High Resolution VSP Survey: Outokumpu Borehole, Finland: Preliminary Results

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Over the last few years, the Geological Survey of Finland and the Institute of Seismology at the University of Helsinki conducted large crustal scale seismic reflection profiles over Finland. Portions of these profiles ran through the historic mining town of Outokumpu: the site of a large base metal mine that is currently not operating. The structures outlined in these profiles motivated a re-examination of the regional geological model and a consequent reassessment of exploration strategies. This led to the complete coring of a 2.5 km deep borehole near Outokumpu to both test the revised models and to attempt to intersect a strong reflector expected to have a high probability of being associated with an ore body. Here we describe additional high resolution geophysical work conducted to further refine the geological model, to study anisotropy in such crystalline terranes, and to construct a velocity model that will be used for locating microseisms induced by fluid injection testing.

Equipment used in the survey consisted of the U of Alberta IVI minivib™ and Geode data acquisition system, and the GFZ-Potsdam logging truck and downhole 3-component geophone package.

The seismic survey consisted of three main parts: a zero offset VSP, a series of walk-away VSPs at various azimuths and three depths, one far-offset multi-level VSP, and a surface seismic component. The U of Alberta mini-vibroseis was used as a source, and employed linear, 8 s sweeps from 15 Hz to 250 Hz in frequency. The three component receiver was located down the borehole, and recorded the seismic signal at a 1 ms sampling rate.

The zero offset VSP (Fig. 1) was acquired at 2 m depth increments from 2500 m to 50 m over a 40 hour continuous period. Due to the small distances between shot gathers, the zero offset VSP allows a very precise determination of the vertical seismic velocity profile to be made. As well, uncorrelated records were obtained every 100 m along the wellbore to provide for studies of dispersion at seismic frequencies.

Three walk-away VSPs were performed at depths of 1000 m (Fig. 2), 1750 m, and 2500 m. The receiver was suspended at the required depth, and the source was moved away from the borehole along three, approximately equally separated, radial lines. The source was moved in increments of approximately 20 m to a maximum distance of 2 km from the borehole. The terrain posed several challenges including the presence of buried pipelines, residential areas, and inaccessible shot locations, as well as difficult topography, which resulted in some gaps in the data set.

These data are currently under examination from a number of perspectives related to both imaging and integration with existing data in the area as well as to detailed development of an anisotropic velocity model. The availability of the full core as well as televiewer logs will also allow comparison of the core scale intrinsic rock anisotropy dependent primarily on metamorphic texture to the formation scale anisotropy that is influenced by both macroscopic fracturing and present-day stress fields.

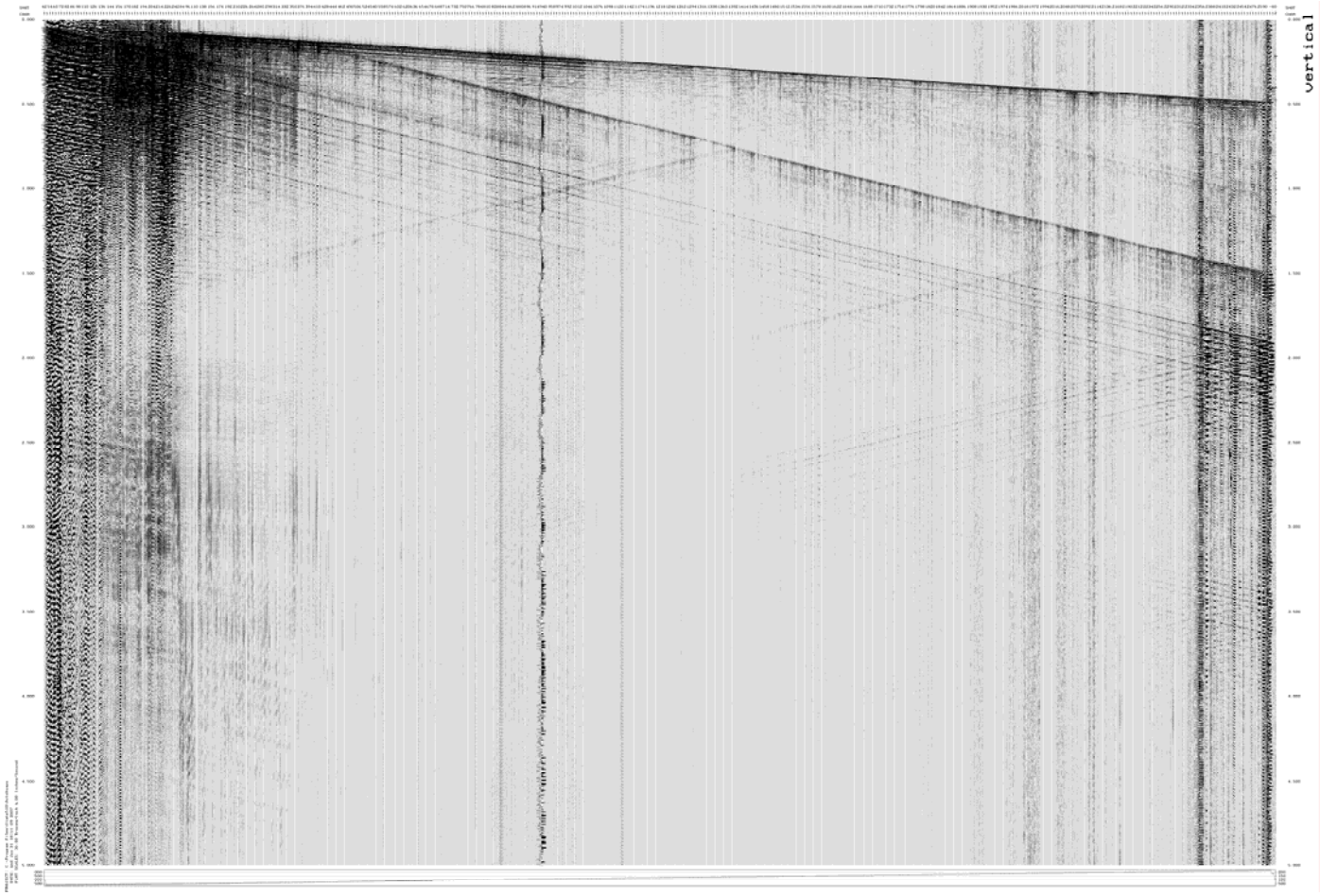

Figure 1. Vertical component of zero offset VSP, plotted as offset vs time.

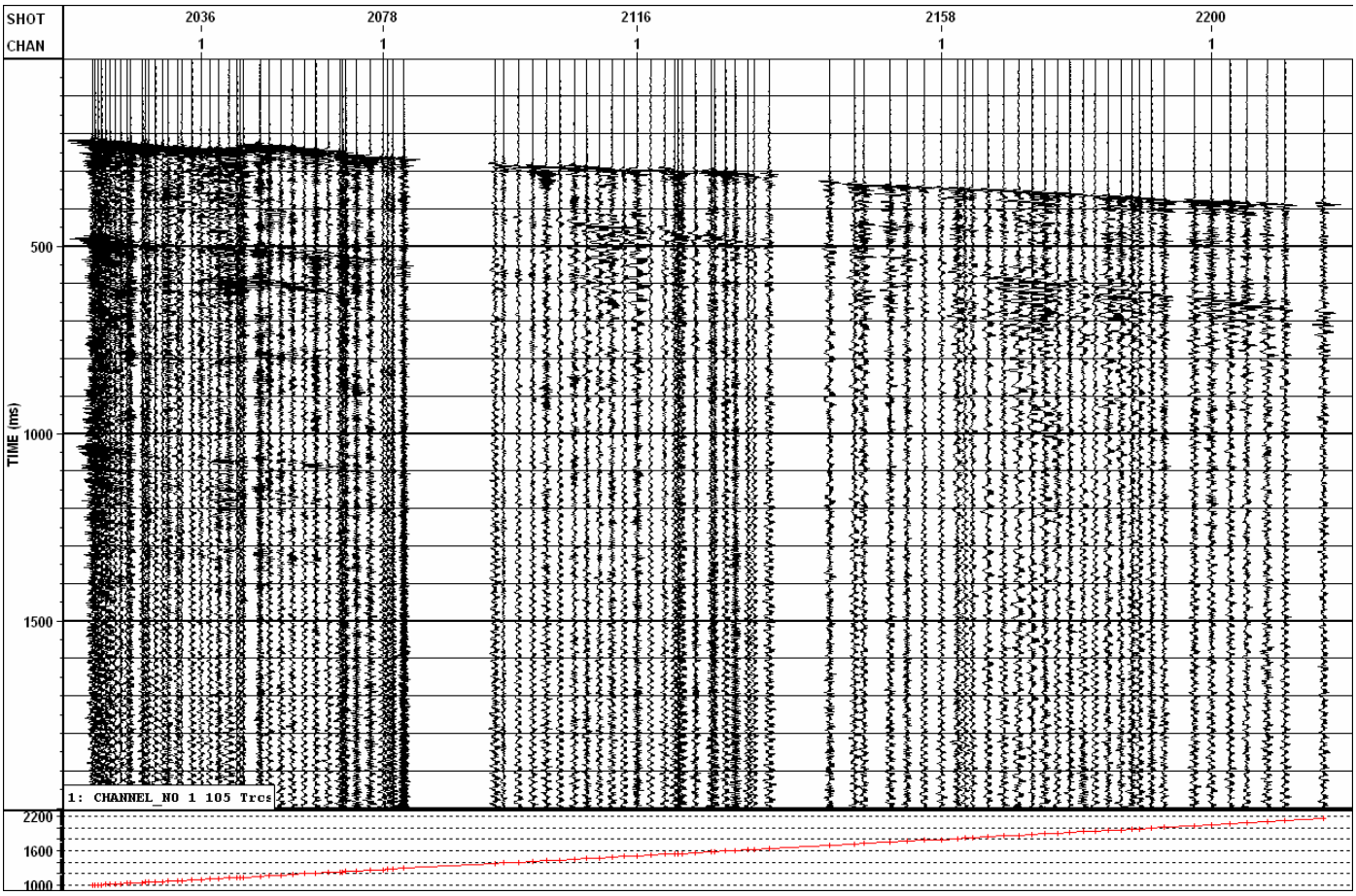

Figure 2. Vertical component of one azimuth of the 1000 m walk-away, plotted as offset vs time