NEAR-SURFACE CHARACTERIZATION FROM REMOTE SENSING DATA

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ABSTRACT

The understanding of the near-surface elastic properties is among the biggest challenges in onshore surface seismic technology. The coupling of sources and receivers to the surface as well as the propagation of the seismic waves in the near-surface attributes to more than 80% of the degradation of the surface seismic signal.

Optical remote sensing using visible, near-infrared and shortwave infrared data allow the mapping of the immediate surface. Thermal infrared data provide also information about the shallow near-surface through conversion of the sunlight into heat radiation. Radar remote sensing using microwave scattering from the surface and the shallow near-surface provides information about the texture and in dry areas about the size of boulders in rough areas.

Remote sensing data can be interpreted for elastic properties of the surface with application to seismic data quality estimation and logistic planning.

INTRODUCTION

The understanding of the near-surface elastic properties is among the biggest challenges in onshore surface seismic technology. The coupling of sources and receivers to the surface as well as the propagation of the seismic waves in the near-surface attributes to more than 80% of the degradation of the seismic signal used for hydrocarbon exploration and reservoir characterization.

Seismic acquisition, however, can provide only local information about the elastic properties in the vicinity of the sources and the receivers due to the characteristics of recording the seismic data along source and receiver lines. When calibrated with vibrator quality control attributes these data can even be converted to surface elastic data which help building near surface models for data processing (Laake 2005). Remote sensing offers the opportunity to densely characterize the near-surface using a optical and radar data (Sabins 1996). Insley et al (2003 and 2004) and Laake et al (2004a, 2004b, 2005 and 2007) have shown applications of optical data to onshore surface characterization.

The design and acquisition of seismic data depends on two main aspects:

- Logistics: access tracks for seismic vibrators and line vehicles
- Data quality: performance of seismic sources and planting of seismic receivers

Both aspects are strongly dependent on the characteristics of the surface and the near-surface. Particularly topography, texture, land use and elastic properties are important factors. Figure 1 lists the surface characteristics and the remote sensing data sets, which may be used to obtain information.

![Figure 1. Surface characteristics important for seismic](image1.png)

Optical and micro-wave remote sensing data combined with a digital elevation model (DEM) can provide extensive information about the surface parameters relevant for seismic. Figure 2 shows a sketch of an idealized geological setting with common surface features and refers to the type of remote sensing data available for their characterization.

![Figure 2. Remote sensing data useful for surface characterization](image2.png)
REMOTE SURFACE CHARACTERIZATION

In the context of surface and near-surface characterization to assist design and acquisition of seismic data the following remote sensing data can be used:

- Multi-spectral data: visible, near infrared, short wave infrared and thermal infrared data
- Microwave data

Figure 3 shows the location of the respective remote sensing data in the electromagnetic spectrum and links them to surface and near-surface features. For illustration the images of four typical bands are shown in the bottom of the figure.

The remote sensing surface characterization can be carried out prior to the scouting of the prospect by surveyors. However, ground truthing by photos is required to generate reliable estimates for logistics and data quality from the remote sensing data. Figure 4 gives examples of photos from the prospect for which the band images are shown in figure 3. Typical desert features comprise limestone escarpments, gravel plains and aeolian sediments such as gypsum and loose sand. Important are also drainage systems such as buried wadis.

APPLICATION TO HARD SURFACE

The location of the first case study from Algeria is located in a table land comprising hard limestone plateaus and soft siliclastic slopes and plains. A gypsum layer outcrops locally at the bottom of the escarpment where the limestone and sandstone layers have been eroded. During more humid climate in the past a river drained the higher plateau and left a wadi bed, which is partly submerged under aeolian sediments such as blown in loose sand and gypsum. In figure 5 a complete overview of all remote sensing data and their interpretation is given.

![Figure 3. Remote surface characterization](image)

![Figure 4. Ground truthing using surface photos](image)
Figure 5. Remote sensing data set for case study 1
From top to bottom the following data sets are shown in virtual 3D draped over the DEM:
- False color composite of visible bands
- False color composite of SWIR and visible bands
- Intensity map of radar backscatter

The last three data sets show interpreted data:
- Hard surface risk map obtained from steep slopes and limestone related hard and rough surface
- Soft surface risk map obtained from siliclastic and sulfatic minerals and drainage systems
- Surface and near-surface elastic estimates obtained from allocation of estimates of seismic velocities to hard and soft surface, respectively.

The hard and soft surface risk map (bottom map of figure 5) could be confirmed by the performance of the vibrators and the receivers.

APPLICATION TO SOFT SURFACE

The second case study is located in the extensive sand dune fields of Eastern Algeria, where the surface is dominated by up to 300 m high sand dunes with sabkha patches. No hard rock outcrops are observed.

The complex logistics in high sand dunes required to obtain an accurate DEM, which has been obtained by airborne LIDAR (figure 6).

Figure 6. Virtual 3D

Figure 7 shows a typical surface photo from an area with high sand dunes and gypsum and sabkha fields to illustrate the problem.

Figure 7. Photo of sand dunes and sabkha

From the DEM the slope can be calculated with the goal to determine exclusion zones where the vibrators were not allowed access because of the roll-over risk.
Figure 8 shows a composite of a false color composite simulating the “true” color impression of the sand dunes, the intensity coded DEM with sun shading to enhance the elevation effect and the digital slope model (from left to right).

The vibrator performance along the seismic line indicated in figure 8 shows some typical characteristics:

- The data quality is poor at the foot and at the top of dunes, where the sand is subject to movement by wind of changing direction.
- The main body of sand dunes, which may have settled for decades, is not generally a problem for the data quality.
- Gypsum fields and sabkha are often generating data quality problems.

APPLICATION TO VOLCANIC DATA

The third case study concerns basalt in the volcanic belt of the sub-Andean mountain ranges in Argentina. The surface is characterized by a large plateau covered by flood basalt with some isolated lava flows. The slopes of the plateau are very steep because the underlying clastic sediments and volcanic tuffs are substantially softer than the basalt.

The logistic problems for the seismic operation are the following:

- Steep slopes which bear the risk of roll-over for vibrators and line vehicles,
- Rough terrain along the solidified lava flows which confines vehicular movement to the space in between the basalt,
- Rough terrain on the plateau where large basalt blocks slow down any vehicular movement even up to the point that vehicles can no longer move.

The first step in the remote sensing data analysis therefore concerned the identification of steep slopes from the DEM and rough areas from radar back scatter data (see figure 10);

The identification of basalt lava blocks on the plateau suffered from vegetation cover by brush. The ground truthing photos (figure 11) revealed that basalt blocks were associated with brush of up to 50 cm height, whereas fine basalt gravel was associated with a thin later of grass.
Since the pixel size of the multi-spectral remote sensing data is 15 x 15 m or 30 x 30 m, the individual blocks or bush are not revealed. The pixel value is rather determined by the averaged contribution from basalt and brush. Therefore the multi-spectral data had to corrected for the vegetation using thermal infrared data, which detect only the basalt but do not show any signal for the brush. Figure 12 (left) shows the initial ASTER 453 false color composite which reveals the basalt but suffers from vegetation contamination. The inclusion of a TIR band (figure 12 center) provides the desired separation of basalt block cover (red tones) from basalt gravel with grass cover (bluish tones). For comparison the roughness map from radar back-scatter is repeated in figure 12 (right).

From these data the survey design concluded that a very large portion of the survey was inaccessible to line vehicles. Consequently heliportable operation was chosen to avoid hand carrying the recording equipment over long distances. The vibrator source lines were adjusted to the complex terrain on the slopes using the digital elevation model.

RESULTS

Remote sensing data from optical and micro-wave sensors proved valuable during the design of seismic surveys for the aspects of logistics and data quality estimation. Hazardous topographic features such as escarpments and steep slopes could be mapped prior to the start of the project. Surface textural features with impact to source and receiver data quality such as rough basalt or limestone outcrops could be identified. Drainage systems were mapped even when they were buried by thin aeolian sediments. The successful case studies presented here cover a wide range of typical surface features found in commercial seismic operation.

CONCLUSIONS

Remote sensing data allow the characterization of the surface and near-surface using the reflected and converted electro-magnetic energy from the sun light as well as radar back-scatter from satellite based radar. When the remote sensing data and their interpretation are stored together with seismic QC data, a cross-validation can be carried out, which in turn provides more reliable estimates of logistics and data quality risks. All estimates are required to be validated by ground truthing to avoid data surprises.

The methodology is not limited to survey design and data acquisition QC. In future estimates of the elastic properties of the near-surface may also provide a start model for static correction and velocity modelling in seismic processing.

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