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3D SEISMIC APPLICATION FOR MAE MOH COAL MINE DEVELOPMENT

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ABSTRACT:

The Electricity Generating Authority of Thailand (EGAT) requested CGG Services SAS to make a high resolution integrated acquisition-processing-interpretation seismic 3D survey over the Mae Moh lignite mine in northern Thailand. The target was two coal seams at a depth of 100m to 600m below ground surface.
The objective of the seismic survey was to image the coal seams and associated fault networks, and from this to better plan future mining operations, in particular how to avoid potential landslides during further excavations. The resultant well imaged geological structures are very useful in future development of the open pit mine.

KEYWORDS: *Mining/Geology/Geophysics/ Seismic / Coal/*

Introduction

Exploration in the coal industry is commonly based on geological cartography and intense drilling designed to describe the terrain, and cores are extracted for mineralogical and chemical analysis to map the coal quality. The issues linked to near-surface mine or open pit development is to identify the volume of coal in place, the structural map of the play and to de-risk any kind of geo-mechanical hazard that may affect the development and planning of the mine.

Traditionally there is very little use of geophysics in open pits or shallow coal mines. In other mining industries, for base metals for example, some geophysical potential methods are used.
We will see how a high resolution integrated acquisition-processing-interpretation 3D seismic survey allows obtaining an indirect characterization of the rock physics properties sufficiently reliable in its accuracy to help manage decision making for the mine development.

Among the geophysical methods available, the only one able to map in detail the coal layers is the seismic method. At Mae Moh, the impedance of the lignite is rather low, having a velocity of 2200m/s and a density of 1.4, to be compared to surrounding claystone rocks at 2400m/s and a density of 2.0.

Objectives of the survey

The geological targets of the Mae Moh survey are the economical K and Q coal seams (Figure 1) from a depth of 100m to 600m below ground surface.

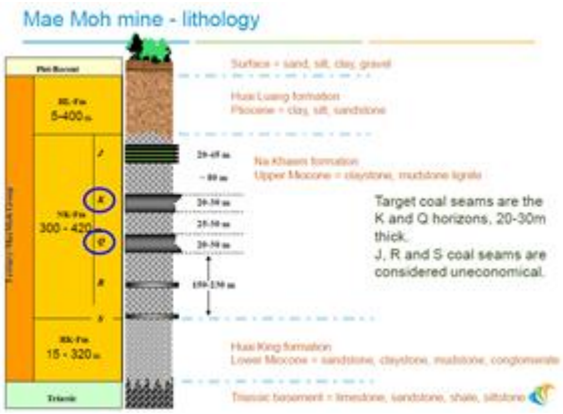

Figure 1 *Geological section at Mae Moh mine.*

Figure 2 *K (top) and Q (lower) coal seams.*

The stratigraphic sequence of the basin is:

- Superficial gravels and alluvium (weathering layer).
- The Huai Luang formation consisting of up to 400m red claystone (main overburden layer).
- The Na Khaem formation made of 300-420m grey claystones containing several lignite beds as the targeted 20-30m thick K and Q seams (Figure 2) separated by 25-30m of claystone.

What EGAT are primarily worried about are slope stability problems. Plotted in Figure 3 are:

- The two coals seams: K (blue) and Q (purple).
- Bedding planes in claystone rock (red).
- Major faults that have previously moved the coal seams relative to the claystone rock.

The two coal seams (Figure 3) are currently stopping the claystone slipping downhill along the bedding planes. The issue is that digging up the coal would create a hole and in case of monsoonal rains the whole claystone rock mass can slip and cause a landslide.

The design of the slopes is one of the major challenges at every stage of mine planning and operations. It requires specialized knowledge of the geology which is often complex in ore occurrence and characteristics when structural geology and/or alteration may be key factors, and of the material properties which are frequently highly variable.

The aim of any open pit mine design is to provide an optimal excavation configuration in the context of safety, ore recovery and financial return. Mine owner expects the slope design to establish walls that will be stable for the life of the open pit which may extend beyond mine closure. At the least, any instability must be manageable. It is essential that a degree of stability is ensured for the slopes in large open pit mines to minimize the risks relate to the safety of operating both life and assets, and economic risks to the reserves.

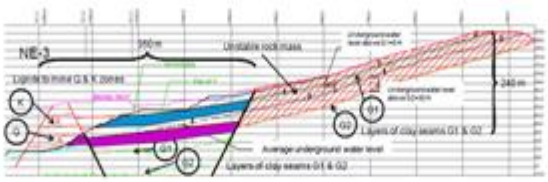

Figure 3 *Representation of the slope stability problem at Mae Moh mine.*

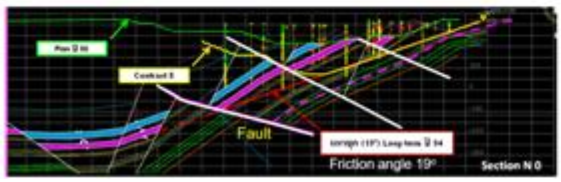

Figure 4 *Section of the pit - green curve is the current elevation profile - yellow curve is the future shape of the pit*

In summary the objectives of the 3D seismic survey is to see if high resolution3D seismic can:

- Accurately image and locate in depth the coal seams themselves and the faults (Figure 4).
- Improve the safety of the mining operations through better understanding of the slope stability.
- Better plan for the future mining operations over a surface acquisition area of 3km².

Challenges of the survey / Seismic parameters choice

The main challenge to the acquisition of seismic data was the high level of noise associated with the daily mining operations as conveyor belts, excavators and moving dump trucks. Good quality seismic data can be recorded, but the noise levels generated by mining activity are too high (Figure 5) and we had to wait for a period of conveyor belt maintenance.

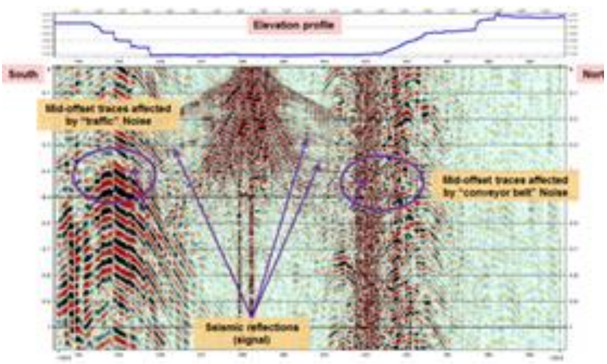

Figure 5 *Noise: traffic and conveyor belts.*

Figure 6 *Vibrator truck at Mae Moh mine*

Such a high resolution 3D seismic survey followed these recommendations:

- Short interval distances between vibrated points (VPs) and receiver points (RPs).
- Wide azimuth, i.e. a large range of SP-RP azimuth vectors,
- Broadband seismic signal to enhance the temporal resolution: sweep (40s) between 8 and 180 Hz with a 6dB/oct increase between 60 and 120 Hz to emphasize the high frequencies.
- Small vibrator mini-buggy (Figure 6), 8.4t and only 2.4 m width for a 15000 lb peak force.

CGG's latest fast acquisition proprietary technology (SRS), coupled with Sercel Unite wireless recorder were used. 5 autonomous vibrators were mobilized, each working with a different sweep enabling the overlapping in time between different vibrators. Acquisition of the 3D survey took place in December 2014 over 6 days, when the conveyor belt was under maintenance.

The main challenges for the processing performed in CGG's Bangkok processing centre were: noise attenuation (industrial, ground-roll), maintaining sufficient resolution (spatial and temporal) to image the faults and coal seams, correct imaging resulting from migration and accurate velocity field for subsequent depth conversion.

Interpretation

Data interpretation took place at GGG's Robertson office in UK. Figure 7 shows a 2D section extracted from the 3D seismic volume. The top and base of the K and Q coal seams can be delineated and also some reflections from the shallower thinner coal seams. The basic steps of interpretation consist of:

- Study 3D seismic data volume and overview structural trends.
- Identify top and base of the K and Q coal seam horizons and tie them with borehole data.
- Identify and interpret any faults in the coal seams, inter-burden and overburden.

The resolution is 5 m for the shallowest coal seams at 100-200m depth. When they are deeper at 600m depth, the resolution is 7 to 8 m. For coals seams thinner than the vertical seismic resolution, the hanging wall and footwall reflectors appear to merge (Figure 7). It is linked to the dominant frequency at horizon and vary across the area (Figure 8).

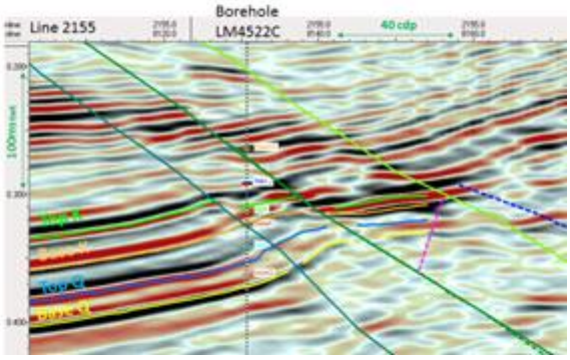

Figure 7 *Line 2155 with borehole LM4522C - K coal is 12m and Q coal is 24m thick.*

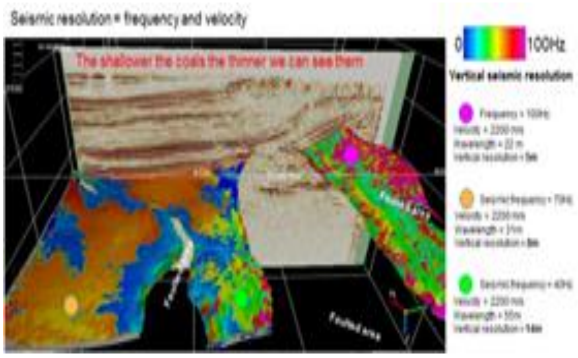

Figure 8 *Q Coal HW: example of vertical resolution.*

The seismic in-lines and cross-lines are used in conjunction with the time-slices to assist in determining the dip direction of the faults, in addition to aiding the accurate positioning of fault planes (Figure 9). More complex fault geometries involving drag folding and thickness changes are also imaged in the seismic data (Figure 10).

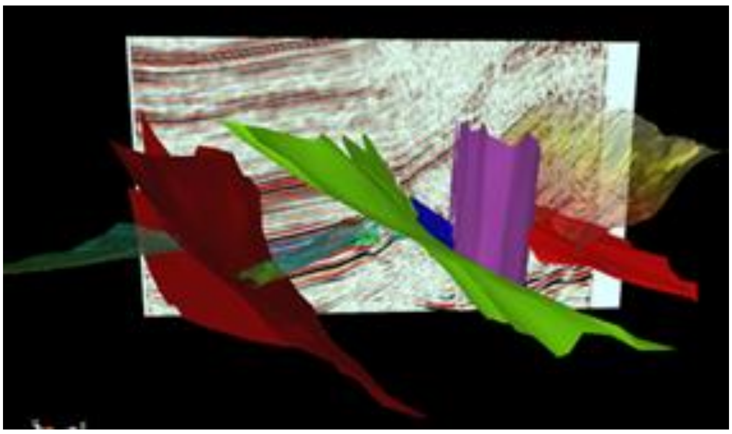

Figure 9 *Eastward dipping faults along inline 2217.*

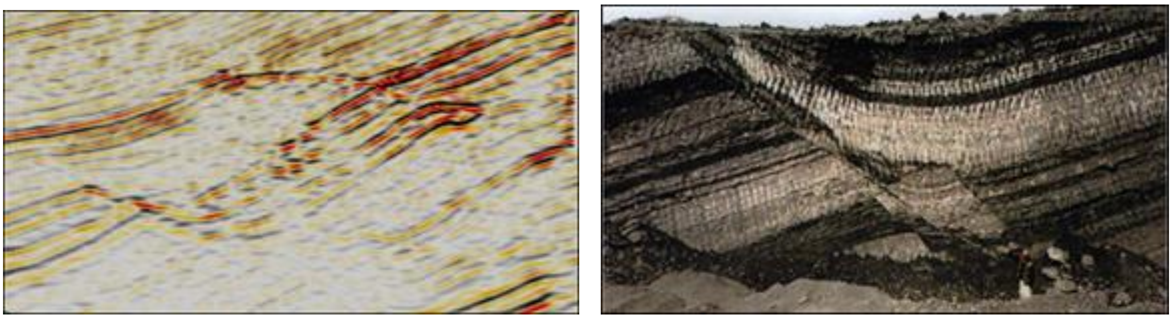

***Figure 10** Complex fault geometries seen on seismic section with its analogy on outcrops.*

Seismic interpretation produces structure maps in two-way time (twt), which must then be converted to depth to be used by geologists and mining engineers (Figure 11). Subtracting the top isobath map from the base isobath map yields the thickness of the coal seams. From this the volume of the coal seams can be determined. Inputs for depth conversion are:

- Two way time maps.
- Velocity model created from borehole information and seismic stack velocities.

Top K and Q coal horizon seismic velocity range is 1990-2400 m/s, typical for coal, shales and sands. Final differences between boreholes and depth map for Top K coal range from 0.38 m to -0.35.

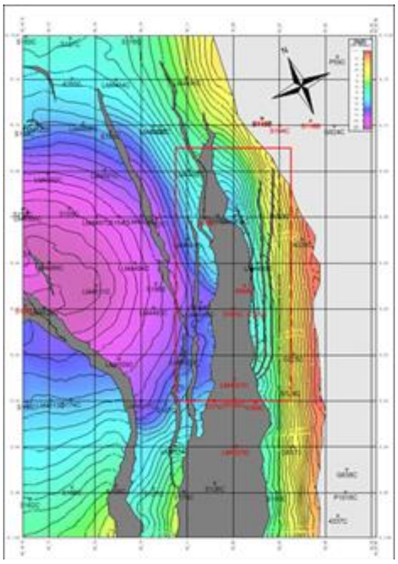

***Figure 11** Top K coal layer - isobaths map.*

Conclusion

The coal seams and a large number of structural features have been successfully imaged by the high-resolution 3D seismic survey. In the majority of the study area, both the top and base horizons of the K and Q coals are resolvable. Towards the densely faulted central area the coals appear to thin below the resolvable limit and their presence is therefore difficult to correlate and interpret.

The interaction of the three eastward dipping faults and a westward dipping fault are the key controls on the no coal area. Their interaction creates the structurally most complex and most difficult to interpret area within the survey.

Value of the seismic

The geologist and geotechnical staff of Mae Moh mine are using indirectly the seismic dataset as a guide for checking, by drillholes, the location accuracy in depth of the coal seams and the characteristics of fault orientation. The information from these drillholes can be used to update and improve the current seismic model.

EGAT's plan now is to develop the open pit on the down-dip side in the central part of the basin. The seismic survey has resulted in better images of the shallow geological structures and coal seams. EGAT has had to re-design the slope angle for pit slope stability.

The seismic dataset has provided cost optimization especially in terms of the greenfield area. For Mae Moh coal mine, this survey was sufficiently reliable in its accuracy to help manage decision making for the mine development.