A 3D isochronal modelling technique and its applications

Shunhua Cao and Brian L. N. Kennett
Research School of Earth Sciences
Australian National University
G.P.O. Box 4,
Canberra, ACT 2601, Australia

Bruce R. Goleby
Research School of Earth Sciences
Australian National University
G.P.O. Box 4
Canberra, ACT 2601, Australia

Bureau of Mineral Resources, Geology & Geophysics
P.O. Box 378
Canberra, ACT 2601, Australia

Abstract

Reflection seismic datasets are obtained in both the exploration of oil and mineral resources and the probing of the deep crust and the upper mantle. To interpret the datasets, considerable effort has been spent on the understanding of seismic wave propagation phenomena by simulating seismic wave propagations in some *a priori* physical models. A rather simple and efficient modelling technique has been developed to study elastic wave reflections with full inclusion of diffractions.

This modelling technique employs an integral representation of reflections from a surface or a scatterer. High frequency asymptotic approximations are used for the propagation between the seismic source or receiver and a surface or a scatterer. At a scatterer, first order scattering is assumed. At a surface, reflection and transmission effects are estimated using the assumption of a locally plane interface and plane incident wave. With these approximations, the reflected seismograms are calculated by convolving the time derivative of a source function with a model weight function for a particular source-receiver pair. The weight function at a particular time is evaluated by a line integral along a contour of equal total travel time from source to receiver via the scattering surface (an isochron). The kernel of this integral at a reflecting point is the local reflection coefficient which which represents the effects of the amplitude of material parameter contrasts at the reflecting point, the angles between the incoming and outgoing waves and the local surface normal and the local speed of advance of the isochron on the surface, and the geometrical spreading factors from the source and receiver to the reflecting point.

This modelling technique is used to investigate the validity of some of the interpretations of a deep crustal reflection profile collected in central Australia. The modelling results confirm that even with a relatively short (4 km) field spread it would be possible to pick up the reflected energy from faults with dips of about 40°. The largest fault, the Redbank Zone, has significant displacement of the crust-mantle boundary and within the fault zone, it is conceivable to have considerable variability in physical properties.

The deep seismic section shows this boundary as a thick (0.5s) band of complex reflections and diffractions at the reflection time appropriate to the crust-mantle transition. Two possible structures for the crust-mantle boundary were investigated, one where the crustal faults have displaced this interface and created a 'block-faulted' geometry and the other where the crustal faults are listric near the boundary and appear to sole out on the crust-mantle interface, giving rise to an undulation of the Moho. The modelling results (Figure 1) for an undulating boundary show a band of reflections which strongly resemble the observed seismic reflection data.

Key words: synthetic reflection seismograms, elastic waves, isochronal technique.

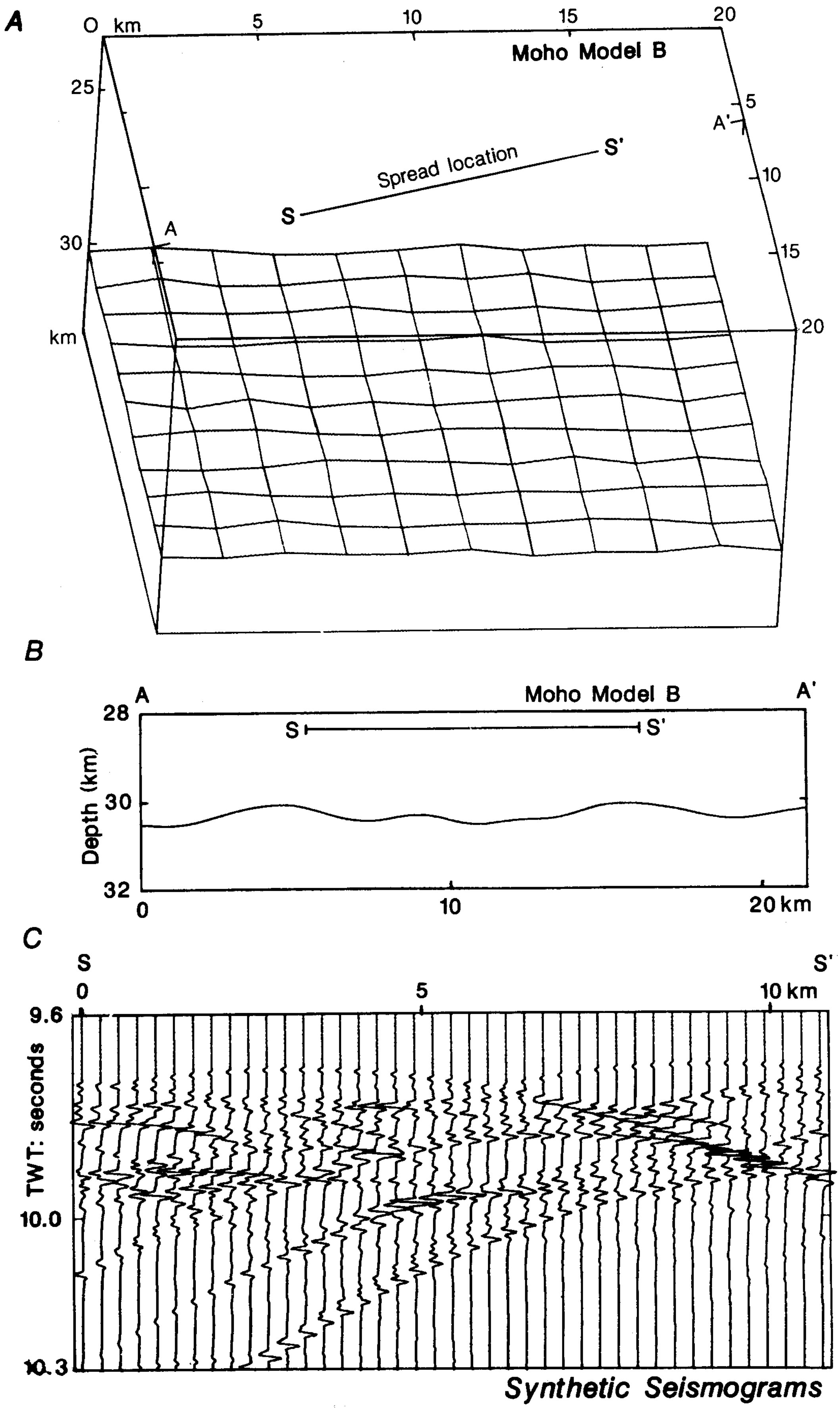

FIGURE 1
The panel schematically shows a randomly pertubed Moho model which has a mean depth of 30.30 km and a perturbation of ±250 m. The middle panel is a cross section through the model coincident with the spread. The lower panel shows the calculated reflection seismograms.