3D East Pacific Rise
MGL0812

Processing Information for
Whole Upper Crust Swath Volume and
Layer 2A Swath Volume

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Part A: Defining 3D swath geometry

Defining an initial 3D geometry or 3D swath box[1] for seismic data acquired along a mid-ocean ridge axis can be challenging due to the fact that mid-ocean ridges can exhibit abrupt and frequent, although relatively small, changes in the orientation of the ridge axis. When defining the geometry of the box required for 3D processing one needs to consider both the best geometry orientation from the subsurface imaging point of view (i.e. the goal is to image the subsurface along the ridge with the same quality) and the most efficient way to do it. At this initial stage, it is also very important to come up with the scheme for numbering inlines and crosslines[2] within the geometry boxes to enable the smooth transition between boxes at the interpretation stage.

Here we describe how the geometry of the two boxes used for processing the swath data set was defined for the region from 9°20'N to ~10°10'N. Within this region, the along-axis lines change orientation to accommodate a change in ridge axis trend at ~ 9°55'N, which is expressed as an azimuth[3] change of ~ 3.9°, i.e. from ν_1=351.7° to ν_2=347.8°. Thus we define two boxes with different geometries, the first one will encompass the ridge axis data south of the bending point and the other north of it. In Figure A.1.A the latter is represented by a green rectangle. The former includes two sub boxes, shown in brown and blue rectangles that have the same orientation (the split into two boxes south of the bending point is to accommodate change in width due to different number of seismic lines included in each swath). Here, we discuss the definition of the "brown" box (hereinafter southern box) and "green" box (hereinafter northern box).

We first define the southern swath box, choosing the location for its southwest (SW) corner (shown with a purple dot in Figure A.1.B) at some arbitrary, but reasonable distance (some 1000 m) from the ridge axis. In our case the chosen origin of the southern box in UTM coordinates is X=581738.6 m and Y=1053295 m. Then, we define the survey angle of rotation (or orientation of the inlines), such that the longer side of the box is parallel to the ridge axis. This angle has a different definition than the azimuth and is measured counterclockwise from the east, as shown in Figure A.1.C. For our southern box, the azimuth of ν_1= 351.7° corresponds with a survey angle of 98.3° and northern box azimuth of ν_2= 347.8° gives a survey angle of 102.2°. The next step is to define the inline and crossline spacing and the number of inlines and crosslines within this box. For our dataset the inline spacing, as defined by our source and receiver geometry, is 37.5 m, and the crossline spacing is 6.25 m, which gives a nominal CMP bin size of 37.5 × 6.25 m. For our case of an along axis box with origin at its SW corner, the inline spacing has to be defined as a negative distance increment to obtain the box oriented as shown in Figure A.1.B (hence spacing is -37.5 m). For the first box defined, the inline and crossline numbering scheme is arbitrary. However, to ensure that the inline/crossline numbering is consistent across adjacent boxes, geometry definition for the second (here northern) box is more complex. For our northern box we first define what we call the "pivot point" or common point for both boxes (marked by a black dot in Figure A.1.B). This point bears the same inline and crossline numbers[4] in both boxes. It is obtained at the intersection between

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[1] The final geometry box with migrated seismic data has different origin and size, but the same orientation as the initial processing geometry box

[2] Within a geometry box an inline (also called subline) is oriented parallel to the survey navigation and a crossline is perpendicular to it.

[3] Here, azimuth is the angle measured from the geographic north in clockwise sense.

[4] Since *Focus* requires numbering of inlines and crosslines to be less than 10000, for our northern box crosslines we established a relationship for which: pivoting point crossline from northern box#=pivoting point crossline from southern box# – 6000 (in our case for the pivoting point instead of the crossline #=7991 that is in the northern box, in the southern box we have crossline#=1991).

the ~ 400th crossline[5] from the northern side of the southern box (in Figure A.1.B shown in red line) and one of its central inlines (shown in thick black line in Figure A.1.B). Once the location of the pivot point is established, we can define the central inline for the northern box (thick white line in Figure A.1.B) with the angle required by the orientation of the ridge axis. The southernmost crossline central point (green dot in Figure A.1.B) of the second box is then defined along this central inline at ~ 2500 m (400 crosslines) distance from the pivoting point. The orientation of the crossline is perpendicular to the central inline. The inline of the origin of the second box can then be determined moving along the southernmost crossline of the northern box (in our case toward SW) for as many inlines as necessary to encompass the geographical extent of the collected data within the region of interest. Origin of the northern box is shown in blue dot in Figure A.1. The rest is the same as for the southern box.

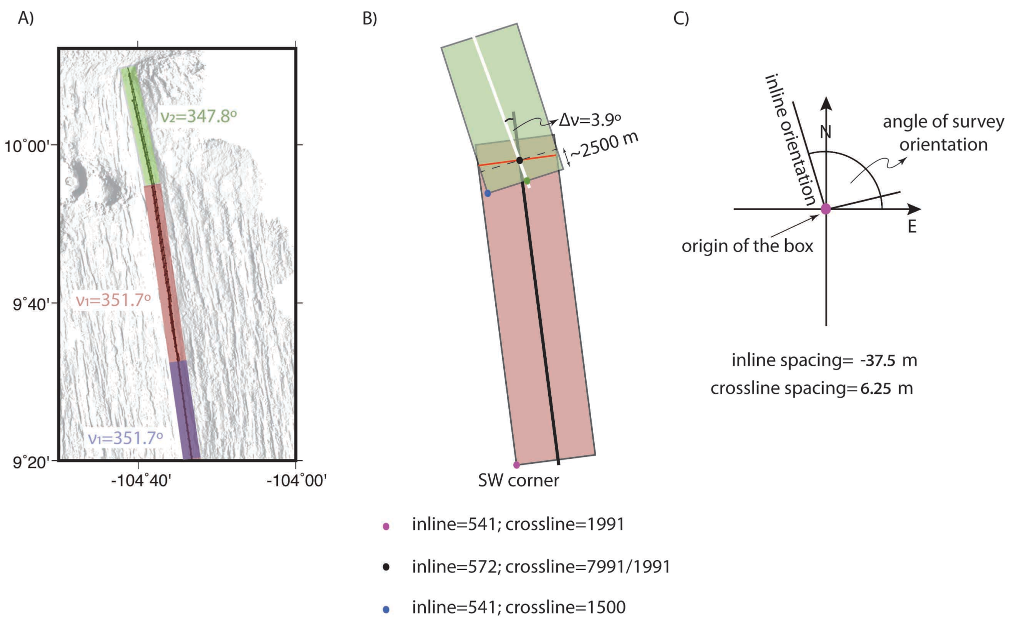

Figure A.1 A) Three swath boxes defined north of 9º20'N: green box azimuth 347.8º, brown and purple box azimuth 351.7º. Brown and purple boxes have different widths to accommodate different number of seismic lines contributing to each (brown box includes axis2r1, axis3p2, and axis4; purple box includes axis2r1 and axis3). B) Step-by-step geometry definition for swath boxes to accommodate azimuth change (see text). C) Illustrated terms used to explain geometry definition of the swath boxes (see text).

[5] According to our calculations ~ 400 crosslines (~ 2500 m) sufficient to account for the migration aperture. It is important to mention that for defining the optimal width of the box for picking in VoxelGeo number of crosslines should be larger (~ 500). Since we used 400, we have some gaps for the picks between the boxes.

Part B: Definition of shots within each box for processing the 3D swath dataset

Another important challenge when processing 3D swath seismic data sets within a survey that requires definition of two or more geometry boxes, is to determine which shot numbers are contributing to each of the defined boxes.

Here we describe a simple way for determining the range of shots that sample the subsurface delimited by the box geometry and with reflected signals captured by receivers within the same geometry limits. Since the streamers are towed behind the ship, the definition of the shots to include in each box will be different for the two cases of the ship entering and exiting the box.

Case 1: Ship entering a box

When entering a box, although a shot may be geographically within the box, the signal reflected from the seafloor and subsurface may sample a region out of the box (Figure B.1.B). Furthermore, some shots may sample the subsurface within the box for near and mid source-receiver offsets, but not at far offsets so that far offset traces would not belong to the delimited box. Thus, the first shot to include for processing is the first to produce reflections located only within the defined box geometry (Figure B.1.B). The general formula is:

$S_{in}=CL/2 + RD/2;$

where: S_{in} is the distance from the first crossline within the box to the first included shot (hereafter referred to as shot-in distance); CL is the cable length and RD is the distance of the first receiver from the source. In our case, CL=6000 m, RD is ~ 200 m, and the first included shot-in distance S_{in} is ~3100 m. Then, for the shot spacing of 37.5 m, the first shot number that we include for further processing is 83 shots from the geographically first shot in the box.

Case 2: Ship exiting a box

When the ship is exiting a box all the receivers are still geographically within the box (receivers are behind the ship), but also due to the distance between the ship and first receiver of ~200 m there are a few shots located out of the box that still contribute to sampling the subsurface within the box limits (Figure B.2). The distance of the last included shot from the last crossline (S_{out}) is:

$S_{out}=RD/2;$

For our shot spacing (37.5 m), the last shot included for processing the box would be two shots after the last shot that is geographically located within the box.

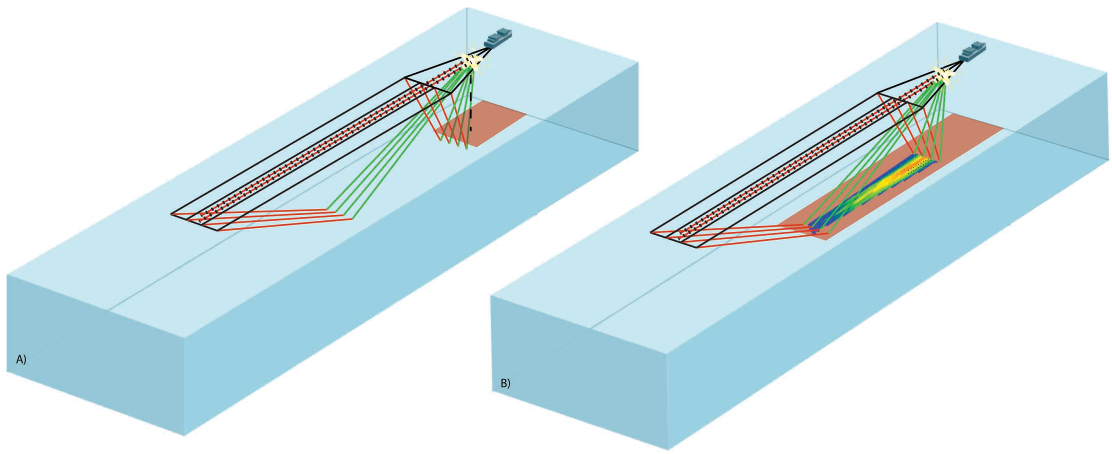

Figure B.1. Identification of shots to include within each 3D swath box: A) For case of ship entering in same direction wrong and B) correct way (see the text). Red lines with black dots represent location of shots (shot in flip-flop mode at every 37.5 m); four parallel black lines represent location of streamers towed behind the ship, green lines show down-going P-waves and red lines up-going P-waves. Orange rectangle represents location of pre-defined 3D swath box, for which the shots are determined. In B) gradational colors from orange to blue represent fold (high to low, respectively) of the data within defined box obtained from the included shots.

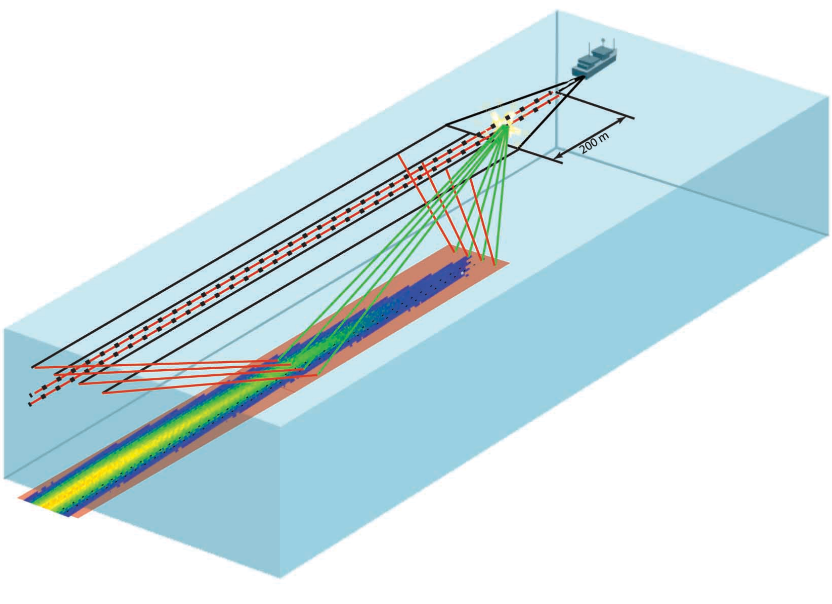

Figure B.2. Defining shots to include for the case when the ship is exiting the swath box. The elements of the graph are the same as in Figure B.1.

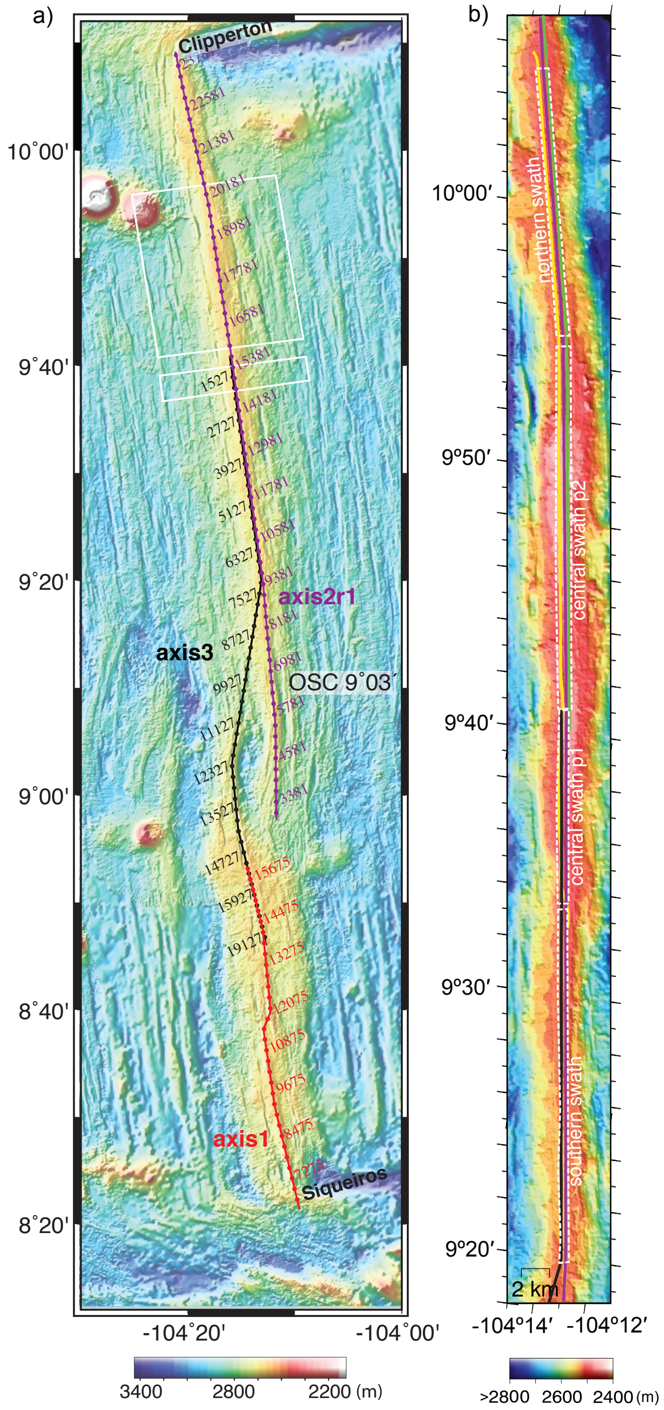

Figure 1. a) Location of multichannel seismic (MCS) datasets collected during expedition MGL0812, aboard *R/V M. G. Langseth*. Tracks of the along-axis profiles used for 2D data processing are shown in red (axis1), black (axis3) and purple (axis2r1) lines with dots marking location of every 300 common-mid points (CMP) along each line (every 1200 CMP is indicated by a number). White rectangles outline the extent of the cross-axis 3D volumes [*Canales et al.,* 2012]. The underlying seafloor bathymetry map is a composite map derived from the Global Multi-Resolution Topography (GMRT) database [*Ryan et al.,* 2009] and multibeam sonar data acquired during the cruise gridded at 50 m, with tectonic discontinuities of the ridge axis indicated: Siqueiros

and Clipperton Transform Faults, Overlapping Spreading Center (OSC) at 9º03′N. **b)** Location of the along axis MCS dataset processed as a 3D swath. The extent of the 3D migrated data is shown in white, dashed rectangles. The lines show location of the sail lines used for 3D processing: yellow - axis3p2; purple - axis2r1; black - axis3; green - axis4. The underlying seafloor bathymetry map is a composite map derived from the data acquired during the cruise and the data from White et al. [2006].