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Automated and Real-time Field PSTM - How to QC More Efficiently 10 Billion Traces Today and More Tomorrow

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SUMMARY

A new automated and real-time field Pre-Stack Time Migration (PSTM) system and method has been developed and was applied during the acquisition of an onshore high-density 3D WAZ survey in Oman. During this five-month acquisition period, the real-time field PSTM system was used to migrate more than one million vibrated points (VPs) for a total of around 10 billion traces. Using a single standard computer, we incrementally generated a real-time field PSTM cube as the seismic shots were recorded. The incremental PSTM cubes were available in the field at any time during the acquisition for instantaneous quality control. Daily automatic reports and migrated seismic data were sent to the end users (i.e., client and processing center). Immediately after the last recorded VP, the complete field PSTM volume was ready to be delivered. The system is designed to work autonomously on a basic desktop PC and does not require extra staff. It is operational for almost all types of acquisition (land, marine, and seabed) regardless of the recording system.

Introduction

Real-time acquisition quality control faces new and very real challenges. In the Middle East, the data quantities we need to control in the field have increased exponentially over the last decade. This trend is particularly true in the case of 'mega-crew', blended, single-sensor, high density, and wide-azimuth acquisitions (Shabrawi et al., 2005, Meunier et al. 2008).
In other parts of the world, seismic exploration is carried out in unconventional areas (rainforest, foothills) where acquisition conditions are challenging (Munoz et al. 2015). For these acquisitions, the ability to control the data quality in real-time is an enormous advantage. In other strategic exploration areas, unstable geopolitical conditions make it hazardous to have quality control staff permanently in the field. Faced with these challenges, we propose a new quality control tool that performs real-time pre-stack time migration (PSTM) in the field autonomously and automatically taking into account the global quality of the seismic data during the acquisition.

PSTM is usually considered as an end-product, and it is generally performed in a processing center once the whole dataset is available at the end of the acquisition. PSTM is known to be computer time-consuming and it requires a few days (or weeks for recent massive datasets) to be run on a high-power (and costly) clustered computer system.

In our solution, called TeraMig, we propose real-time field PSTM that is implemented directly in the field and takes advantage of the acquisition period to run PSTM in a recursive and incremental manner. The data is migrated for each vibrated point (VP) one after another. The goal is to provide high-level quality control that evaluates the raw quality of the seismic in the image domain. The goal of the real-time field PSTM is not to replace the end-product PSTM but it could very well replace the field stack control.

Computational effort and cost

As opposed to the post-acquisition PSTM carried out by high-qualified processors in the time-pressured processing center, we have plenty of time to run the PSTM in the field. We can use the whole acquisition period of several months (Figure 1). This allows us to use a much reduced computational effort, sized to follow the acquisition production of a few seconds between consecutive VPs in high-density land acquisition (Pecholcs et al., 2010). Hence the total computational effort for real-time field PSTM is spread over the whole acquisition period using simple, standard (low-cost) computers.

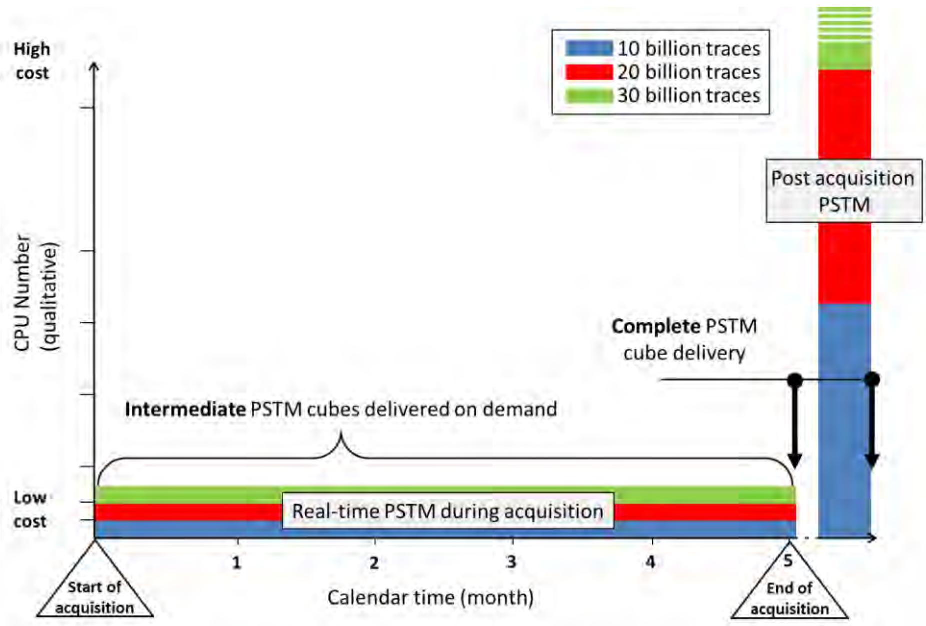

Figure 1

Comparison of computational effort between real-time field PSTM and post-acquisition PSTM.

Computational effort is represented by the surface of the colored rectangles which is equal to the computing time multiplied by the number of CPUs.

Network design

Seismic surveys are often carried out far away from the processing centers. Expensive and limited satellite connections remain inadequate to transfer the huge amounts of raw VP data. When the field location is not relatively close to the processing office, tape transfer by physical ways (truck or air shipment) from the field to a processing agency is considered as an issue (Duncan et al., 1997). Finally, data transmission would not be feasible in our case study and in most of the Middle East acquisitions (time constrain, cost and HSE). This explains why the proposed system is implemented in the field. Moreover, as the PSTM is done automatically in the field, the updated field PSTM cube can be continuously controlled by the field geophysicist in charge of the data quality control (Figure 2a).

The proposed system is designed to send samples of the field PSTM cube to a processing center (Figure 2b). In this case study, the satellite connection is extremely limited and only established once daily within a short, underutilized time window at night. This connection is nonetheless sufficient for transmitting inlines, crosslines, and even several time-slices on a daily basis. This enables the project staff in the processing center to remotely follow the building of the field PSTM cube during acquisition on a daily basis.

In the processing center, the data received daily is automatically organized and displayed in a report file (pdf format). It is then automatically sent worldwide to end users via intranet or internet so that they can follow the building of the field PSTM cube while acquisition is ongoing (Figure 2c).

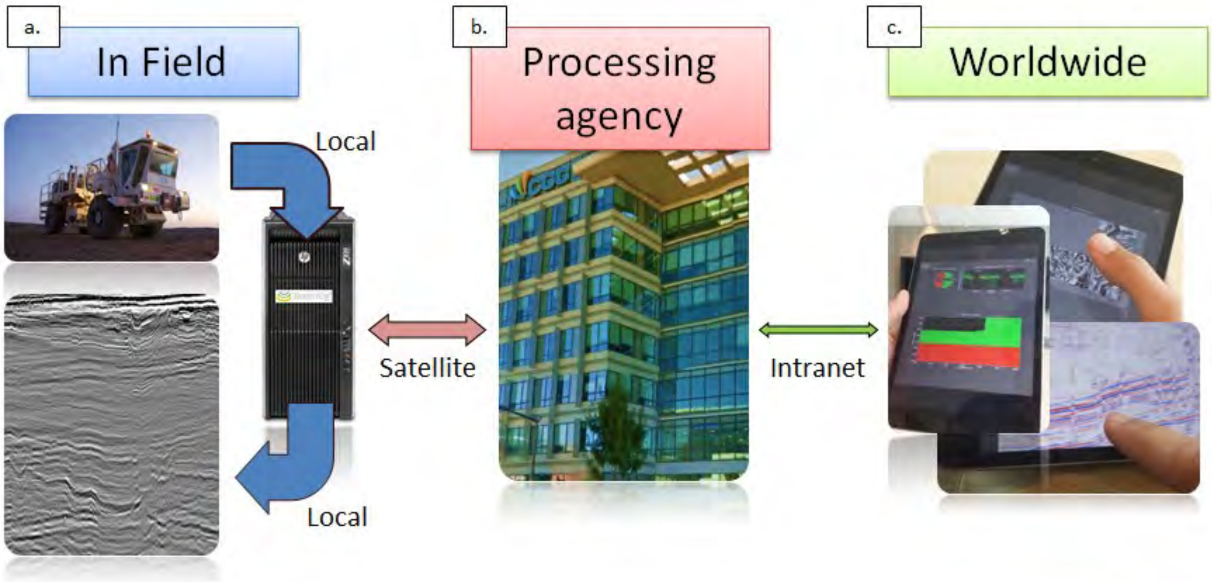

Figure 2 *Real-time automated field PSTM network.*

Results

The dedicated computer processed the raw VP data with only one intervention needed to reboot subsequent to a seismic crew global power down. The application proved remarkably stable given that it operated autonomously 24/7 during the five months of acquisition. The real-time field PSTM migrated around one million VPs representing 10 billion traces.

In this case study, we used one desktop computer powered by 8 cores, each cadenced at 3GHz. The computer had 32GB of RAM. With this quite light computer capacity, we have been able to process an average of 15,000 VPs per day (one VP processed every five seconds) that proved sufficient to follow the real-time seismic acquisition rate. Figures 3a and 3b illustrate typical daily reports sent to the end users. In Figure 3a, the pie chart shows the status of the field PSTM cube completion as well as the total count of processed VPs up to a given day. In Figure 3b, we show the processing of the VPs as a function of time during the same given day over the two acquisitions shifts at 6 am and 6 pm. The duration of the processing per VP is not constant but depends on its maximum offset, its position compared to the field PSTM cube (edge effects), and the number of active channels selected.

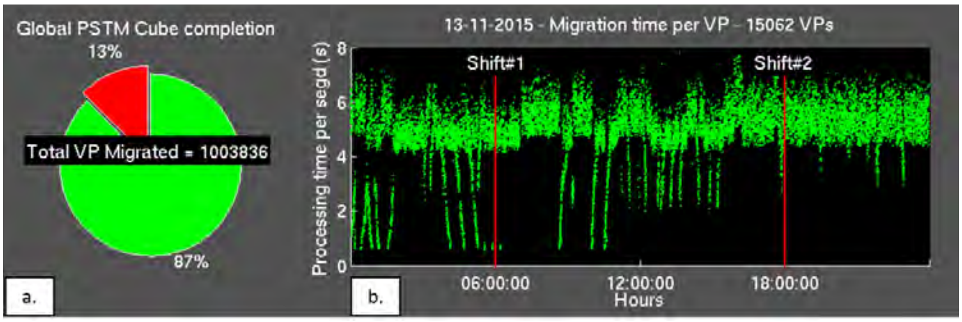

***Figure 3** Operational results as of 13 November (extract of the automated daily reports).*

We compare the real-time field PSTM (Figure 4a) and the conventional field stack that is produced weekly by the quality control geophysicist in the field (Figure 4b). The field stack pre-conditioning embeds elevation statics, random noise attenuation, ground-roll filtering, amplitude equalization, predictive deconvolution, normal move-out, and stretch mute adjustment. By comparison, the proposed automated real-time field PSTM pre-conditioning is composed of only two steps: automatic high-energy noisy-trace detection and edition and elevation statics. Compared to the field stack, the real-time field PSTM has improved continuity and shows better imaging of the deep structures including faults and anticlines. PSTM is naturally a very good de-noising technique.

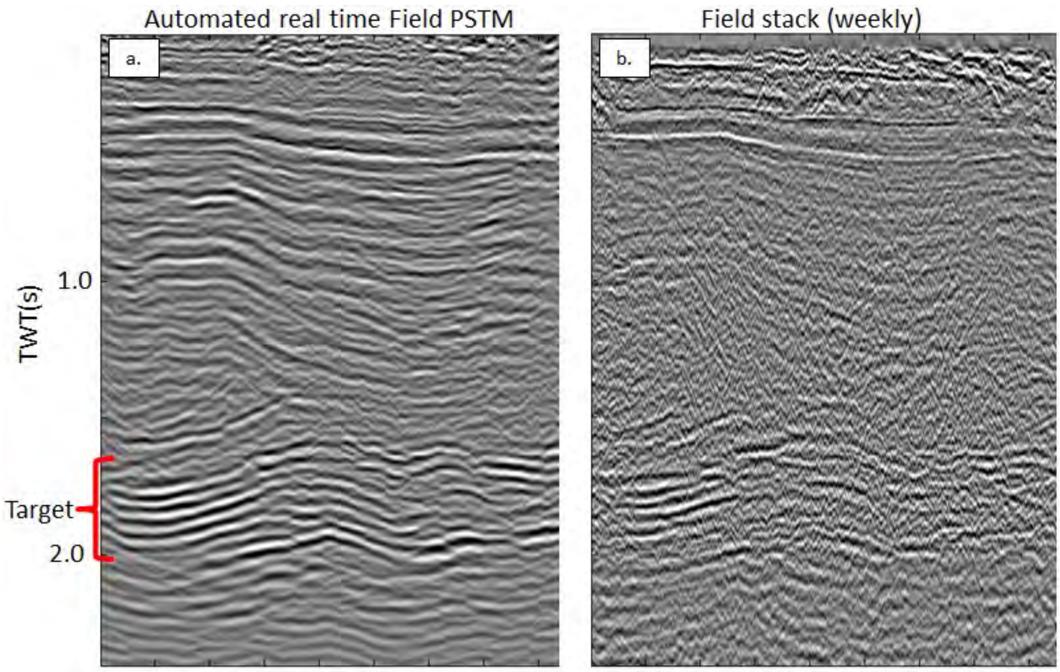

***Figure 4** Comparison of the seismic images obtained during the acquisition: automated real-time field PSTM (a) and field stack (b).*

We can then compare the real-time field PSTM with a post-stack time migration following the end of the acquisition (Figure 5). The post-stack time migration pre-conditioning embedded all the processing steps used in the field stack. Firstly, we observe that the two images are consistent despite different pre-conditionings. However for the deep events (below 2 seconds), including the target, the imaging quality is better on the real-time field PSTM both in terms of continuity and fault definition. This can be explained by the efficiency of the compared technique (pre-stack migration vs. post-stack migration) and the pre-migration de-noising used to obtain the field stack (and the post-stack migration). Perhaps the pre-stack de-noising, particularly the ground-roll filtering, was too harsh. This is sometimes the case when applying ground roll filtering and only looking at shotpoint gathers (and not migrated data). As a result, the ground roll filtering may have affected primary diffractions as well. Note that the shallow data quality is better on the post-stack migration. This is explained by a better fine-tuning of the stretch mute used in the field stack (and the post-stack migration).

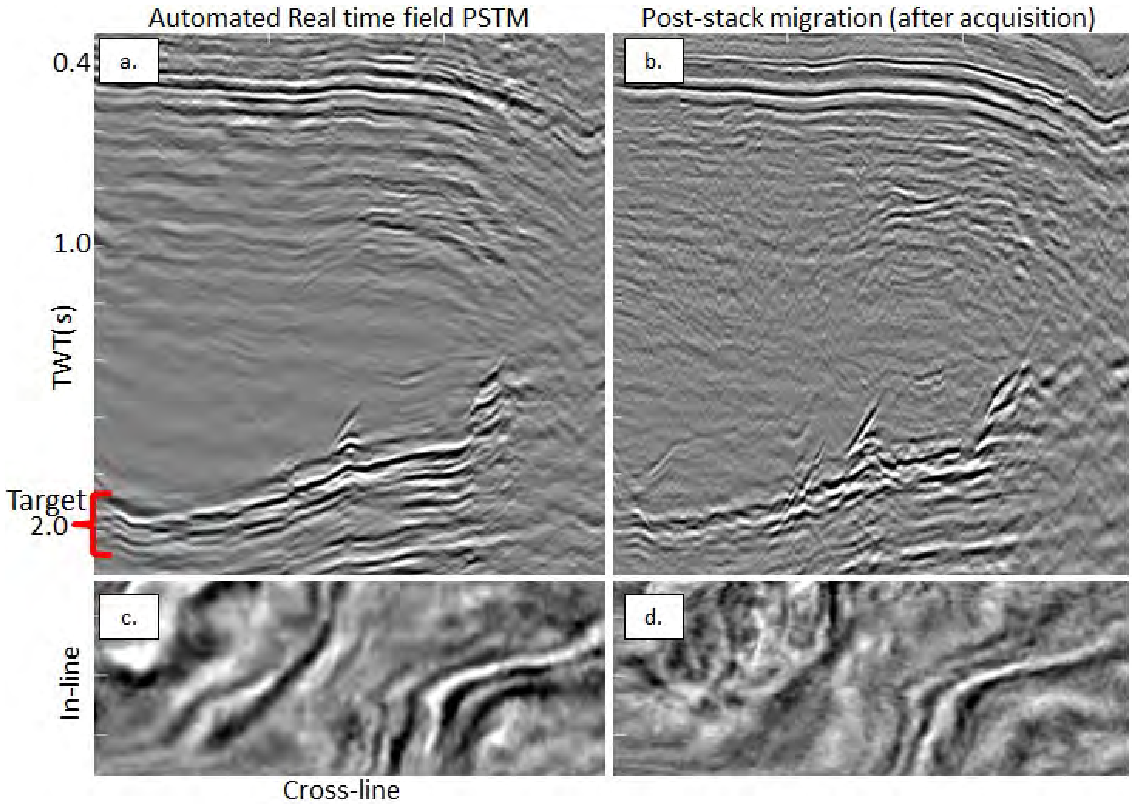

Figure 5 *Real-time field PSTM, (a) and (c), and the post-stack time migration, (b) and (d). Inline sections are displayed in (a) and (b). Time-slices at 2 seconds are shown in (c) and (d).*

Conclusion

In this paper, we demonstrate that true real-time field PSTM is achievable in the case of massive 3D WAZ data, even with limited computer capacity and without extra staffing. The proposed system opens a window on new aspects of quality control in the imaging domain. As well as being an operational success, this first test shows that we can get high-quality results with basic data pre-conditioning. The real-time image allows us to estimate the multiple content, statics issues, and velocity model imperfections. By knowing where to concentrate efforts in terms of processing, we have already gained a significant advantage that allows us to achieve more advanced processing in the seismic imaging center.

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