Wide-geometry 3D land seismic acquisition in limited channel-count environment

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Outline

- Land 3D seismic acquisition challenges in Kuwait
- Relevant concepts and definitions
- Channel-count requirements for wide-geometry
- Alternative techniques for wide-geometry in limited channel-count environment
- Conclusions

Acquisition considerations for Kuwait

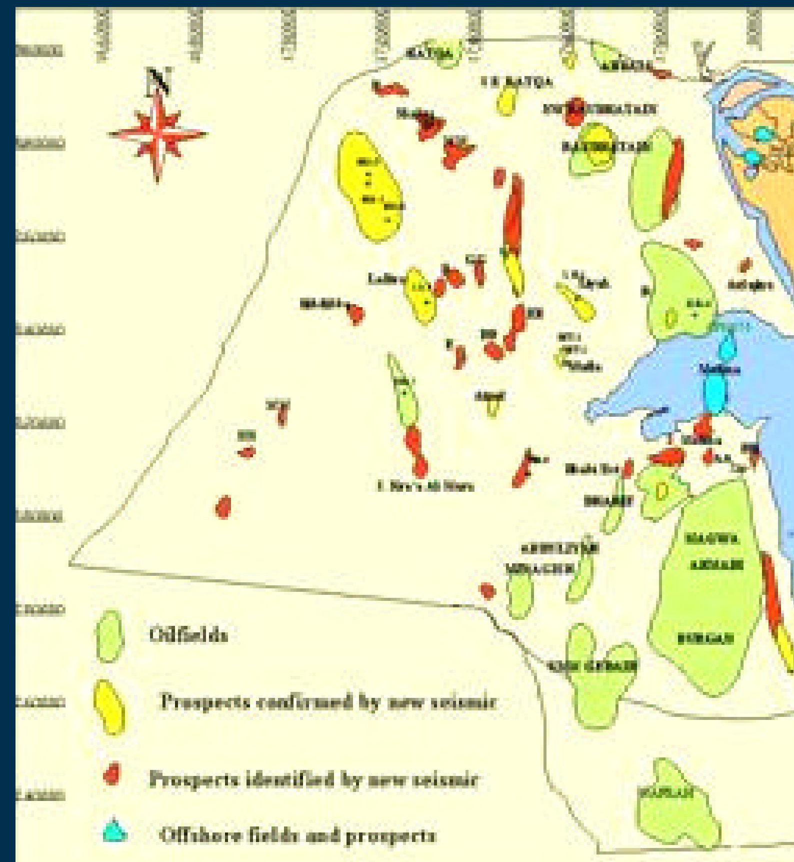
Land seismic data acquisition in Kuwait has to address a number of challenges among which are:

- **Coherent-noise wavelengths in the order of 8m-10m**
- **Image a shallow horizon for statics determination**
- **Image deep reservoirs requiring offsets > 6,000m**
- **Achieve high vertical resolution for reservoir characterization**
- **Minimize geometry footprint to enable successful attribute analysis, AVO, inversion, etc.**
- **Attenuate multiples**

Acquisition considerations for Kuwait

Kuwait contains large number of onshore structurally similar fields and prospects.

Because of its small land area (17,820 sq kms), it makes sense to consider one land 3D acquisition template that addresses all the challenges and enables future seamless merging of all individual surveys to produce a single 3D volume covering the whole of Kuwait.



Interpretation requirements

Seismic data interpretation is no more only focused on structural interpretation.

Many interpretation tools are based on amplitude analysis. Bias pattern in the amplitudes should be minimized at the acquisition stage and not left to be handled in processing with techniques that generally distort relative amplitudes.

One of the major techniques to minimize bias pattern in amplitudes and improve areal resolution is to reduce the source and receiver line intervals.

Concepts

- The signal to random noise ratio (S/N) is a function of the trace density seen by the migration operator. By increasing the acquisition trace density, the S/N in the final volume would be improved. [1]

- Trace multiplicity needs to build consistently with sources to receivers offset and azimuth. [2]

- An even, finely sampled distribution of source-receiver offsets over all azimuth ranges is extremely critical when AVO analysis or fracture detection is to be performed.

1 *Krey, Th C. 1987, Attenuation of Random Noise by 2-D and 3-D CDP Stacking and Kirchhoff Migration, Geophysical Prospecting 35, 135-147.*

2 *Robinson Don K. and Al-Hussaini, Moujahed, 1982, Techniques for reflection prospecting in Rub" Al-Khali, Geophysics, Vol 47 No 8.*

Concepts

- The fold and offset distribution have a clear impact on the data quality particularly in the shallow section.

- They also have an impact on the Pre-Stack Migration because of the “holes” showing up in many offset planes as the shot and receiver line spacing increases.

- The spatial sampling of the coherent noise wavefield must be appropriate to ensure un-aliased recording of the noise energy.

Concepts

Array forming in the field by straight analog summation provides suboptimal performance:

- The responses of such arrays are distorted by the presence of intra-array perturbations which are differences in amplitude, phase and timing.
- Residual ground-roll will alias and consequently will not be effectively removed in processing.
- Uncorrected intra-array perturbations could introduce pseudo-random noise, cause loss of signal and increased leakage of coherent noise.

Sampling

Proper 5-D wavefield sampling is the alias free sampling of temporal and all four spatial coordinates. [1]

Adequate sampling is the use of a sampling distance that prevents the noise wavefield from aliasing into the signal passband [2] . Thus, it is possible to adequately spatially sample with sensor spacing a little more than half of the ground roll wavelength.

[1] Vermeer, G.J.O, 2002, 3-D Seismic Survey Design , SEG

[2] *Baeten, G.J.M, Belougne, V., Combee, L., Kragh, E., Laake, A., Martin, J., Orban, J., Özbek, A., and Vermeer, P.L, 2000, Acquisition and processing of point receiver measurements in land seismic, 70th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, p 41-44.*

Uncommitted Acquisition (Universal)

In "uncommitted acquisition" in which we are not committed to a processing and/or interpretation sampling grid during the acquisition process.

i.e., in the field no irreversible step should be carried out such as group forming by conventional arrays.

Ongkiehong, L. and Askin, H. J., 1998, Towards the universal seismic acquisition technique, First Break, Vol. 6, No.02, p 46-63.

Acquisition footprint

Seismic amplitudes vary with offset, if we have changes in the offset distribution from one bin to the next, we will end up with a bias pattern in the amplitudes of the stacked traces, which is called acquisition footprint (geometry imprint).

The number of different bin configurations, which are repeated periodically over the area of a survey is 2 for a

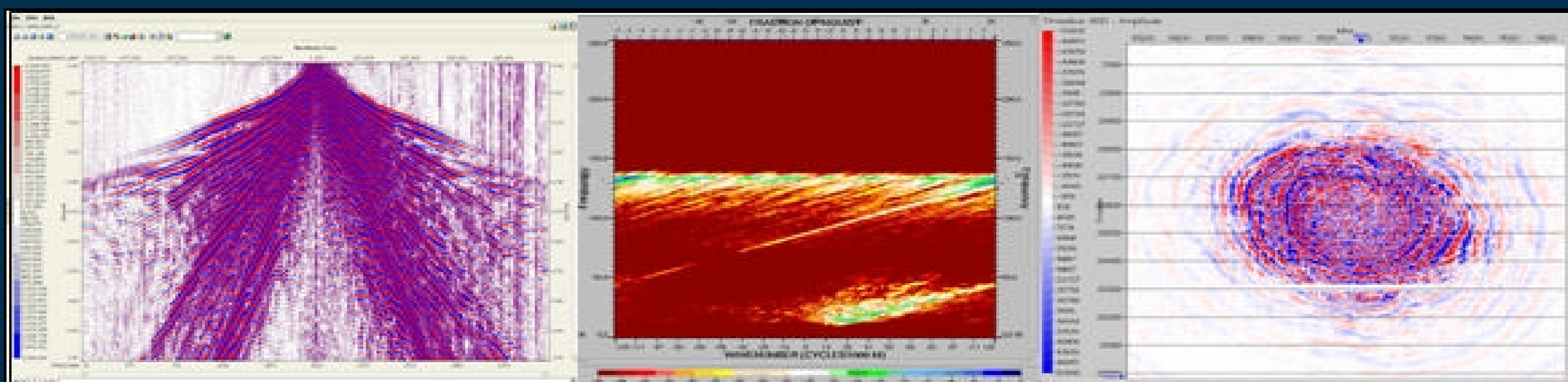
3D full fold scheme, “BSC=2”.

Design changes caused by cost and equipment availability considerations usually result in large increase in the number of different bin configurations and hence acquisition footprint.

Marschall, R. [1997] 3-D Acquisition of seismic data. Proc. of the 17th Mintrop-Seminar, Münster. DGMK Deutsche Wiss. Ges. für Erdöl, Erdgas und Kohle e.V.

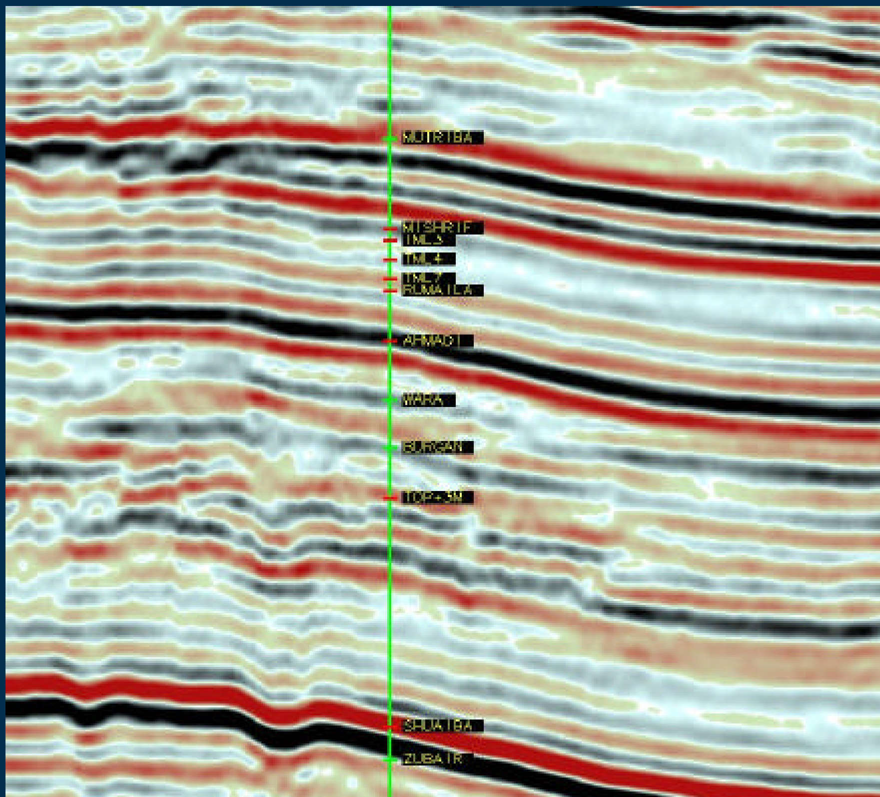
Noise tests

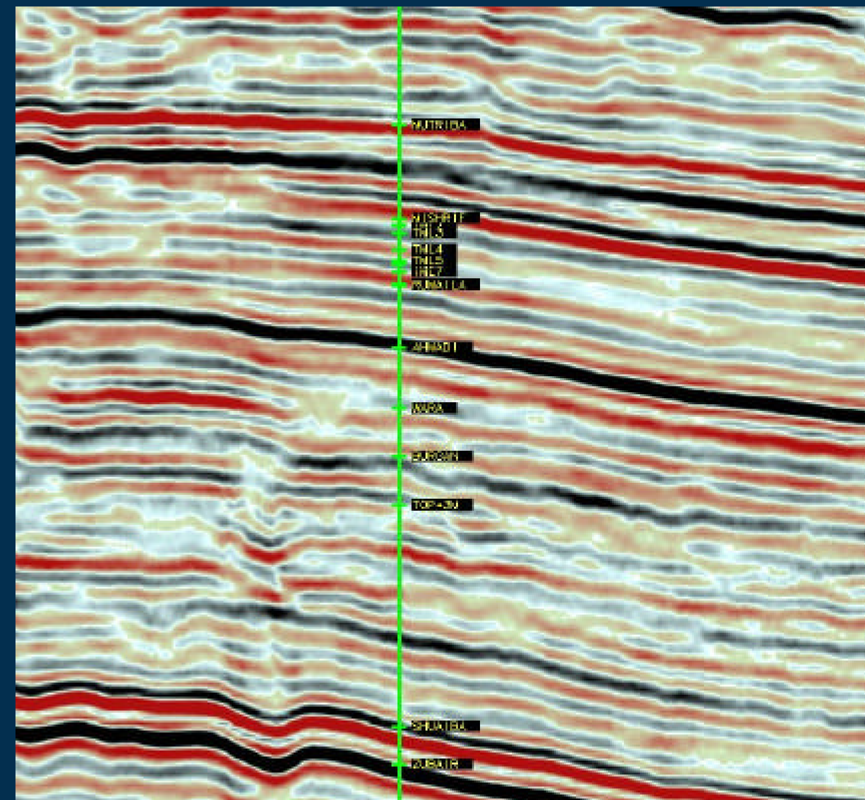
Noise tests conducted in Kuwait have shown that the shortest wavelength of ground roll is in the order of 8m to 10m, which would require receiver and shot spacing in the order of 4m to 5m. However, the concept of adequate sampling could allow relaxing this anti-alias requirement.



Raw single sensor shot gather, FK spectrum, Time-slice at 600ms from cross-spread showing anisotropy in the ground roll velocities.

The impact of single sensors and bin size





3D conventional

Array of 24 analogue geophones

Bin 25x25

3D digital 1C single sensors

Array of 8 digital sensor formed post initial processing

Bin 10x10

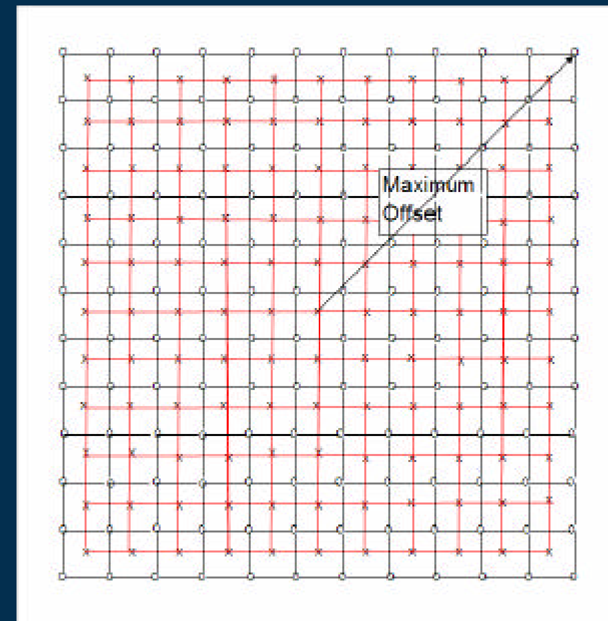
Uncommitted (universal) nominal 3D full fold acquisition

Let us start by an acquisition template consisting of two square grids with equal bin sizes:

- Source-grid: Red
- Receiver-grid: Black

An active single-sensor is located at each receiver-grid point and a source at the center of the source grid. The roll-along in x- and y-directions is with increments of one grid point.

?R=?S=?r=?s=5m



NL = 2,400, NRL= 1,720
X-inline=x-crossline= 6,000m
NR = 5,760,000 sensors
Fold = $(1,200)^2$

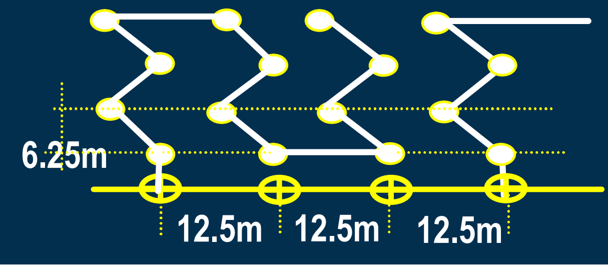
This is neither practical nor achievable. But the concept is intended as the theoretical reference against which all other schemes are to be evaluated [1]

[1] *Marschall R., 1999, 4D Seismics-Principles and Applications, Journal of Seismic Exploration, Vol. 8, No. 4, 1999, p 309-346*

Why Single Sensor

- To avoid the potential errors of array forming in the field by straight analog summation.
- With single sensor we can achieve uncommitted acquisition.
- In an orthogonal geometry, noise can be effectively suppressed in the cross-spread gather prior to group forming.
- Effective attenuation of noise in the receiver side decouples the source array from the receiver array.
- Typical digital arrays used in Kuwait comprise 4 sublines:

Single sensors in 4 sub-lines 12.5m inline separation, 6.25 m stagger and 6.25 m cross-line separation.



Data acquisition – shallowest horizon

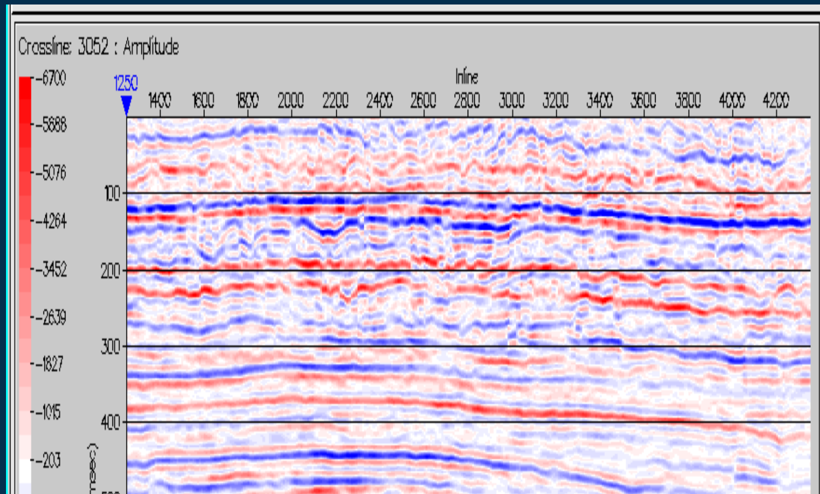
The shallowest horizon to be imaged has to be identified and considered in relaxing the requirement of the nominal 3D full fold acquisition.

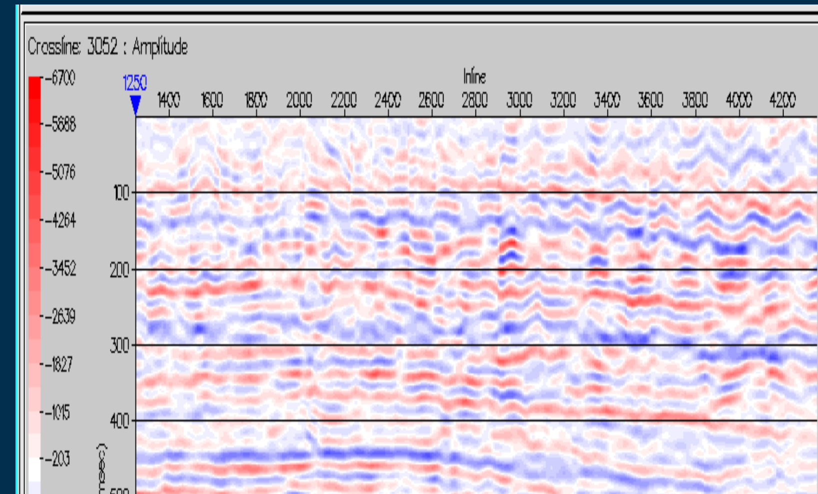
The imaging of a shallow horizon “the Rus in Kuwait” is needed for static determination and as a reference for depth conversion and multiple attenuation.

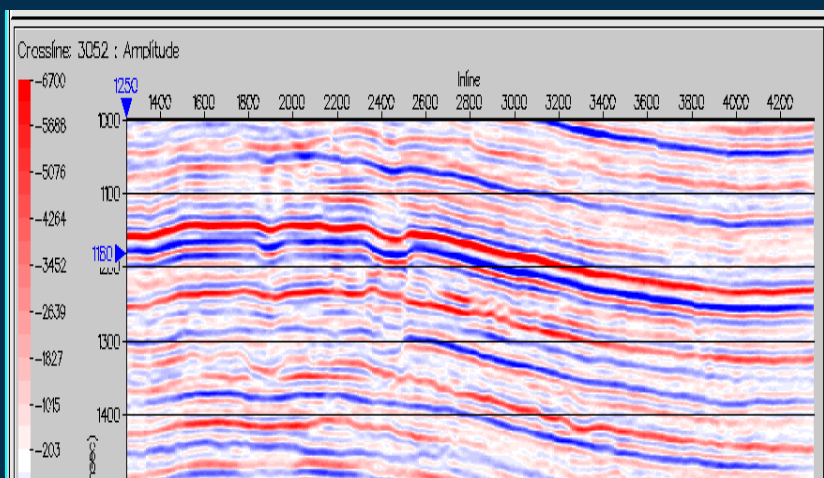
The Rus lies at depths ranging between 200m and 600m. Ideally, a fold of 4 would be desirable at this level.

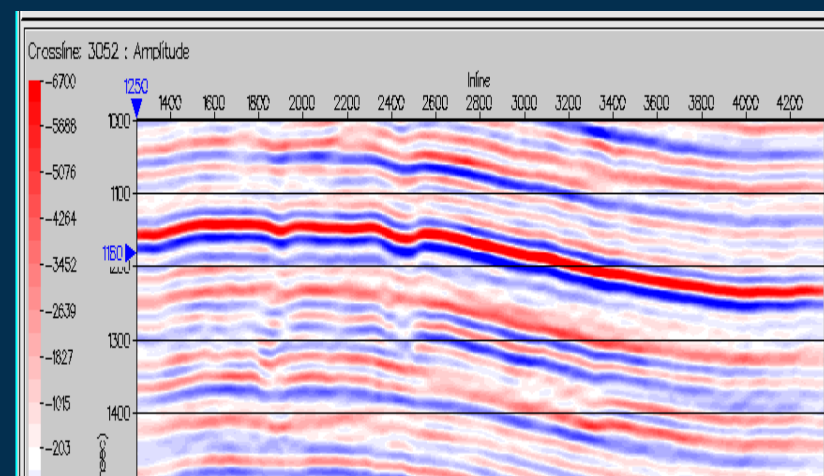
In consideration of this requirement let us choose 200m for receiver and shot lines spacing.

Data acquisition – line spacing









200mx200m **400mx400m**

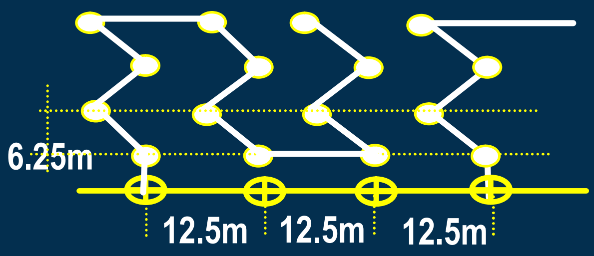
Homogeneous scheme, one line roll, 1C single sensors

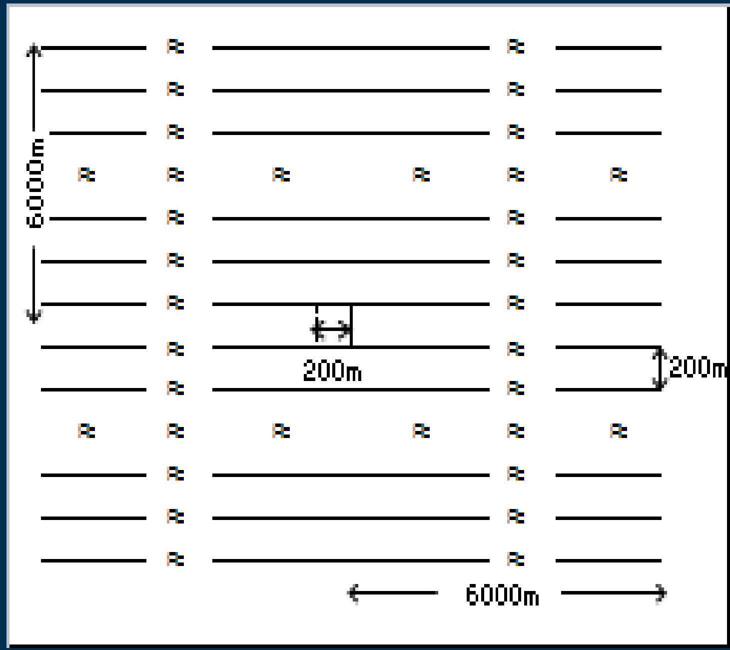
let us now compromise and select a less ambitious acquisition scheme using single digital 1C sensors .

?R=?S=200m.

?r= 6.25m. ⟶ 25m.

?s=12.50m. ⟶ 25m.





NL = 60 (4 sub-lines)

NRL = 960 @ 12.5m

NR = 230,400 sensors (channels)

Homogeneous scheme, one line roll, 3C single sensors

Considering the 3C MEMS-type sensors, such as Sercel's DSU3 or Input/Output's VectorSeis and depending on using adaptive filtering for noise attenuation, we can modify the design to:

?R=?S=200m.

?r=?s=25m.

NL= 60

NRL=480 , 3C digital sensors

NR=28,800, Channels= 86,400

Even if achievable, this approach might not be good enough to attenuate the various types of noise encountered in Kuwait.

Homogeneous scheme, one line roll, conventional

Replacing each 3C unit with an array of 12 conventional analog velocity geophones would result in a requirement for 28,800 active channels.

Even if achievable, straight analog summation provides suboptimal performance in signal preservation and in antialias filtering. [1]

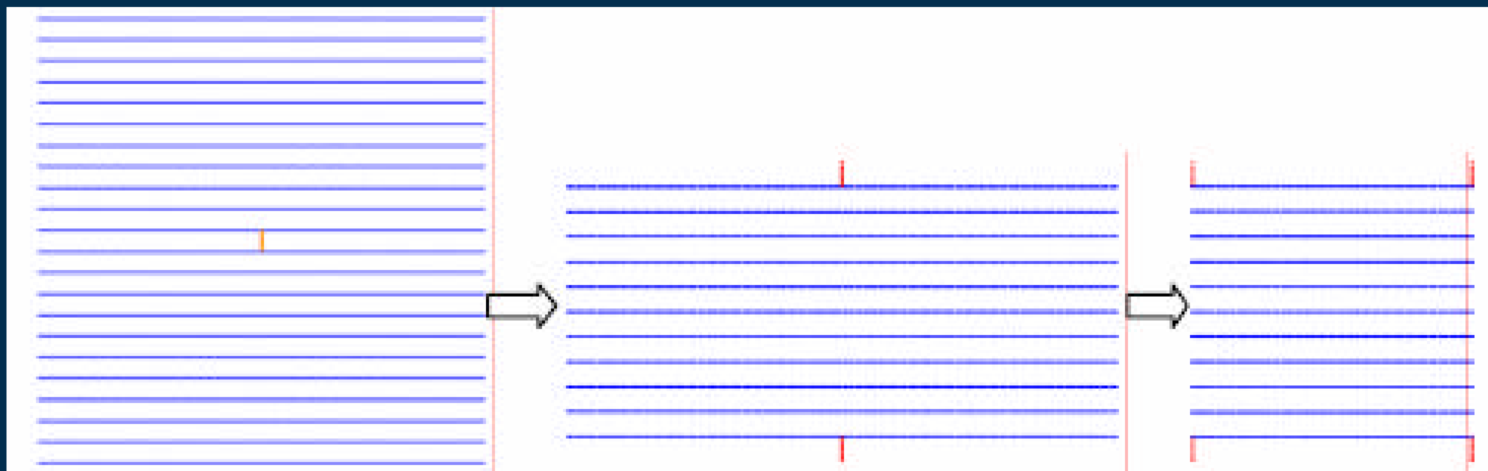
The response of the analog array is distorted by the presence of intra-array perturbations.

[1] *Rached G. and Al-Fares A. [2006] Single-sensor 3D land seismic acquisition in Kuwait, 76th Meeting, Society of Exploration Geophysicists, Expanded Abstract, 2.5.*

Alternative acquisition techniques

Repeated shooting to reduce channel-count requirements

3D wide-azimuth-swath (WAS) geometry, one line roll, two sets of shots on either side of the acquisition template or four sets of shots at all four corners.



*Hastings-James, R., Green, P., Al-Saad R., and M. Al-Ali, 2000, Wide-azimuth 3-D swath acquisition: GeoArabia, **5**, 1003.*

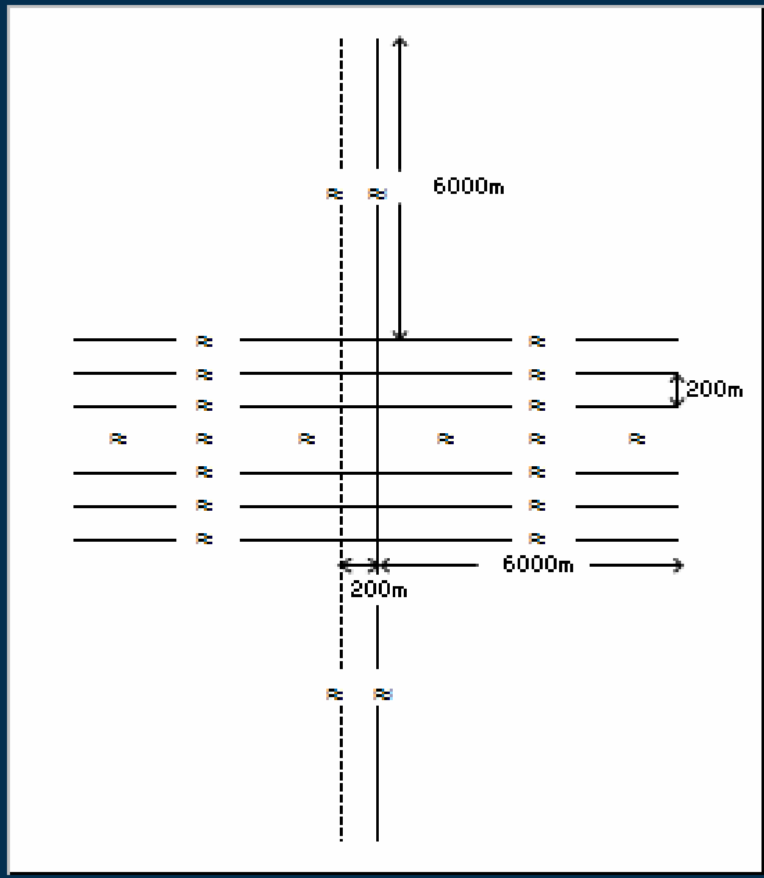
Operation of Multi-Thousand Channels 3DAcquisition with Limited Equipments in Libya Heng Zhou (BGP, CNPC), C.H. Wang (BGP, CNPC), M.G. Zhang (BGP, CNPC) & D.T. Zhou (BGP, CNPC)*

Alternative acquisition techniques

Repeated shooting to reduce channel-count requirements

Cross-spread, Full-swath roll

The salvos extend outside both sides of the acquisition template:



Case 1: The salvos extend a distance resulting in a shot repeat factor of 2 (Critical distance).

Case 2: The salvos extend far outside both sides of the acquisition template to allow recording of the required maximum crossline offset (ideally this should be equal to the required inline offset).[1]

[1]*Vermeer, G.J.O., 2002, 3-D Seismic Survey Design: SEG.*

Limitations

- Techniques that require repeated shooting of the same shotpoint into different templates to simulate the nominal design geometry result in more than one discrete data set from one shotpoint location.
- Consequently, statics coupling and shot repeatability are issues that should be taken into consideration.

Summary of channel-count calculations

Survey Design	lines	Sensors/line pre-grouping	sub-lines	Channels/line post-grouping	sensor spacing	Channel/source spacing	line spacing	Live channels
Single sensors 1C, array of 8	60	960	4	480	12.50	25	200	230,400
Single sensors 3C	60	480	1	480	25.00	25	200	86,400
Conventional, array of 12	60	2,880	2	480	4.17	25	200	28,800
Single sensors 1C, array of 8	30	960	4	480	12.50	25	200	115,200
Single sensors 3C	30	480	1	480	25.00	25	200	43,200
Conventional, array of 12	30	2,880	2	480	4.17	25	200	14,400

Conclusion

Acknowledgments

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THANK YOU

http://www.rached.net