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CHINA MARGIN

Seismic Processing

Three types of seismic data were collected: Expanding Spread Profiles (ESP), Wide Aperture CDP, and standard single ship CDP lines. The processing steps vary between the data types and are described in detail in the following sections.

ESP

Because the shooting and receiving ships are not the same, we must make a single timing correction for all shots within each profile. On both ships at shot instant or start of recording we read to the millisecond a precision clock driven by a stable oscillator. To check the off-set between the clocks and to detect any relative clock drift, we periodically sent a tone from OCEAN 4 to CONRAD via VHF radio. This tone coincided with the clock read on OCEAN 4 and was used on CONRAD to trigger the recording process which caused a reading of its clock. As the VHF radio has only a short range, this clock check typically was done as the ships passed at the midpoint of an ESP. A compilation of these timing checks during the two legs showed relative drift of less than one millisecond per day. In addition we saw only two jumps in the relative clock offset, so the timing corrections have been simple and straightforward.

With the preliminary timing correction we demultiplexed the field tapes which contained shots near the ESP midpoint. For these shots we have both Mini-Ranger and Raydist ship-to-ship range measurements, so the ship's tracks offset is well determined at the ships crossing. The direct wave from the airguns is prominent in the recordings made as the OCEAN 4 passed along

CONRAD's streamer. Examination of the arrival time of the direct wave provides a check of the timing correction established by the shot tone transmission.

The next step is to derive the individual shot to receiver channel distances. As CONRAD was the receiving ship, it was constrained to make only small heading changes for the duration of an ESP run. This avoided kinks or bends in the streamer, which we then assumed to be straight, albeit with an unknown feathering angle. To calculate the shot to receiver distances we need a ship-to-ship range, ship-to-ship bearing and streamer bearing for each shot, as well as the fixed measurements such as the distance from the Mini-Ranger antenna to the airguns on OCEAN 4.

The Raydist tracked well during the full length of each ESP. As it is a relative system a constant must be added to all readings. In addition it has an error which depends on the aspect each ship presents to the other. As these aspects change rapidly as the ships pass, the Raydist cannot be used during this time. In contrast the Mini-Ranger is an absolute system, but is reliable only at short ranges. Under the atmosphere conditions which prevailed during the project, it was limited to less than 10 km. As the ships approached at short range, the Mini-Ranger and Raydist readings were compared and a correction constant for the Raydist determined. A separate constant was determined as the ships diverged. These constants differed by about 50 meters. For the shots in the vicinity of the midpoint Mini-Ranger readings are used for the ship-to-ship range.

Bearings from CONRAD to OCEAN 4 were taken every minute at shot time for the half hour surrounding the ships passing. The streamer bearing was assumed to lie along the CONRAD gyro readings. It is the difference between these bearings which forms the key angle in the individual source receiver offset calculations. To correct this angle we examine plots of the seismic data with a reduced time scale. The reduction is either linear for the direct wave in the vicinity of the midpoint, or hyperbolic for the seafloor at larger ship-to-ship ranges. The bearing angles are varied in the plots and we select the angle for each shot which produces the best reduced plot.

The timing correction, range accuracy and bearing angles must be determined separately and in the given order, as the errors are all manifest as timing errors.

With the above corrections the individual traces are sorted by source receiver offset into 50 meter range bins. The traces in each bin are added after shifting each trace to the bin center along an 8 km/sec line. This shift avoids attenuation of high frequencies due to adding out of phase. The effect, however, is small. The 50 meter bin spacing selected is determined by the 50 meter hydrophone group spacing of the streamer and assures a near uniform bin population. Smaller bin sizes are desirable from a spatial aliasing standpoint, but can lead to large fluctuations in bin population.

The seismograms which are generated by the binning process have uniform spacing and thus we can apply transform techniques such as velocity filtering. Velocity filtering can suppress unwanted coherent arrivals such as the seafloor reflection and its multiples and enhance deeper reflection which cut across them.

We take two approaches towards deriving a velocity-depth function from the seismograms. The first starts with a transformation to the intercept time, ray parameter (tau-p) domain. Here the various post-critical arrivals; reflections, diving rays, and head waves, contribute to the inversion via the tau-sum method. The second method is an interactive adjustment of layer velocities and gradients by ray trace matching of the X-T seismograms. This later technique is often used to fine tune the tau-sum solution. Furrier refinements include amplitude matching with the ray tracing method and synthetic seismogram modeling using either the WKBJ or reflectivity algorithms.

The seven ESPs of the western transect (RC-2613) have been carried through the 50 meter binning stage. Most show weak but distinct arrivals in the 60 to 80 km range, preliminary identified as critical angle Moho reflections. They also contain a wealth of arrivals from most of the upper crust. An initial solution using tau-p techniques is available for one of these.

The ESPs of the eastern and central transects are at various points in the timing/geometry correction stage.

Wide Aperture CDP

The wide aperture CDP data consists of four sets reflecting the possible combinations of shooting and receiving ships. Timing corrections are of course simpler when a ship records its own shots. These data covers the shortest offset ranges, 0.3 to 2.7 km. The CONRAD navigational data is used as the basic for the CDP sort. Ship-to-ship range is determined as outlined in the ESP section. This task is easier as this range is only about 5 km and varies slowly. Shot-receiver ranges are less sensitive to bearing errors with the ships in the in-line formation. The CONRAD to CONRAD CDP sort is identical to single ship sorts. To sort the other combinations the ship-to-ship range is also used. Timing and range corrections are spot checked by making hyperbolically reduced plots of full range of available offsets to check for continuity across the ship pair boundaries. Potential timing and range errors are separated by examining arrivals with different ray parameters.

Data from the four ship pairs are treated separately except for the velocity analysis step. Hyperbolic semblance is used if velocity gradients are not strong and there are no large velocity jumps. We are still experimenting with the best way to produce wide aperture CDP stacks. Preliminary indications are that the far offsets contribute best to the deep section.

We have a brute stack of the CONRAD to CONRAD portion of the wide aperture line connecting the ESPs of the eastern transect. We have concentrated on this line as both air gun arrays on OCEAN 4 were used. We have successfully modified our demultiplex program to handle OCEAN 4 SEG-B field tapes. An erratic bimodal timing error on OCEAN 4 shooting and receiving is apparent from single channel monitor records of the other three ship pairs. The extend header of the OCEAN 4 tapes contains information for detecting these errors and this information will be used to derive timing corrections. We will then complete the demultiplex and CDP sort.

CDP

Standard processing of the single ship CDP lines involves demultiplex and CDP sort using CONRAD navigation, brute stack, velocity analysis, final stack, and where appropriated, migration.

All of the lines in the sovereign area, including all of RC-2614 and the two long lines of RC-2612, have been stacked using regional velocities and accounting for the gross layer topography. The CDP lines connecting the ESPs of the western transect of RC-2613 have been similarly stacked.

The semblance velocity calculations are complete for all the lines of RC-2613 and detailed velocity analysis is in progress. We are now doing the semblance calculations for the other CDP lines. The calculations can incorporate a multiple suppression velocity filter which has proven useful for shallow water data.