Identification and application of PmP multiples from onshore-offshore seismic surveys in Eastern Guangdong

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Introduction

- We have observed special seismic multiples at land stations
- The seismic multiples and PmP phases appear within the same offset range, and its travel-time increase as the offset distance grows.
- **The propagation path of multiples and their impact on seismic imaging require systematic investigation.**

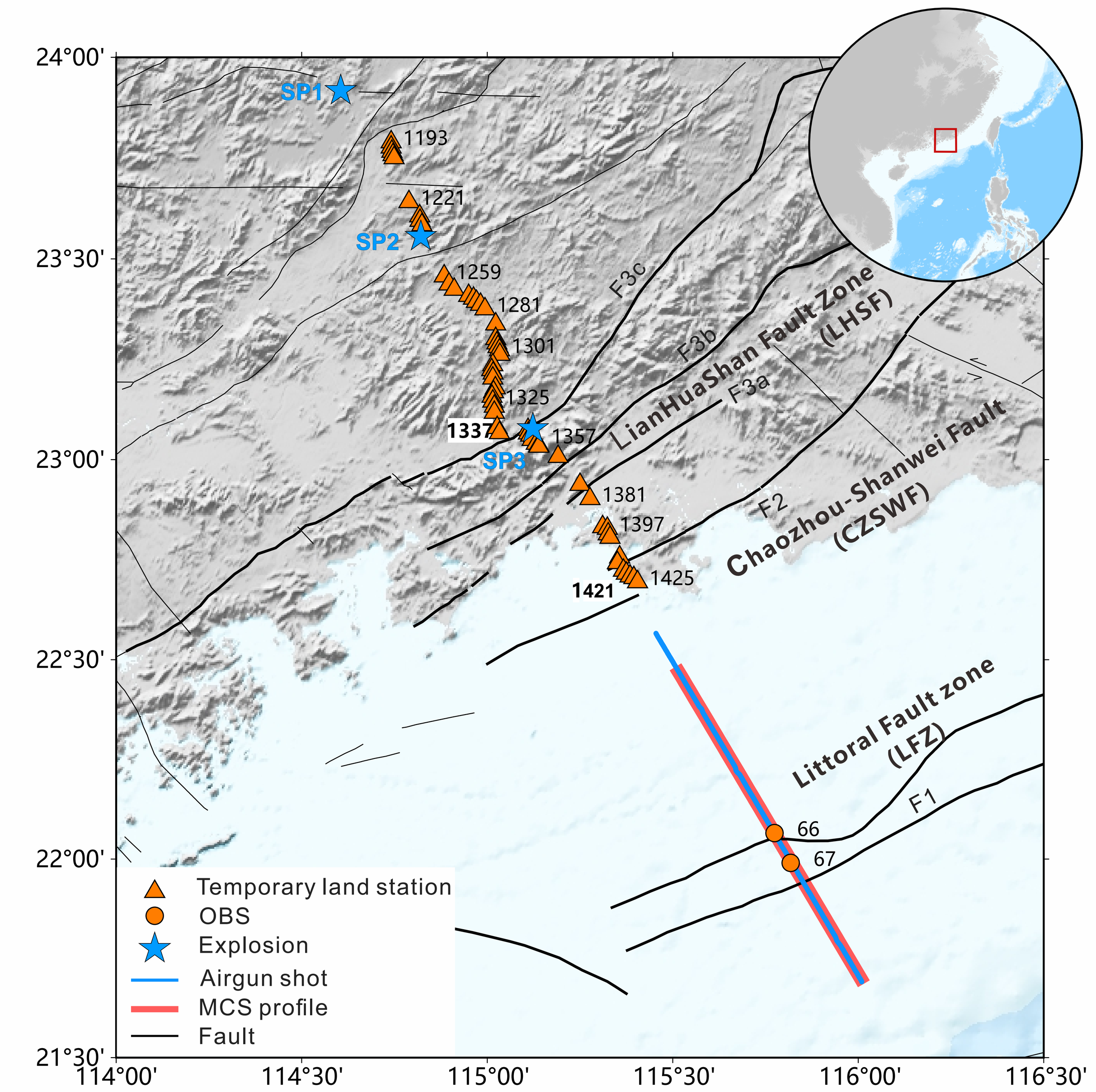


Fig.1 Location of onshore-offshore seismic surveys in eastern Guangdong

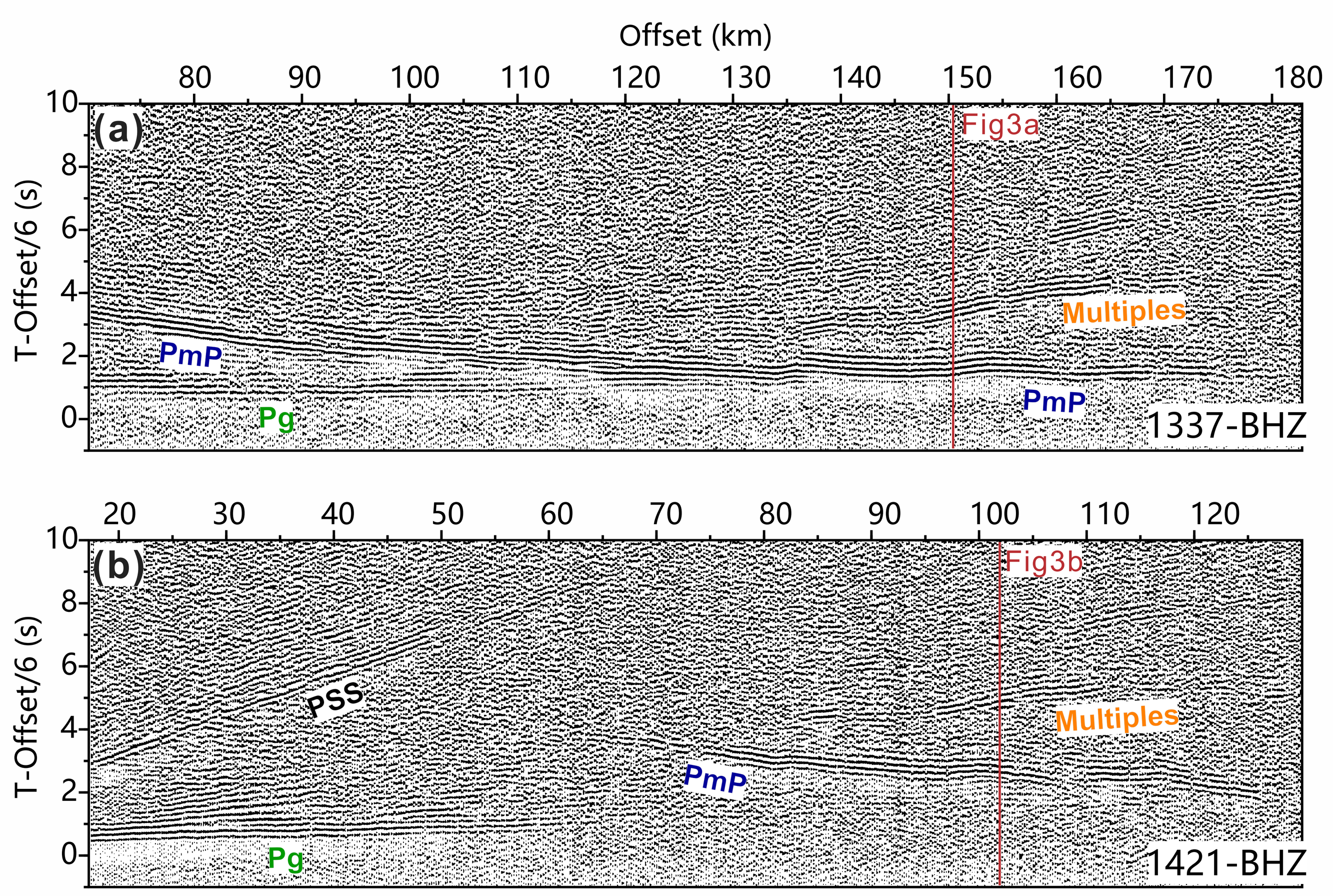


Fig.2 The air gun signal recorded by the land stations show seismic multiples
The crustal refraction phase (Pg), Moho reflection phase (PmP), and multiples can be clearly identified.

Propagation Path of Multiples , and Seismic Imaging

- Multiples and PmP phases share identical frequency components (4-6 Hz), while the multiples exhibit travel times delayed by approximately 2.63–3.26 s compared to PmP phases.
- **Multiple are identified as PmP2PsP, which are caused by reflections at both the seafloor (top reflect boundary) and the sedimentary basement interface (bottom reflect boundary). The sedimentary layer is the reflective layer.**
- A forward P-wave velocity model constructed using the RayInvr method (Zelt and Smith, 1992) has been derived from all seismic phases, including the PmP2PsP phases. Crustal velocity anomalies around fault zones are observed.

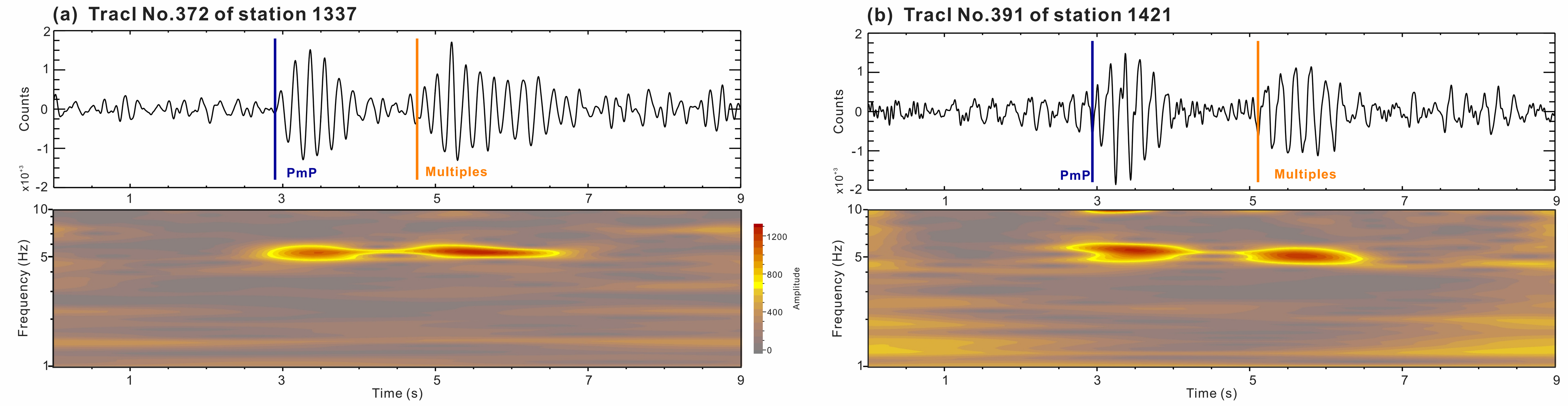


Fig.3 Spectral analysis demonstrates that multiples and PmP phases share identical frequency (4-6 Hz)

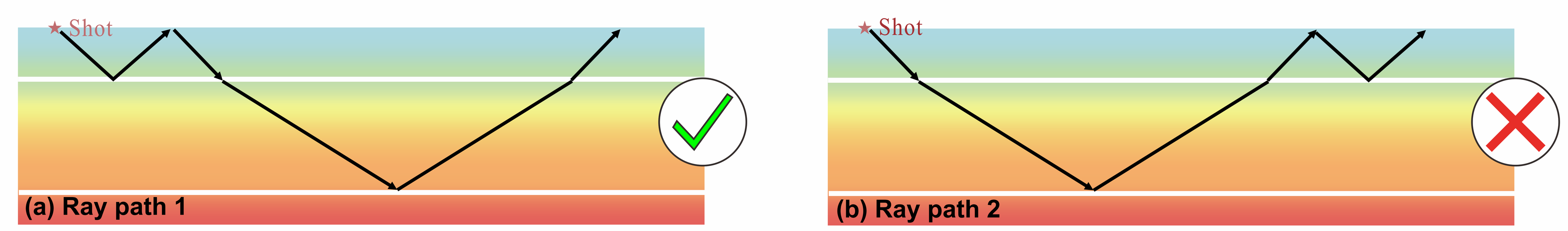


Fig. 4 Schematic diagram of multiples propagation path
(a) Ray path 1 illustrates reflected waves undergoing multiple reflections at the source side.
(b) Ray path 2 demonstrates waves experiencing multiple reflections at the receiver side after initial reflection.

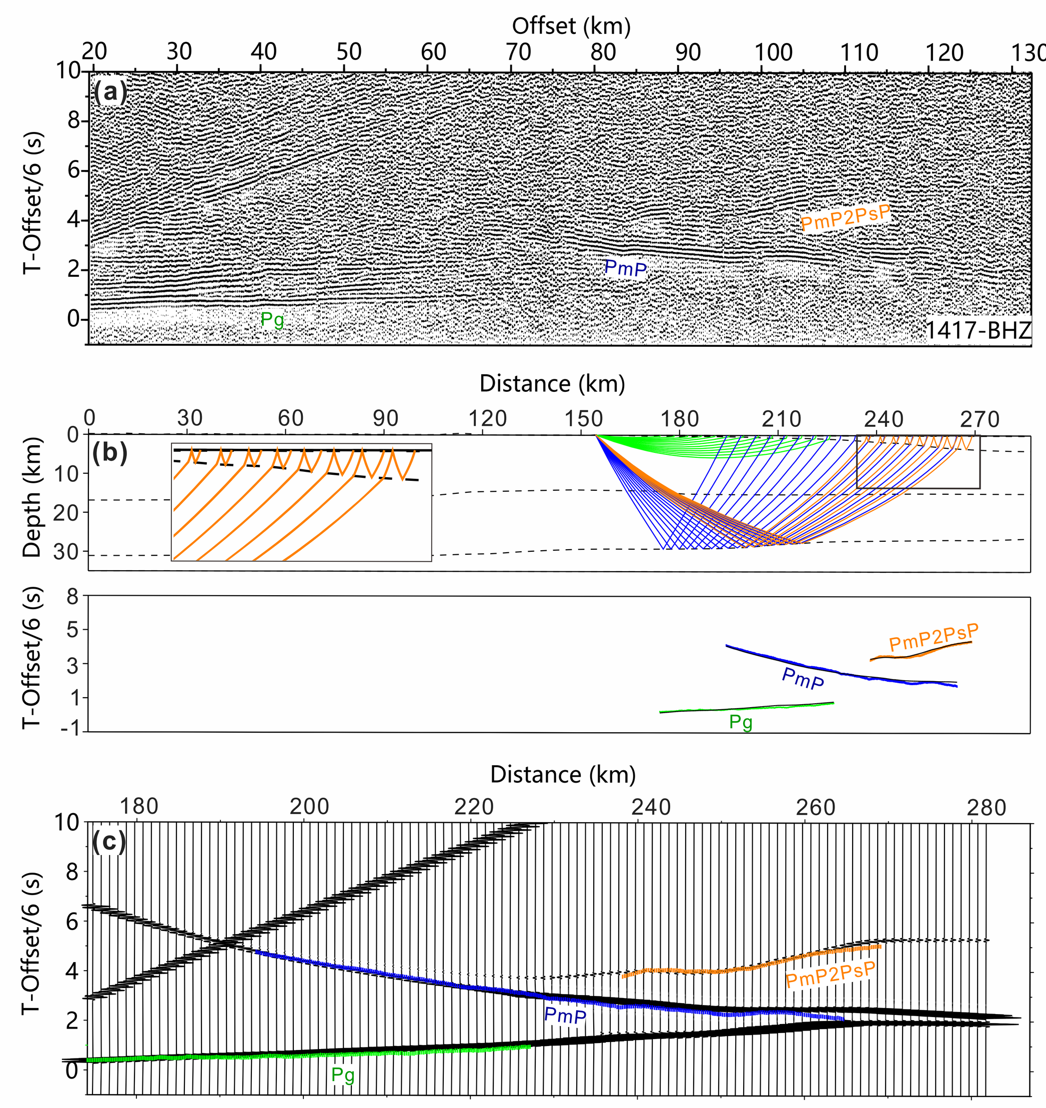


Fig.5 Phase identification, ray tracing, and travel time fitting in the seismic profile from station 1417

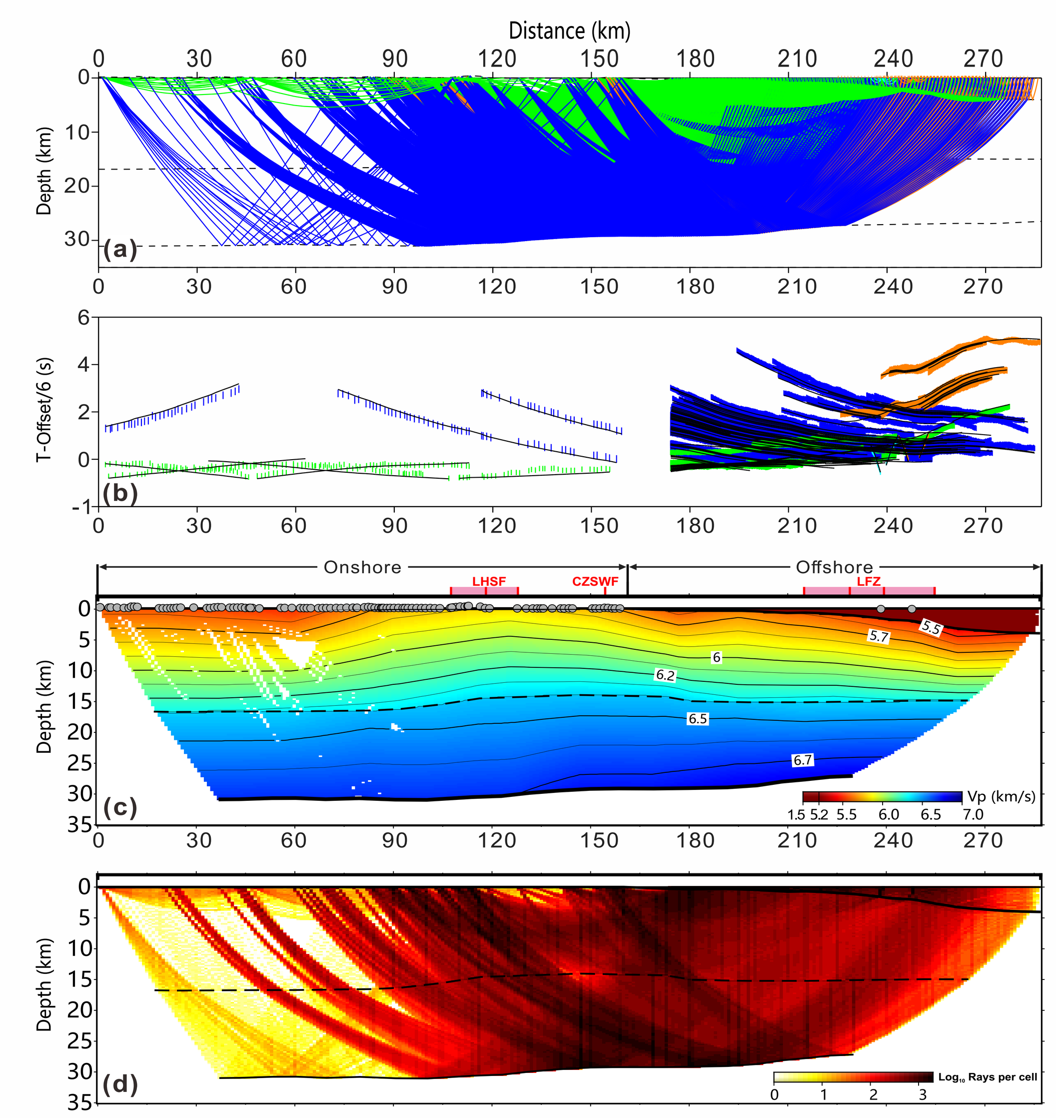


Fig.6 P-wave velocity model along the L1-NW03 survey line
P-wave velocity model with contour intervals of 0.1 km/s.

High-Resolution Constraints on Sediments

- VMONTECARLO tests (Loureiro et al., 2016) demonstrate that using PmP2PsP phases **reduces depth uncertainty from ±0.21–1.16 km to ±0.11–0.58 km.**
- The imaging resolution of the shallow crust and sedimentary layer improved.
- **Travel time delays** between the PmP2PsP and PmP phases primarily originate from two-way travel time during **seafloor-basement reflections**. It show **strong consistency** with **multi-channel seismic reflection profiles**, which supports the derivation of a velocity-dependent **time-depth conversion formula for the sedimentary basement interface.**

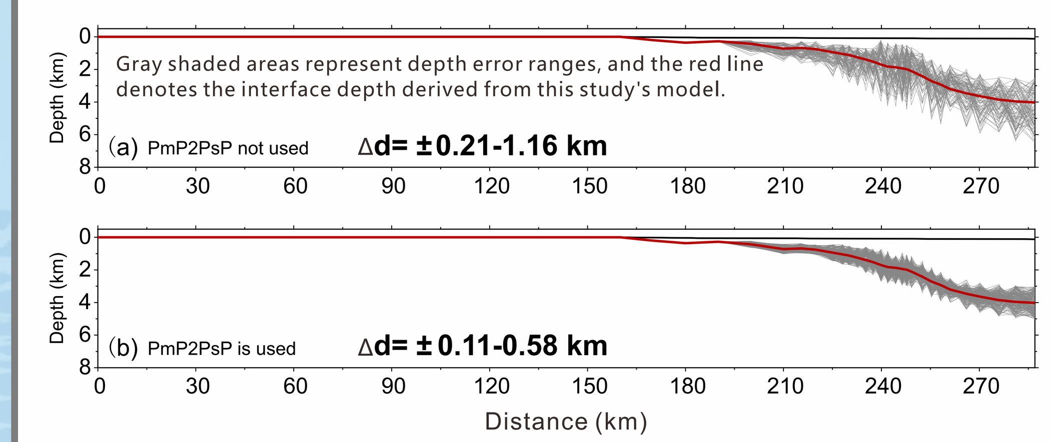


Fig.7 Uncertainties analysis of sedimentary basement interface based on the VMONTECARLO method. (a) and (b) are analysis results from the PmP2PsP seismic phase data exclusion and inclusion groups, respectively.

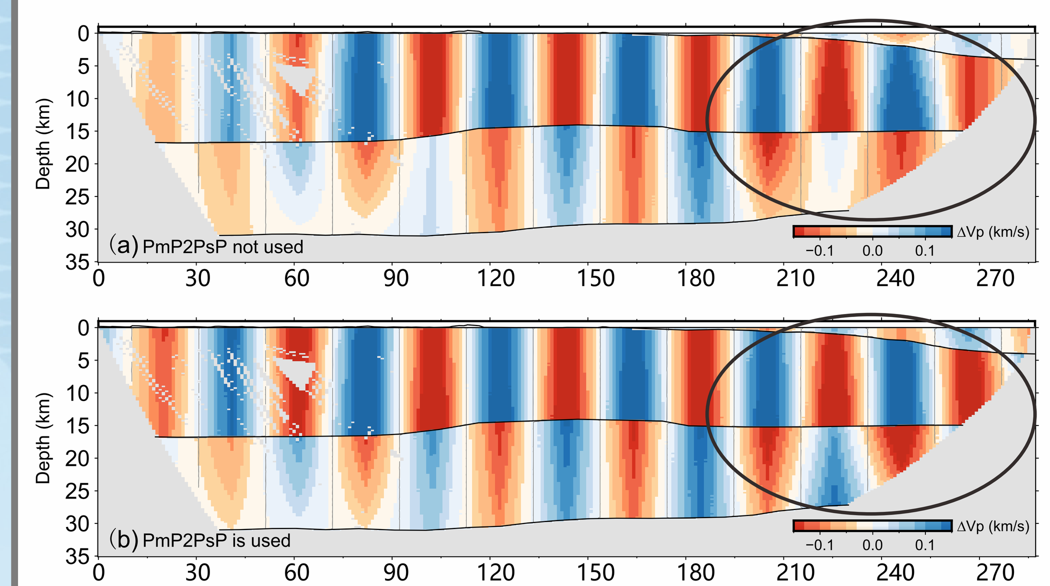
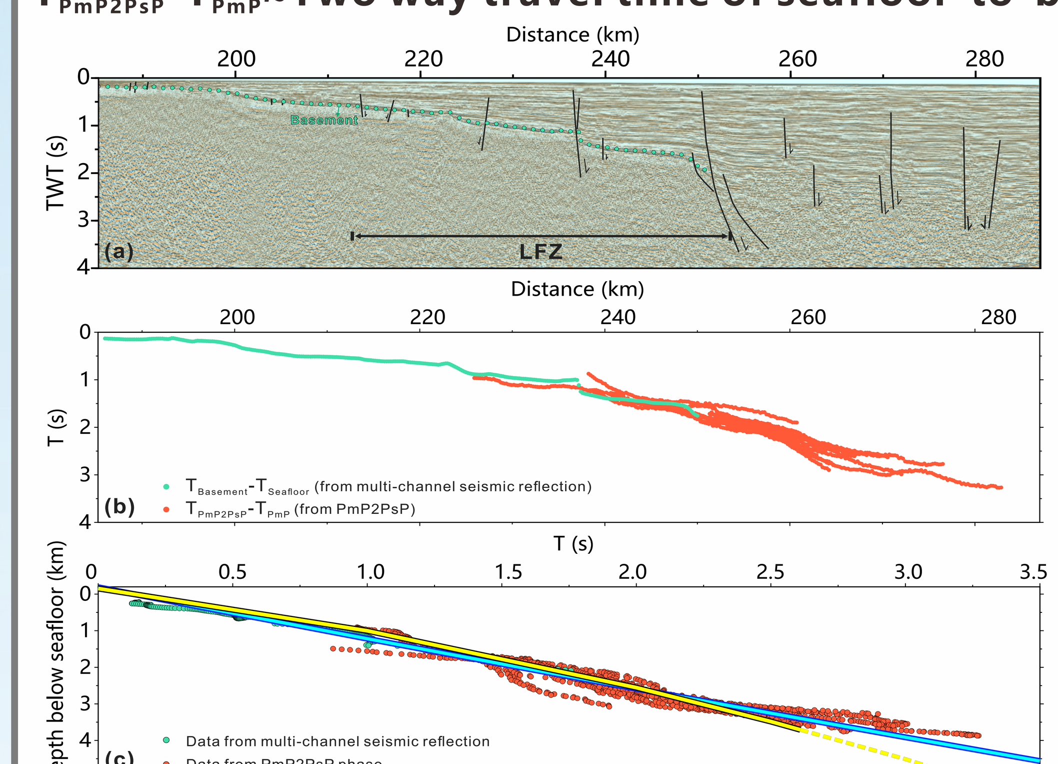


Fig.8 The resolution test for the velocity model. (a) and (b) are velocity anomaly recovery results from the PmP2PsP seismic phase data exclusion and inclusion groups, respectively.

$T_{PmP2PsP}$-T_{PmP}≈Two way travel time of seafloor-to-basement = MCS data



The yellow curve represents the time-depth conversion formula proposed by Li et al (2011), with yellow dashed lines indicating regions of sparse data coverage.
The light blue curve shows the newly fitted time-depth conversion formula from this study.

Fig.9 (a) Multi-channel reflection seismic profile of the offshore section along the survey line, with green dots marking the picked sedimentary basement interface. **(b) Data of two way travel time difference between the sedimentary basement and seafloor interfaces (green dots) derived from MCS profiles, and travel time difference between PmP2PsP and PmP phases (red dots).** (c) Scatter plot showing the two-way travel time versus depth relationship of the basement interface.

References

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Loureiro. A, Afilhado. A, Matias. L, Moulin. M and Aslanian. D. 2016. Monte Carlo approach to assess the uncertainty of wide-angle layered models: Application to the Santos Basin, Brazil. Tectonophysics.

Zelt .C, Smith. R. 1992. Seismic traveltime inversion for 2-D crustal velocity structure. Geophysical Journal International, 108(1):16−34