C054 A HIGH-RESOLUTION 3D VIBROSEIS TRIAL SURVEY OF A POTENTIAL NUCLEAR WASTE REPOSITORY

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Introduction

United Kingdom Nirex Ltd is responsible for providing and operating a repository for the disposal deep underground of intermediate-level radioactive wastes and certain low-level wastes (UK Nirex Ltd 1993). It is focussing its investigations at a Potential Repository Zone (PRZ) near Sellafield, West Cumbria, where the Ordovician Borrowdale Volcanic Group (BVG) at 400-600 m depth below the surface holds good promise as an eventual repository host rock. The volcanics are overlain by Permian breccias and Triassic sandstones dipping gently SW, and are cut by normal faults mainly trending along strike. Within the PRZ, Nirex is planning to construct an underground Rock Characterisation Facility (RCF) to study the safety and engineering properties of the BVG.

Nirex had commissioned several 2-D seismic reflection surveys, both with vibroseis and dynamite as the source. Dynamite appeared to provide higher resolution than vibroseis, but neither source resulted in good, unambiguous 2-D images of the PRZ target. The Swiss experience of imaging a similar target (Birkhauser 1993) suggested that a 3-D survey using optimised vibroseis acquisition might be a way forward. A dynamite source for a 3-D survey was considered to be logistically impracticable as well as being prohibitively expensive.

Acquisition

In summer 1994, the University of Glasgow conducted a trial 3-D vibroseis survey of the RCF area on behalf of Nirex. The aim was to test the feasibility of vibroseis as a semi-high resolution source, both logistically and in terms of quality of data obtainable.

IMCL was subcontracted as the acquisition crew, the fieldwork being carried out by the combined forces of the University and IMCL. A 240-channel Sercel SN348 system recorded a spread of 10 rows by 24 channels, the strings of 10 Hz phones being planted in a linear array along the rows of 12 elements per channel. Station spacing was 25 m. The spread was rolled along the rows while the source moved up and down columns in a conventional 3-D swath pattern.

The source array initially comprised four buggy-mounted Failing Y-1100 vibrators at a 12.5 m spacing operated at half of peak force, but after a few days this was replaced by a 2-vibrator array operating at 80% peak force (~22,000 lbs). Production had been slow due to the manoeuvring of the 4-vibrator array in and out of the fifty or more small fields of the prospect, but with two 2-vibrator arrays - one active, the other on standby in the next field - the production rate was increased by about 70%. There was vibration monitoring of sensitive structures such as buildings, pipelines and hydrological monitoring strings down the RCF boreholes.

A 12-120 Hz linear sweep, 12 s long and with a 2 s listening time, was used. The survey design assumed ideally that every VP on every column could be shot with 5 sweeps at a 5 m move-up, but in practice only 48% of the total was achieved due to obstructions and omissions. Offsets range from zero to 600 m with very little azimuthal bias, and within the migration aperture there are azimuthally biassed offsets of up to 900 m.

The resulting subsurface CDP coverage varies from <30 to >250 fold in 12.5 m bins over the 1 km² of the target (Fig. 1), with a mean of 130-fold. The survey design adopted the migration aperture criteria of Armstrong and Pion (1993), so that full migration down to the target at 600-700 m depth would be achievable over an area of about 500 m² encompassing the existing exploratory boreholes. Individual correlated sweeps were recorded, to permit software array synthesis and comparison of single sweeps *vs.* summed sweeps.

Processing and preliminary results

IMCL has processed the data through to preliminary post-stack time migration using ProMAX-3D. Ground-roll, mode conversion, air-blast and environmental noise have not been problematic, although the field shot gathers, with no reflectors, looked unpromising.

Static corrections have been applied satisfactorily by assuming a constant velocity between the datum (sea-level) and the ground surface 80-100 m above for a brute stack, then calculating surface consistent residual statics. The low-fold perimeter of the data volume shows that reflection quality remains good from the high-fold areas down to fold as low as 30, confirming that future surveys need not be as dense as this trial. Reflection energy bandwidth lies between 20 and 75 Hz, and it remains to be seen whether useful extra resolution will be obtainable by pushing more refined stacks and migrations to higher frequencies.

Structure is clearly three-dimensional; the reflection stratigraphy within the BVG dips 20-30° SE, unconformably below the SW-dipping sediments. Penetration is good, down to 2-3 km. The previous 2-D surveys had been unable to image the BVG as clearly, and results were also complicated by out-of-plane reflections from the faults. The results of this trial confirm the feasibility and cost-effectiveness of carrying out 3-D vibroseis acquisition over complex shallow targets.

References

Armstrong, T. L. and Pion, J. 1993. 3D seismic survey - how big do we need to make the acquisition area? *EAEG Extended Abstracts 55th meeting, Stavanger 1993*, no. A007.

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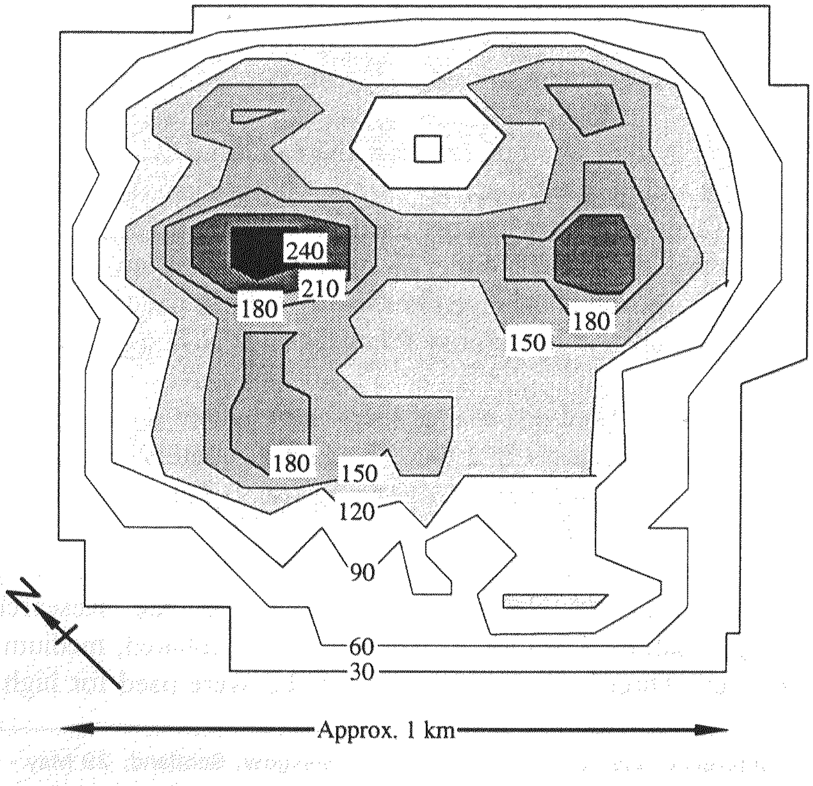

Fig. 1. Subsurface (CMP) fold of coverage obtained in the trial vibroseis survey in 1994.