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Ocean-bottom seismograph tomographic experiments—a consideration of acquisition geometries vs. resources

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SUMMARY

Over the last 20–30 yr numerous seismic images of the Earth's crust have revealed details of its gross structure, including intra-crustal layering, the geometry of that layering and its composition. As more and higher quality studies are undertaken it is becoming apparent that identified structures have a greater degree of 3-D variability than first anticipated. Thus, the methodology of crustal imaging by seismic means has also developed into the third dimension with a tomographic approach now being widely adopted, particularly so in the marine environment. Such surveys not only focus on mapping the finer scale 3-D structural variability, they also aim to achieve sufficient density of azimuthal coverage and resolution to address preferential orientation patterns of features such as porosity, fracturing and faulting.

Recent developments in technology, and consequently cheaper construction and deployment costs of instruments, have resulted in an expansion in the number of instruments available in ocean-bottom seismometer pools. Consequently, individual experiments are being designed to accommodate the maximum number of instruments available and this, coupled with dense grids of shot profiles, significantly impacts on survey cost. In this paper we consider a variety of approaches to achieving the best resolution of detail for minimal associated cost of acquisition, and for instrument pools of various sizes. A number of different geometries are compared, including example grid designs in current use. Comparison of resolution tests and relative costings for a range of acquisition geometries suggest that, if instrument numbers and/or funds are limited, the most cost effective ways of achieving the desired target resolution may be by (1) shooting additional shot profiles at the expense of deploying more instruments and (2) multiple, overlapping deployments of a small geometry, tailored in shape to the target structure and depth.

Key words: acquisition geometry, ocean-bottom seismology, seismic tomography.

1 INTRODUCTION

As our knowledge of crustal structure improves hand-in-hand with the ever-increasing number of geophysical, geological and geochemical surveys, it is becoming clear that lateral and vertical intra-crustal structure and properties are far more variable than once thought. To address this variability, wide-angle seismic experimental geometries have been adapted from the more traditional 2-D style, where data are collected solely along a series of linear profiles, to 3-D where data are acquired in a more areal fashion. The latter approach has been made possible by technical advances and a greater degree of versatility and general increase in numbers of instruments in accessible equipment pools.

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In the case of crustal seismic tomography, whether on land or at sea, the 3-D approach to acquisition has resulted in an associated increase in experimental costs. In the marine case in particular, using ocean-bottom seismographs (OBS), the 3-D approach has resulted in the desire to access a large number of instruments (50–100+) and, consequently, a greater number of ship days for deployment and shot firing along the associated network of profiles. Although currently there are a few instrument pools that comprise in excess of 100 OBS, many national and research group pools average around 20–30 instruments and are likely to remain so for some time to come. Thus, the desire for large numbers of instruments necessitates internation, or inter-group collaborations or hire arrangements.

The purpose of this paper is to consider whether similar, or at least acceptable, resolution of an example target structure may be achieved with instrument numbers typical of research group or national pools to that obtained by a dense grid packed with 50 or more instruments.