Seismic resolution (and frequency filtering)

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Seismic data is an important tool when studying palaeo-environments and geomorphology. Two-dimensional (2-D) seismic data is normally used to get a regional overview in an area, for instance when searching for petroleum resources in a relatively unexplored area. Such data are relatively cheap to gather, compared to three-dimensional (3-D) seismic data. 3-D seismic data are used for more detailed mapping of prospects that have been found. In addition, high-resolution 2-D seismic (and 3-D seismic) may be useful in this stage of the exploration, as such data provide a better resolution than regular 2-D/-D seismic.

Vertical resolution

Seismic resolution is a measure of how large an object need to be in order to be seen in seismic. The vertical resolution (box 1) is derived from the length of the sound-wave and layers can be discerned when their thickness is below ¼ wavelength. Still, you can detect layers down to 1/32 wavelength. When referring to vertical resolution, it is normally the ¼ wavelength.

> <u>I – Vertical resolution</u>
>
> The wavelength is calculated by:
>
> $$\lambda = V/F$$
>
> The vertical seismic resolution is calculated by:
>
> $$\lambda/4$$
>
> λ = Wavelength
> F = Seismic frequency
> V = Seismic velocity

Horizontal resolution

The sound wave sent out from the source move in three dimensions and spread out over a larger area the further away it get from the source. The horizontal resolution is derived from the Fresnel-zone (Fig. 1), the part of a reflector covered by the seismic signal at a certain depth. On a buried horizon, all features with a lateral extent exceeding the Fresnel-zone will be visible. Migration of the seismic data focus the energy spread in the Fresnel-zone, re-arranges reflections misplaced due to dip and remove reflection patterns from points and edges. This improves the horizontal resolution to about ¼ wavelength (Fig. 1).

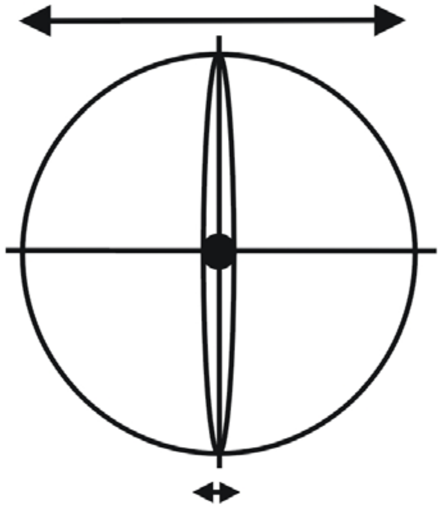
Seismic resolution

Normally depth is measured in milliseconds two-way travel-time, meaning the time the sound wave use from it leaves the source until it hit the reflector and return to the receiver. With increasing depth the frequency of the sound signal will decrease while the velocity and wavelength increase. This means that with increasing depth the seismic resolution will be poorer. The high frequencies are reflected from relatively shallow reflectors, while the lower frequencies reach further down. With increasing depth the sediments are gradually more compacted and therefore the sound velocity increase with increasing depth.

In 3-D seismic data you can see an object if it is larger that *either* the vertical or the horizontal resolution limit. An example is from a dataset with a vertical and horizontal resolution of around 10 m (Fig. 2). Here 2,5 meter deep plough marks are visible because their horizontal extent is several kilometres, exceeding the horizontal resolution.

Fresnel zone before migration

$= V(T/F)^{0.5} = \mathbf{195.66\ m}$

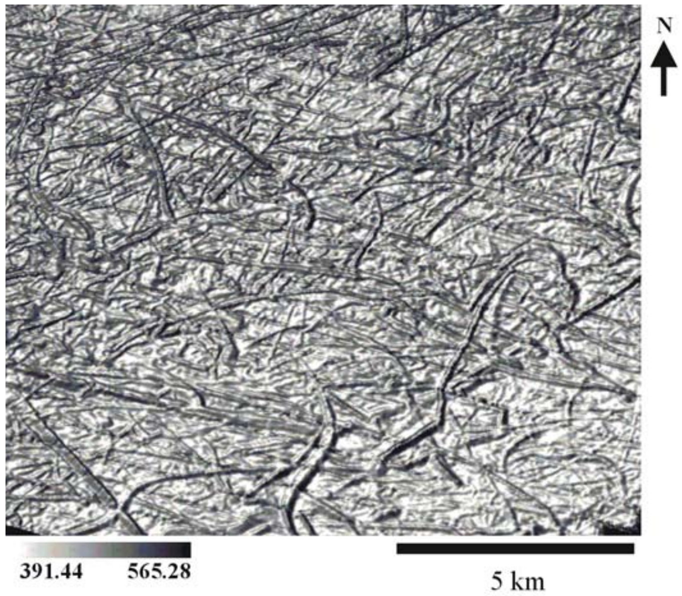


Fresnel zone after migration

$= \frac{\lambda}{4} = \frac{V}{4F} = \mathbf{10.94\ m}$

λ = Wavelength
F = Seismic frequency = 40 Hz
T = Depth in time = 0.5 s
V = Seismic velocity = 1750 m/s

<= **Figure 1.** The focusing effect of migration in two and three dimensions. The Fresnel zone will be reduced to an ellipse perpendicular to the line for 2-D migration and to a small circle by 3-D migration. Modified from Brown (1999).



Figur 2. Plough mark with a relief from 2,5-20 m, shown on the sea floor from a 3-D survey in the south-western Barents Sea. The scale in the lower left corner indicates depth in milliseconds two-way travel-time. Modified from Rafaelsen et al. (2002).

Frequency filtering of seismic data

The frequencies affect both the horizontal and vertical seismic resolution in the data; high frequency give high resolution while low frequency give low resolution. By using a frequency filter the lower frequencies are removed and the resolution is apparently improved (Fig. 3). The resolution has not been improved, but the data masking the high frequencies has been removed. The drawback is that the amplitude is weakened as the total amount of data is reduced.

<u>II - Frequency</u>

The dominating frequency is normally used when calculating seismic resolution. This may lead to an underestimate as high frequencies in the data may improve the resolution.

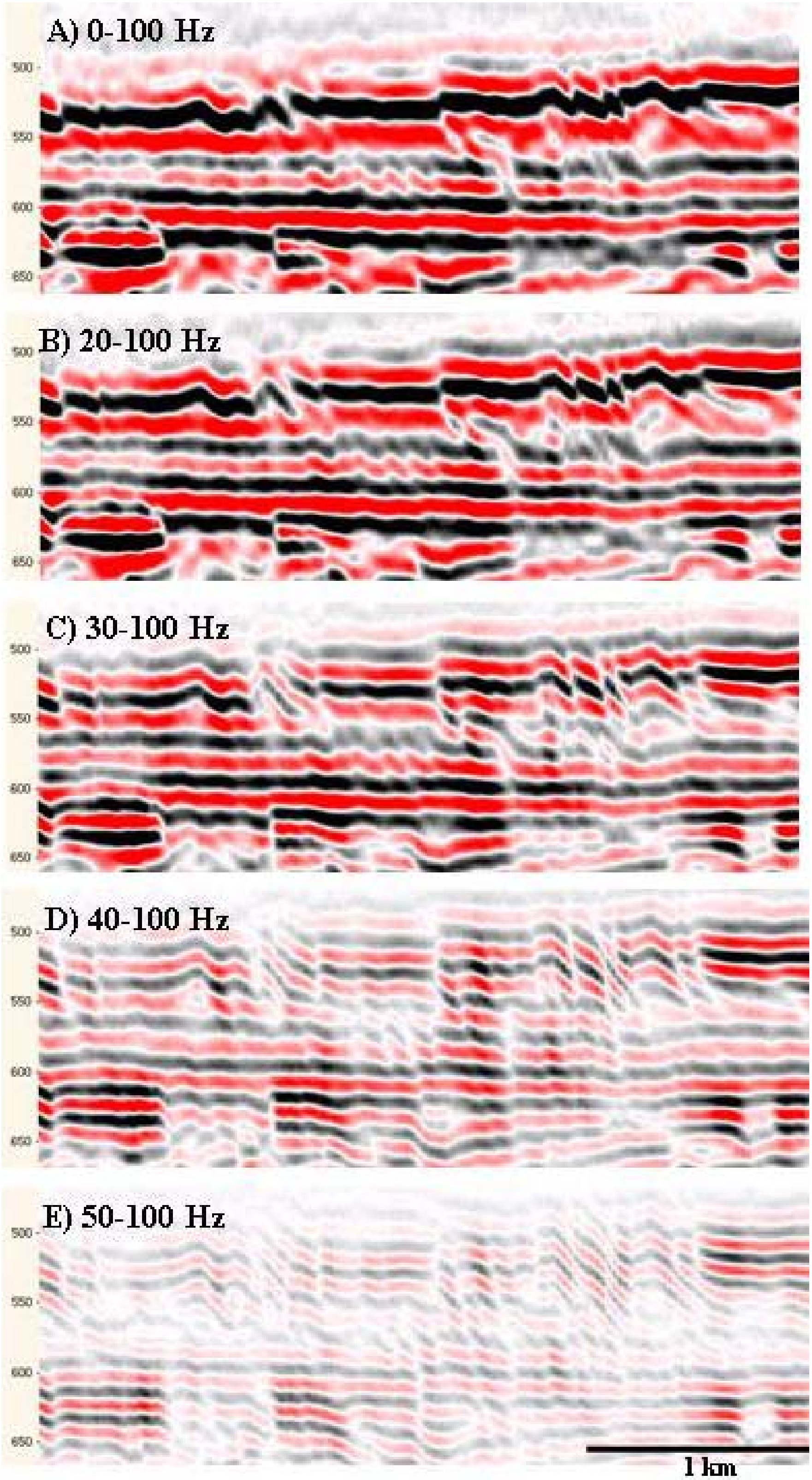


Figure 3. A-E) Examples of how a gradual removal (from top to bottom) of the low frequencies in the data apparently enhances the resolution and weakens the amplitude. Features that in A may look like disturbances in the upper part of the succession are in fact thrusted sediment sheets stacked in an imbricating manner (D and E). On the left the depth is shown in millisecond two-way travel-time.

References of relevance

Brown, A.R. 1999: Interpretation of three-dimensional seismic data, 5th edition. AAPG Memoir 42, Tulsa, Oklahoma, pp. 514.

Rafaelsen, B., Andreassen, K., Kuilman, L. W., Lebesbye, E., Hogstad, K. & Midtbø, M. 2002: Geomorphology of buried glacigenic horizons in the Barents Sea from 3-dimensional seismic data. *In* Dowdeswell, J.A. and O'Cofaigh, C., (eds.): *Glacier-Influenced Sedimentation on High-Latitude Continental Margins*. Geological Society of London, Special Publication 203, 259-276.