

SEISMIC VELOCITY ANALYSIS

Objective Data from a seismic survey consisting of regularly spaced multi-offset shot recordings along a profile are provided. The objective in this exercise is to construct a seismic P velocity model for the survey profile. This is a preparatory step towards conversion of the shot recordings into a synthetic zero offset seismic section by the CMP stacking method (the objective of Exercise S3).

Background - You are supplied with the data from a small 2D (profiling) seismic reflection survey over a part of the western Canadian basin where the strata are relatively uniform and flat-lying. The survey objective is a seismic P wave reflectivity cross-section in which even very minor lateral variations in the stratigraphy can be seen. Because the geological structure of this area is simple, it is acceptable to achieve poorer spatial resolution in the horizontal direction than in the vertical direction. For this very common sort of application, the desired imaging product is a "synthetic zero offset seismic time section" (SZOSTS) in which new traces are constructed by the common mid-point (CMP) stacking method. (See Lab Manual S3 for more detail)

An accurate velocity model is required both for making the NMO correction in required in CMP stacking, and also for geological interpretation of the resulting seismic time section (SZOSTS).

Data supplied:- The survey data recordings consist of fifteen shot gathers of 120 traces each. The survey profile is a straight line with geophones located at stations spaced 33.0 m. Shots were located every 8 stations and recorded by a 120 trace symmetric spread with a one station gap at the shotpoint. The recordings are stored in a single data file (DEMOLINE.SGY) in C:\SEISDATA\STACKING, and are not needed in this form until S3. The geometry of the survey is given in Table 1, below.

Provided in STACKING\VELANAL are a pair of shot gather records and three files that are called CMP *supergathers*. A CMP supergather is like a simple CMP gather (see Lab Manual), except it contains all the traces for a group of nearby mid-points, and has the traces ordered by shot- receiver offset. Each supergather is centred on the station number used in the file name. Each is used to estimate subsurface velocity structure beneath one point on the seismic profile. Because of the simple stratigraphy of this area, differences between sites are expected to be relatively minor and smoothly varying from one location to another.

The DEMOLINE.SGY data are a superset of the data you examined in Exercise S1. There you examined the recorded data in its (nearly) raw state (i.e., as it was recorded), and you performed some basic filtering and scaling operations on it to enhance its appearance. The traces in the CMPxxx.SGY files have had some processing steps applied to improve the ratio of the P wave reflection signal amplitude to the amplitude of other signals and extraneous noise.

Exercises As described in LabManual S1 and S2, the variation in arrival time of a reflection or refraction event with shot - receiver offset can be used to estimate average velocity from the surface to the reflector or refractor. Furthermore, the average velocity from the surface down to the different reflectors needs to be known accurately to do the NMO correction in a CMP stack. Estimates can be made by analysing refracted or reflected waves.

1. Estimating near surface velocity from refractions:- For this task, you must work with unfiltered data with no time corrections applied. Thus, you are supplied with a pair of simple shot-gather records of the same type as you used in S1:- records sg221 and sg253 for which the shotpoints are 32 receiver stations apart. (Station interval = 33m.) Analyse the first arrivals on sg221 that run towards station 253 and those on sg253 running towards station 221. Plot the early parts of these (half) records at an expanded scale so that you can see each first arrival event clearly (separate plots for each half). Apply AGC or GAIN to the records before plotting, and possibly adjust the trace amplitude scaling factor in SET so that the initial (first arrival) events are very clearly displayed. Please note that there is a "gap" of one extra trace interval (33 m) between traces 60 and 61 to make room for the shot. The shot point is at the missing station, i.e., one station interval from the closest geophone.

On your section, mark the first arrivals carefully (perhaps with a colour marker) and then try to identify consistent linear segments such as would be expected from a simply layered medium. Measure slopes and intercept times graphically. They should show strong similarity on the two sections. Estimate an appropriate shallow direct arrival velocity (the inverse slope of the arrivals nearest the shot; traces 1-3 at most) even if these arrivals are obscured. Remember that the shot is located in a borehole. See the Lab Manual - S2 for details of the calculations

Interpret your observations of the intercept times and velocities in terms of a simple, horizontally layered model. (For corresponding event lines for the two sides, average the intercept times and find geometric means of the velocities.) Compare these results with those obtained from reflections (next section). You may use them there to constrain the top of the stacking velocity model .

2. Accurate velocity analysis using reflections:- To perform the NMO correction in common mid-point stacking, a good estimate is required of stacking velocity versus reflection time for each mid-point of the seismic profile. (See Lab Manual S1) In well-stratified geology, we may expect this to vary only slowly along the survey profile. But because lithology can vary greatly with depth, the variation of stacking velocity with reflector depth (as measured by travel time) can be substantial. If the rock strata (and therefore the reflectors) are even approximately horizontal, the stacking velocity of a reflector is very close to the mathematical root-mean-square, time -averaged velocity for the seismic wave to travel vertically from the surface to the reflector, or vice versa).

Stacking velocity is usually obtained by a method akin to that used in exercise S1 where hyperbolae were fitted to some of the reflection events and the parameters of each hyperbola gave a velocity value. However, in that exercise, you analysed data from a single shot, and it was necessary to assume that the strata were perfectly horizontal. If the seismic traces being analysed all have the same (or nearly the same) shot-receiver midpoint, the time - distance curve will be hyperbolic, even the reflector is dipping. Thus, you are provided with three such trace selections labelled `cmpXXX.sgy`, where XXX is the station number of the midpoint on the "Demoline" profile, in `C:\SEISDATA\STACKING\VELANAL`.

Use the VISTA routine VPICK (and its preparatory routine SEMB) to determine the rms velocity structure of the strata under the three midpoints. SEMBlance is a program that applies a normal moveout correction to the CMP data set, then stacks it and computes the energy of the stacked record in successive short time intervals relative to the summed energy in the unstacked traces. (This ratio is called *semblance* and it measures how similar were the component traces in the short time window.) The operation is then repeated for a complete range of velocities, resulting in a contour map of semblance vs reflection time and stacking velocity that indicates the optimum stacking velocity and reflection time for each significant event on the CMP gather.

A velocity range 2500 to 5000 m/s at 100 m/s intervals should be suitable for this data set. Then VPICK can display, side by side, both the CMP record and the semblance map (in stacking velocity and reflection time coordinates). You can then use a cursor system to choose the best fitting velocity model.

Apply VPICK successively to the three superCMP gathers and their semblance data. Determine $V_{ms}(t)$ at each by picking 5-10 reflections. You may chose the hyperbola display or the semblance colour contours for picking, preferably a combination of both. Remember to estimate values for the near-surface part of the data. Use the results of part 1 for this. You can also get a rough velocity value for the near surface by putting the hyperbola directly along the first arrivals.

Note:- you will need to create a file into which VPICK can store the velocity data.. VPICK automatically records the velocity picks as pairs of ASCII numbers there. The file can be read by other programs such as NMO or by any editor program such as "notepad".

Exit from VPICK only after analysing each supergather and making a hard copy of the screen display. Check the final pick file using VDISP and make a copy of the graph. Save your pick file outside of `USER\TEMP` for use in S3.

3. Interpretation:- Comment on the consistency and repeatability of your stacking velocity functions. If you think your estimates of RMS average velocity are reliable, try converting them to interval velocity with the program DIX. Comment on the accuracy of these estimates. What do the velocity estimates tell you about the lithology the strata?

TABLE 1 -Survey geometry of the DEMOLINE.SGY profile

LINE: unknown

AREA: unknown

TRACES: 120s

STATION INTERVAL: 33.0 m

SHOT INTERVAL: 264.00 m

COMMENT #1:demo data from ITA

of shots=15, First column below gives shot #, last five columns give station

sp#	sp_stn	tr#1	tr#60	tr#61	tr#120
30	165	105	164	166	225
29	173	113	172	174	233
28	181	121	180	182	241
27	189	129	188	190	249
26	197	137	196	198	257
25	205	145	204	206	265
24	213	153	212	214	273
23	221	161	220	222	281
22	229	169	228	230	289
21	237	177	236	238	297
20	245	185	244	246	305
19	253	193	252	254	313
18	261	201	260	262	321
17	269	209	268	270	329
16	277	217	276	278	337