Seismic parameter design for reservoir monitoring, Brooks, Alberta

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ABSTRACT

The main objective of this paper is to evaluate a 3D-3C seismic survey in order to make possible 4D and reservoir studies to monitor CO2 injection and map the underground layers and structures. A porous and permeable formation (the Medicine Hat sandstone) as a reservoir with reliable cap (low permeability) that is the Colorado shale are injection targets for CO2 sequestration and also for the seismic survey design. The project area is a field located southwest of Brooks, Alberta. The first part is data gathering and analysis results for velocity functions and desired frequency content of targets (shallow and deep) and the second part is the parameter estimation for preventing spatial aliasing and suitable resolution for the reservoir study. For the bin size and migration aperture estimation, constant and linear velocity methods were considered. Finally, two options are introduced and their attributes (fold map for PP and PS data) are compared.

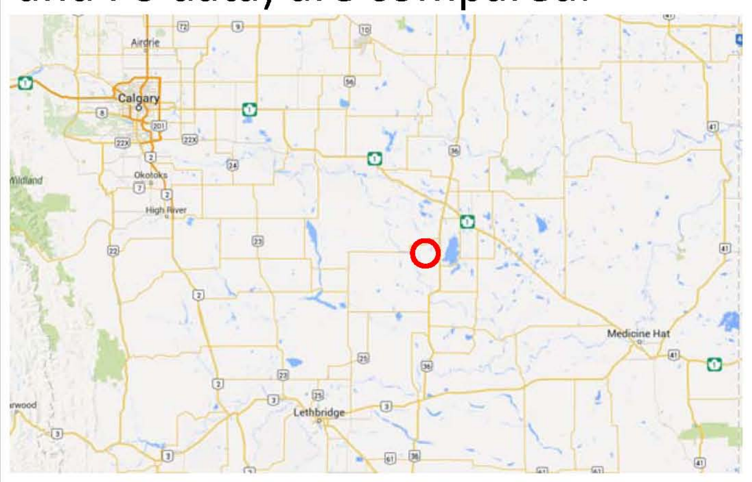


Fig.1. The project area (the red circle) is the west of lake Newell (source google map).

BACKGROUND INFORMATION

The following information should be collected and considered before a regular designing:

1.Geology of area
2.Terrain conditions (topographic, permit …)
3.Frequency contents in the targets
4.Velocity and velocity as a function of depth
5.Objective of acquisition
6.Full fold Image zone for structural or reservoir studies to estimate acquisition boundary
7.Seismic data
8.Technical part and existence technology
9.Financial conditions and limitations

FREQUENCY CONTENT IN THE TARGETS

For a flawless Bin size estimation and designing, max and dominant frequency on the target formations should be analyzed from old VSP and 2D, 3D seismic data. Relation between max frequency, deep angle (θ), interval velocity and bin size (B) for unaliased data is:

$$B = V_{int} / (4 f_{max} Sin\theta) \quad \text{(Eq.1.)}$$

There are old 2D and 3D seismic surveys in area. Row shots are not accessible so seismic stack before filtering was used for frequency analysis. According to frequency content analysis, dominant frequency for the target formations are between 30-70 Hz and for the max frequency it is 80 Hz.

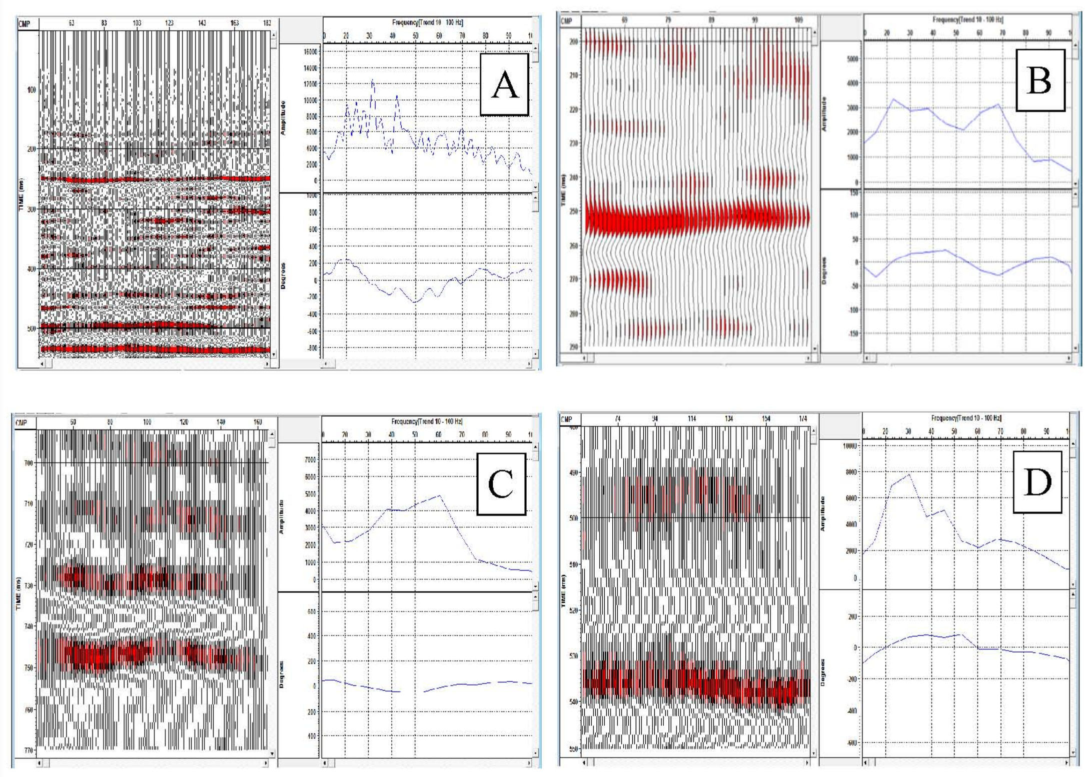


Fig.2. Frequency analysis on the whole seismic section from 0-550 ms (A), The shallowest target (B) and the deepest targets (C,D)

VELOCITY AS A FUNCTION OF DEPTH

Well log data is a liable source for compressional and shear wave velocity profile, in the lack of shear wave velocity here ,it was considered half of Vp. For bin size and migration aperture estimation, it is possible to use constant and linear velocity. Using linear velocity in the calculations can optimize cost, especially it decreases migration aperture and acquisition area.

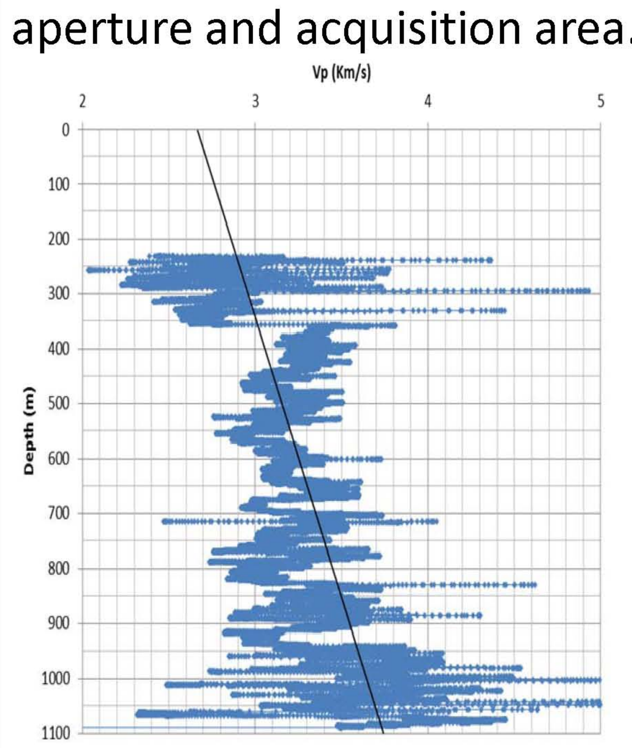


FIG.3. As mentioned, linear function for velocity can be used in the bin size's and migration aperture's calculation. Velocity function for Brook's project regards to well log data (CVE 7B countess 7-22-17-16) is: $V=V_0+kz=2650+z$.

BIN SIZE

Appropriate Bin size can guaranteed a data set without aliasing problem, small bin size can prevent to acquire unaliased data, but also can decrease S/N ratio (Cordsen et al., 2000).

The project area is situated in flat plain, and also subsurface layers have a gentle dip angle less than 2 degree. For a flat subsurface condition, dip angle that is used in formula is θ = Max (30, real dip angle) (Vermeer, 2002). It is to make possible for gathering all diffraction events.

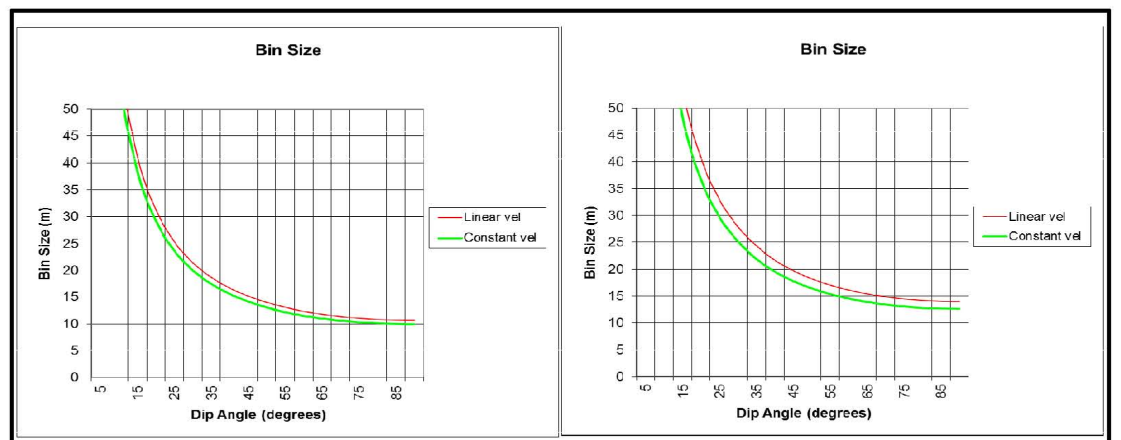


FIG.4. Bin size for the shallow target with 80Hz max frequency (left diagram) and for the deep target with 65Hz (right diagram).

BOX SIZE AND GEOMETRY

The box size and geometry can bring the LMOS (largest minimum offsets) concept to the designing. As mentioned, the target depth is from 300-700 m, and for acquiring data with suitable fold on the target depth, LMOS should be equal or smaller than first target depth, because it make a no data zone equal to LMOS. Other problem that increases fold in the shallow depth is NMO stretch and mute so for the project, and in the parameter designing should be considered (FIG.5). For the reservoir and AVO studies, a symmetric geometry for the box and the patch with aspect ratio ~1 is selected.

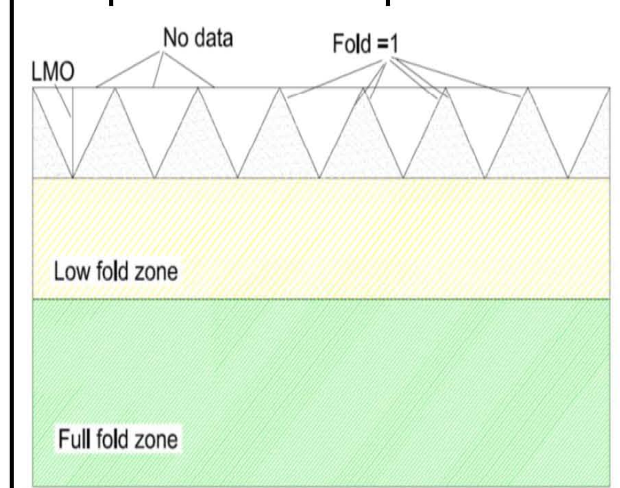


FIG.5. Influence of mute function (in low data zone) on calculating maximum offset and effect of LMOS on no data zone. The stretch factor (SF) defines the maximum offset, the small SF will make less fold in the survey and consequently data will be expensive and the larger one will decrease resolution (Vermeer, 2002).

2D SYNTHETIC SHOT MODEL

Fig.6 is a 2D geological and velocity model made by 3D seismic interpretation result and well log data. Modelling method is ray tracing. Figures 6.right is synthetic shot records for S reflection and refraction events. A thin weathering layer is added to the model.

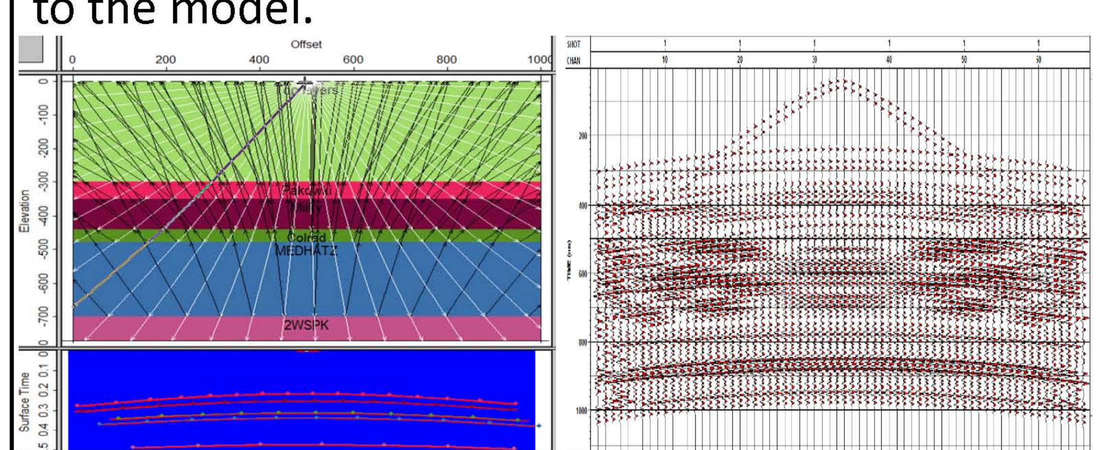


FIG.6. Left : 2D geology and velocity model for the interest zone and ray tracing model and its result in Right: time Synthetic shot of full S and P wave reflections and refractions for the model with a thin weathering surface. This model has 1 km length , 65 live geophones and group interval is 15 m.

SUGGESTED OPTIONS

Analysis and parameters calculation in the last sections, and necessity to have a semi high resolution seismic profile for the research purpose, lead us to suggest two option (following table).

Parameters	Option A		Option B
	Main	Mid core	
Bin size	5	5	7.5 m
Receiver interval	10	10	15 m
Reciever line interval	100	50	60 m
Shot interval	10	10	15 m
Shot line interval	100	50	75 m
Total Survey area	1000*1000	500*500	1020*975 m
Maximum Offset	1407 m		1407 m
minimum offset	14	7	10.6 m
Largest minimum offset (LMOS)	134	64	85.5 m
Maximum fold	83	185	221
The highest fold (pp)	185		221
Maximum inline offset	1000		1000
Maximum xline offset	1000		1000
Aspect ratio	100%		95.50%
Total shots	1600		952
Total live geophones	1600		1170

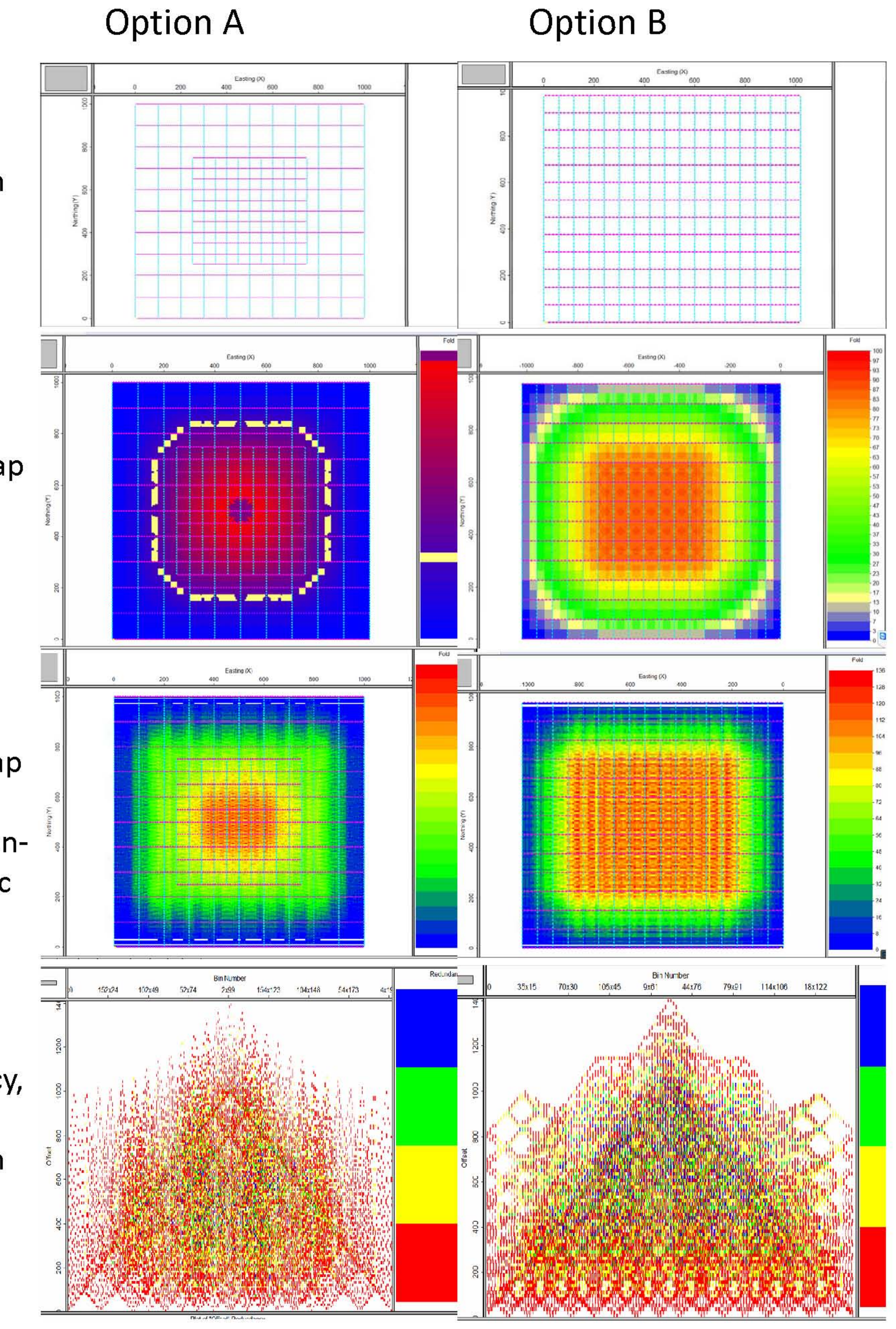
Option A | Option B

Acquisition Pattern

PP fold map for offset 0-700 m

PS fold map for 500 m depth , non-asymptotic

Offset redundancy, PP wave acquisition



CONCLUSION

The fold map condition for the option A shows a high fold range in the mid core (500*500m). For the second option, fold map is spread constantly in the acquisition area and can make a bigger image and data zone if injection plume grow during injection. With considering shot and receiver points, economically option B is a better choice as shot points are 40% less than first option, especially high fold contents are supported by reservoir points more than source points. However option A has better resolution because of smaller bin size.

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