics, kinematic corrections, some out-of-plane, and cross-dip effects. That is called multi-factor iterative processing (red "loop" in Fig.4). Separation comprises several iterations, usually with possible extra processes applied in between, e.g. noise attenuation, and re-set of constraints e.g. frequency window, maximum time shifts, accepted velocity range. Convergence and correctness of this multi-factor procedure are actively supervised internally in processing team, and by geologist expert from the area. Success of the separation and turnaround time depend on experience of processor: order of separated factors, weights of corrections, and possible repetitions. Multi-line, interactive, and iterative approach make the approach immune to irregular gaps in the data, and to ambiguities – intrinsic property of 2D seismic. The methodology applied in this project is time-consuming, but can extract new quality image from the old seismic without new acquisition at low cost. Improvement is visible iteration by iteration, and the stack of the final result can be seen in Fig.5.

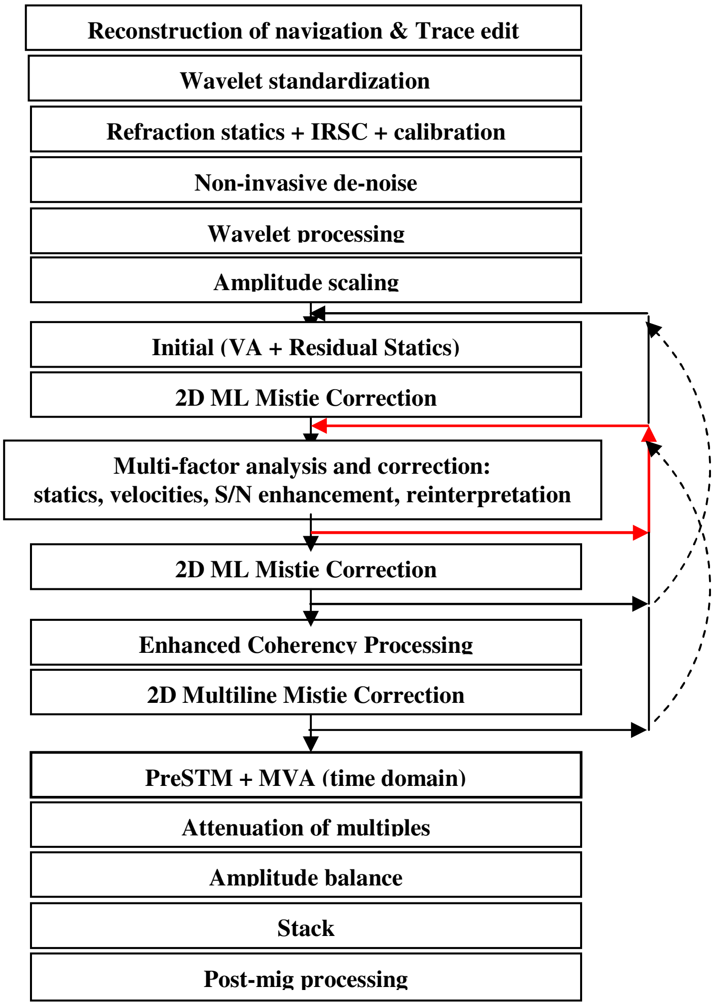

Fig.4. *Simplified flowchart of the reported processing. Continuous arrows point at iterations selected more frequently. The routine loop is in red.*

Enhanced Coherency Processing (refer to [2] and [3]), looking for coherency within 1st Fresnel zone, brought improved S/N. That enabled improved solutions for statics and velocity with geophysicists getting new perception of the area geology. This new workflow entailed more iteration of multi-factor analysis and correction. However, that created new value for the project, and the additional associated steps of the 2D processing are fairly fast to implement. The focus of such 2D seismic reprocessing projects moves from automatic to much more interactive work, some can say hand-made products.

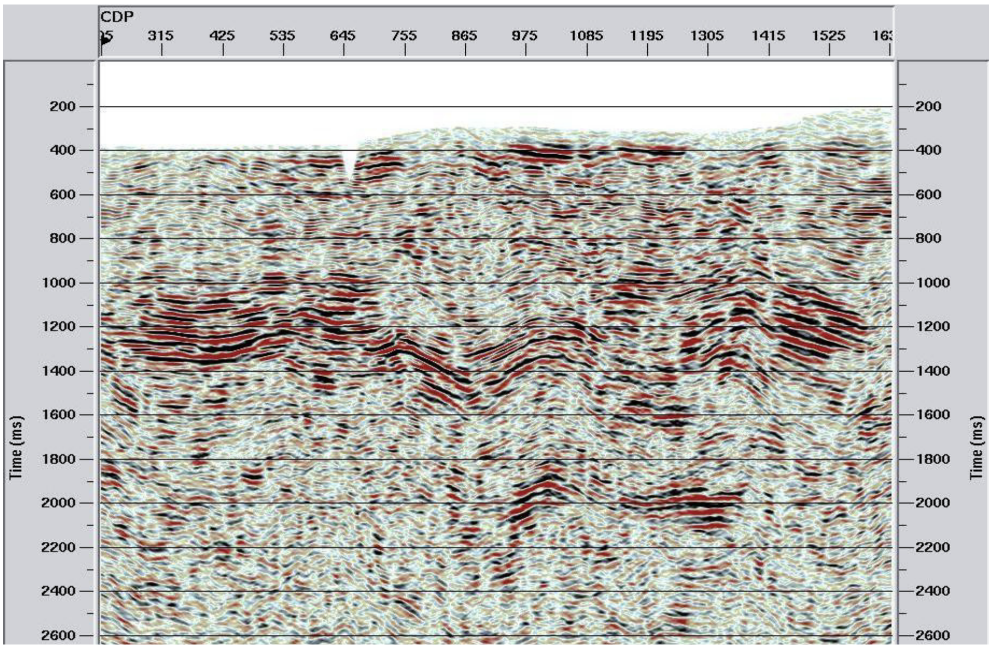

Fig.5 *Final stack of the same seismic line as Fig. 2 and Fig. 3 after reprocessing.*

Conclusions

The other lines of the survey are of the same quality but the uplift is not so dramatic, as the corresponding vintage stacks were of better quality which is odd as the acquisition parameters were identical.

This reprocessing project is potentially a game changer for the block prospectivity. Before the final migration, it was considered to engage a 3D seismic acquisition in a challenging terrain with difficult access and many other HSE threats. Interpretation is on-going and there is a possibility to locate a well without shooting a new 3D seismic at a huge cost.

It also a reminder that it is worth reprocessing a data-set as part of an acquisition feasibility study even if there is a very little chance of success.

But the main wake-up call is to realize how important is the processing geophysicist experience and knowledge. Technology alone is not sufficient to maximize the value of a seismic dataset and nowadays 2D datasets are often seen as old data with no value when they can, in some cases, save time and money in a world where exploration cycle periods are shorter and shorter.

Acknowledgements

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References

[1] Tlalka, S., 2015, Amplitude preservation in non-invasive methods of land noise elimination, 77th EAGE Conference and Exhibition 2015.

[2] Tlalka, S., 2014, Enhanced Coherency Processing ECP-2014. Technical Brochure available from www.gtservices.pl

[3] Civello, S., Janisek, J.M., Strobbia.C., 2D seismic line reprocessing test using common reflection surface technique, 12th Offshore Mediterranean Conference and Exhibition 2015