README file: IODP371 borehole ties to seismic

This archive contains the physical property data used to create the synthetic seismograms to tie the borehole lithology to the multichannel seismic data for the six International Ocean Discovery Program Expedition 371 boreholes. The analysis in this dataset is presented in the GJI paper "Timing of Eocene compressional plate failure during subduction initiation, northern Zealandia, southwestern Pacific", by Stratford et al. *In press.*

This section covers the parameters and data corrections used in the data analysis section in the paper. The full report for this cruise is available from the IODP website. http://publications.iodp.org/preliminary_report/371/

All raw data from this cruise can be downloaded from the LIMS explorer reports downloader site https://web.iodp.tamu.edu/LORE/. Those wishing to work with physical property data from this cruise should use the raw data available on the IODP LIMS explorer website.

Seismic reflection data can be obtained from GNS Science (data.gns.cri.nz/pbe) or NZ Petroleum & Minerals (data.nzpam.govt.nz).

Borehole ties to multichannel seismic profiles

Physical properties measured on the cores and from wireline logs measured downhole were used to construct impedance (product of velocity and density) with depth profiles for each of the borehole sites. Impedance values are used to construct synthetic seismograms for comparison to seismic multichannel traces extracted at the borehole sites.

A simple method was used to tie borehole physical properties to seismic data, where percentage changes are applied to P-wave velocity measurements. Due to differences in recovery, deformation, drilling method and seismic data characteristics at each site, the measured P-wave velocities require site specific adjustments.

A few scattered datapoints that are outliers have been removed from some of the datasets where the cause large amplitude reflections not visible in the seismic data. These are usually associated with thin layers or lenses that are too small to cause a seismic reflection. Density values are either left unaltered or modelled as a smooth profile with depth as they only effect reflection amplitudes. Core measurements are made at a significantly larger spacing (metre scale) than the wireline measurements (mm scale) and, as such, core measurements are more likely to contain sample bias. An impedance (velocity x density) profile with depth is calculated for each borehole. The reflectivity method is used to calculate a synthetic seismogram from this profile. The input source is a Ricker wavelet with a period of 10 ms. The output synthetic trace is bandpass filtered to match the frequency content of the seismic trace data. As velocity-depth measurement spacings and coverage vary, best fit solutions for each borehole are found by matching the two-way travel times of prominent reflectors. As seismic velocities predominantly increase with depth, rarer negative polarity reflections (low velocity zones) are useful for providing confidence in the fit to the data. The corrections applied to each borehole to produce the final velocity-density pairs are listed by site below.

Site U1506

The seafloor and volcanic basement reflectors at Site U1506 are used to constrain the impedance with depth profile. Observed seismic reflectivity between these two horizons is low amplitude and cannot be replicated with confidence using the synthetic seismic trace. Core-measured P-wave velocities in the sedimentary section are increased by 8% to fit the two-way-time (TWT) between the two reflectors. Velocity corrections are not applied to volcanic basement measurements.

Site U1507

Site U1507 was logged for P-wave velocity and density between 70 m and 840 m depth. The density values are interpolated at wireline P-wave velocity (Vp) depth measurement sites for impedance calculations. To improve the fit between synthetic and seismic trace data, the wireline velocities are reduced by 1%. The best fit solution for correcting the core data in the top 70 m of the borehole was achieved by applying a standard carbonate rebound correction.

Site U1508

As the bore hole at Site U1508 was susceptible to collapse, the density tool was not included in the wireline logging tool and a smoothed density profile based on core density values was used to calculate impedance. The best fit synthetic solution is calculated by decreasing the wireline logged P-wave velocities by 5%. The top 80 m and the bottom 45 m of the borehole were not logged so core measurements are used with the same percentage decrease in Vp applied. Confidence in the fit of the model to the trace data is provided by matching the TWTs of two unconformities observed in the seismic data and the core at 321 and 379 m depth.

Site U1509

At Site U1509 core measured velocities and densities are used to calculate impedance down the borehole. Densities are interpolated at velocity measurement positions. An early Eocene limestone layer in the core coincides with a significant increase in velocity and density values and is interpreted as the source of a strong positive reflection on the seismic data at 4.3 s TWT. This layer is used as a pinning point for the borehole tie to seismic model. A good fit to the TWT to the limestone reflector and a tentative match to a 4.5 s TWT reflector in Paleocene claystone can be achieved by increasing P-wave velocity by 3%.

Site U1510

Physical property measurements from the core from Site U1510 are used to calculate an impedance profile for the borehole. Density values are interpolated at velocity measurement positions. Sediments at Site U1510 were disturbed by drilling and the cores were crushed in places. Good recovery of core was achieved in the top 140 m in Miocene sediment, but below this the Eocene sediments are silica rich, contain chert fragments, and recovery was poor. Recovery improved below 350 m depth but remained poor compared to the other Expedition 371 boreholes. Although numerous chert fragments were recovered between 140 m and 350 m, the seismic data between 1.8 and 2.1 s TWT has low reflectivity indicating that the chert layers are too thin to produce distinct reflections. The chert fragments have high Vp and density and the increase in P-wave velocities required to produce a synthetic solution for this section of the core indicates that the chert layers may be numerous. Drilling through interbedded hard (chert) and soft (chalk) layers may account for the low recovery. A 10% increase in Vp produces a reasonable fit between seismic trace and synthetic data. Confidence in the model is provided by matching the strong reflector at 138 m depth associated with the onset of silicification of the sediments and a disrupted layer that can be traced laterally to lava flows on the adjacent volcano with volcanoclastic deposits that occur at 415 m depth in the core.

Site U1511

Core measured P-wave velocity and density values are used to create the synthetic solution at Site U1511. The borehole is cored between 0 m to 70 m depth and between 200 m to 500 m depth, with a drilled interval between. The velocity and density of the drilled section are estimated using an exponential velocity increase with depth. The top of the second cored section at 200 m depth is close to a lithological change that likely produces the negative polarity reflection observed at 6.7 s TWT on the multichannel data. However, the physical properties measured from the core do not constrain the velocity contrast across this reflector. Forward modelling suggests that a velocity of ~1700 m/s is required at the base of the drilled section to replicate the amplitude of the negative polarity reflector from the boundary between clay and diatomite at ~200 m depth. A 3% velocity correction is applied to the cored clay and diatomite sections. All major reflectors below the drilled section fit the synthetic solution produced using this corrected velocity.

Archive content:

There is a folder for each borehole site, labelled with the site name, e.g. U1506. Three files for each borehole site are included. The first file is a text file named 'Site'_raw_Vp_Rho.txt. The file contains the raw velocity and density data. Columns are depth below seafloor in meters, velocity in metres per second, density in Mg/m^3. Velocity and density outliers have been removed from this dataset.

The second file is name 'Site'_sythetic_model_Phys_prop.txt. This file contains the corrected velocity and density data used to create the synthetic seismograms, and the impedance contrasts and calculated two-way-travels times for model. Columns are depth below seafloor in meters, velocity in metres per second, density in Mg/m^3, two-way-travel-time (ms) and impedance for the preferred velocity/density model.

The third file is a text file named 'Site'_seismic_synthetic_traces.txt and contains the time series data for the synthetic trace data produced using the velocity/density information form the boreholes described above and the seismic trace data extracted from the multichannel seismic data at the borehole site. The three columns contain, two-wave-travel time (ms), synthetic data amplitude, and seismic data amplitude. Multichannel seismic data records names and source location can be found in the main publication.

Sites U1508 and U1510 folders contain additional files.

The "other_model" subfolder in the U1508 folder contains parameter files for an additional model. These include a rejected physical properties model, the synthetic seismogram it creates and a figure showing this model. Seismic velocities in this model have been increased by 10%. Unconformities and major lithology changes in the borehole do no line up with unconformities and changes in seismic character in the seismic data. The rejected model is included to illustrate the level of constraint on the base of the borehole at this site. The model does not produce a good fit to the lithology and should not be used.

The "other_model" subfolder in the U1510 folder contains parameter files for two additional models. These include a rejected physical properties model, the synthetic seismogram it creates and a figure showing this model, and a model constructed from rate of penetration drilling data.

Rejected model: a model assuming a higher percentage of chert present in the sediments (i.e. as faster velocity model). In this model the seismic velocities below the chert horizon depth of ~ 150 m are increased by 20-25%. The model mimics the inclusion of ~20-25% high velocity chert (Vp~3000 ms) in the borehole. This model is included to illustrate the level of constraint on the base of the borehole at this site. The model does not produce a good fit to the lithology and should not be used.

Rate of penetration model: The additional files contain the weight on bit (WOB) and Rate of penetration (ROP) data recorded during drilling that were used to create a synthetic seismogram for this borehole site. Rate of penetration (ROP, m/s) and weight on bit (WOB, kN) were computed from data logged every second by the Rigwatch (TM) v.8.7.12_C_2 system on the RV Joides Resolution, combined with core depths and times of core retrieval (time on deck) logged in separate core tables. The block position was smoothed using a sliding 15-point median and then non-drilling operations identified and removed. Drilling noise introduced by waves and brief manual interventions was removed by median filtering over a 300 s time window and 0.3 m depth window.

A clear correlation between weight on bit and rate of penetration was not observed. As such the rate of penetration data was used to create a synthetic seismogram for the lower half of the borehole. Drilling data is only available below 150 m depth in the borehole, so core values of velocity and density are used above this depth. Rate of penetration is assumed to be a proxy for impedance, or how hard the rock is. Rate of penetration values are adjusted to values that reflect impedance values and an appropriate range of impedance using the core measured velocity and density values as a rough guide. The impedance values are separated into a smoothed density with depth profile (below 150 m) and a velocity with depth profile. The enclosed figure shows the impedance profiles from the core measured values of velocity and density and the impedance profile produced from the rate of penetration data. The profiles show similar velocity with depth trends down the borehole

The enclosed files also contain the synthetic model, the raw WOB and ROP data and the output synthetic seismogram. The model was not an improvement on using the core measured data and is not the preferred model.

Borehole depth/twt data:

A file containing the velocity with depth relationships for the synthetic models are used to produce numerical solutions for TWT with depth for seismic ties at the borehole sites is also included (TWT_Depth_IODP371.txt).