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Short Note

Refraction statics in mountainous terrain

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INTRODUCTION

Refraction statics are often applied to data gathered in mountainous regions in order to correct the data to datum. The motivation for this is to enable standard processing techniques to be used on the data. Unfortunately, the refraction inversions often yield poor results which do not make sense geologically and which cause error in the statics corrections.

The refraction statics program considered here works by inverting the first break picks in order to obtain a model for the near surface low velocity layer. Once the near surface model is obtained, a static correction is calculated based on this model. The refraction inversion algorithm assumes that the first breaks are refracted head wave arrivals. In mountainous regions this assumption breaks down, and the presence of transmitted arrivals causes substantial error in the inversion. A ray tracing program is used to model refracted head wave and transmitted arrivals. These synthetic arrivals are input to the refraction inversion program to demonstrate that refraction statics programs fail when transmitted arrivals are present in the data. The transmitted arrivals are faster than the refracted head wave arrivals, and cause substantial error in the refraction statics inversion.

MOTIVATION AND PROGRAMS

This model study is motivated by the observation that refraction inversion results often do not make sense geologically. Typically the inverted refractor model thickens over regions of elevated terrain. This is counter intuitive. The low velocity layer is expected to thin out or disappear in elevated regions and thicken in basins. This would be consistent with the occurrence of sediments in valleys and outcropping formations in elevated regions. Refraction inversions often converge to solutions which exhibit the exact opposite behavior.

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I wrote a ray tracing program to calculate realistic first break pick times for models with complex topography. The program calculates the arrival time of refracted head waves by integrating the ray path along the interface. Once the refraction paths are calculated, the program checks for the possibility of valid transmitted paths. In areas of large topographic relief, energy impinging upon the interface between two media at angles slightly less than the critical angle is propagated under the refractor as transmitted waves. If these paths exist, their travel times are calculated and designated as first arrivals. These arrivals can be substantially faster than the head wave arrivals.

The program RINSE (Ray Inversion for Near-Surface Estimation) is used to demonstrate the effect of transmitted arrivals on refraction inversion. RINSE utilizes the slope of the first break travel time curves to determine the direction of rays arriving at a group and rays leaving a shot. Ray travel times from shot to group are then compared to the actual travel times to determine the depth to the refractor and refractor velocity. These results are then used to calculate near surface static delays. A detailed description of the algorithm is given by Jones and Jovanovich (1985).

MODEL RESULTS

The input to RINSE is a simple cosine shaped mountain with an elevation of 800 m and a width of 1500 m. The model consists of a 50 m thick low velocity layer which follows the surface topography. The low velocity layer has a velocity of 1200 m/s and overlays a half space of velocity 2300 m/s. The synthetic data is split spread with 200 shots, 96 groups per shot. The shot and group intervals are both 30 m.

Two sets of synthetic data are generated for this model. In the first data set, only refracted head wave arrival times are calculated. The second data set is the realistic simulation because the transmitted arrival times are calculated.

The results of the refraction inversion are presented in Figure **??**. The top plot is the RINSE refractor model generated by inverting on the unrealistic head wave arrival only data. This results in a nearly perfect reconstruction of the input model. The bottom plot is the RINSE refractor model generated by inverting on the realistic transmitted arrival data. The stars on the plot represent shot location and the lines emanating from the shots represent the location of the refractor as determined by RINSE. The presence of transmitted arrivals in the data causes the pronounced thickening of the refractor model over the top of the mountain. The erroneous thickness is about 170 m, instead of the actual thickness of 50 m. This results in a static error of up to 45 ms in one way time.

This simple model demonstrates that the thickening over mountains observed in refraction inversions is due to the fact that the data does not fit the assumed refraction model. When only refracted head wave arrivals are included in the inversion (top of Figure **??**) , the assumptions of RINSE are satisfied and the program works well.

When the transmitted arrivals are included in the analysis (bottom of Figure **??**), the program fails.

The effect of transmitted arrivals on refraction inversion varies with elevation, spread length, and velocity. It is found that models identical to the one in Figure **??** but with elevations of 200 m and 400 m result in one way static errors of up to 7 ms and 17 ms, respectively. If spread length is decreased, the effect is the same as decreasing the elevation (or curvature) of the mountain. The static error decreases. The error in the inversion increases in regions of lower velocity and decreases in regions of higher velocity. This is because the difference in arrival time between transmitted arrivals and the assumed refracted arrivals is less when the velocity is higher.

CONCLUSION

Refraction statics work well when the first arrivals are actually refracted head waves. In mountainous terrain the presence of transmitted arrivals causes erroneous thickening of the low velocity layer in elevated regions. This causes substantial errors to arise in the statics calculated from these erroneous solutions.

Transmitted arrivals and the unique nature of the acquisition geometry in mountainous terrain must be taken into account to perform proper statics corrections. In order to properly image data from mountainous regions, a different approach to the problem must be devised. It is possible to implement refraction inversion programs which account for transmitted arrivals. A more interesting approach might be to perform a tomographic reconstruction of the near surface velocity structure and use that result to shift the data to datum. Yet another approach would be to perform the imaging and velocity analysis along trajectories which reflect the topography instead of along hyperbolas.

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REFERENCES

Jones, G.M., and Jovanovich, D.B., 1985, A ray inversion method for refraction analysis: Geophysics, **50**, 1701–1720.

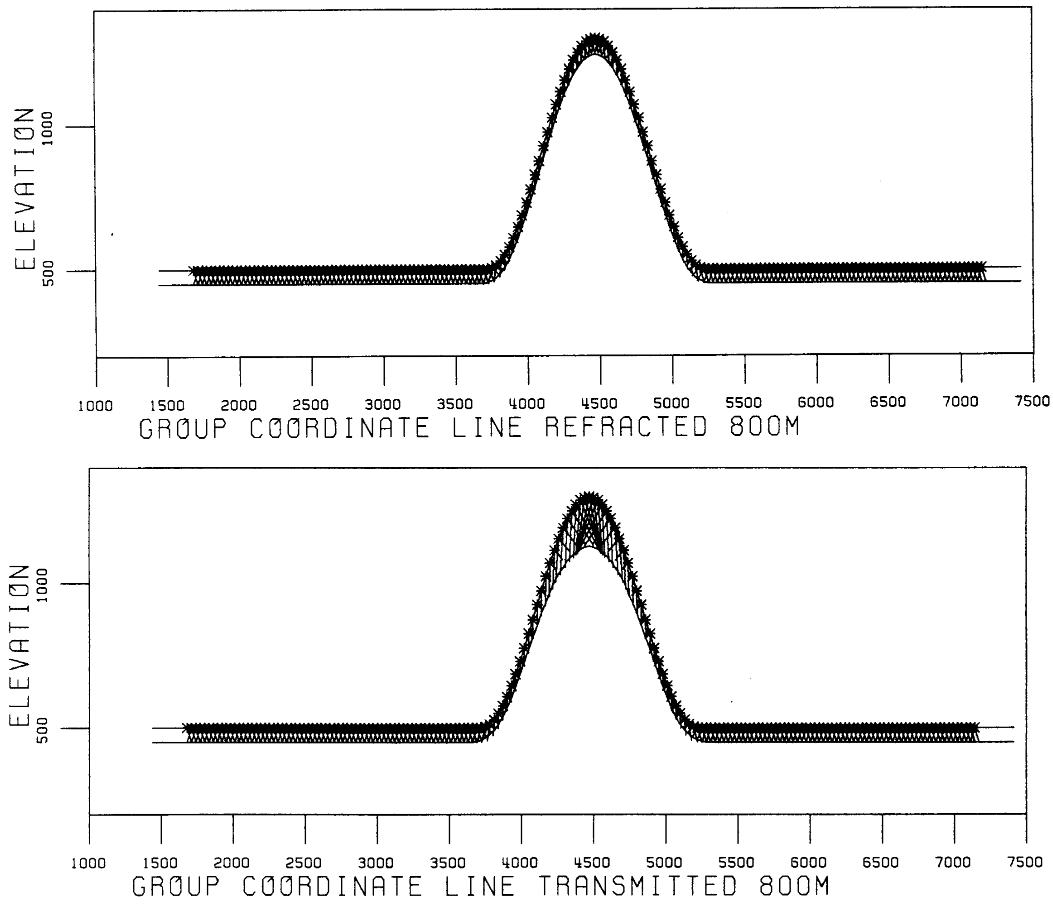

Figure 1: Refraction inversion results for two sets of travel time calculations. The top plot is the result of inverting only on refracted head wave arrivals. The bottom plot is the result of inverting on refracted and transmitted arrivals. The refraction inversion (RINSE) gives erroneous results when transmitted arrivals are included in the analysis. dimitri-refvert4 [NR]