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Some Causes of Artefacts in 3-D Seismic Surveys and Strategies to Minimise Them

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ABSTRACT

Artefacts in final processed 3-D seismic data volumes are becoming more frequently reported because such datasets are used increasingly in reservoir management projects. These artefacts commonly take the appearance of amplitude variations which are not due to geology. This leads to confusion and some loss of detectability when using data in amplitude studies, as in stratigraphic plays. They may also demonstrate structural features, usually small-scale, which again do not depict geology. In this paper, a description of some causes of such artefacts are complemented with suggestions made on methodologies for minimising, if not eliminating, their effects. Practical examples of artefacts are shown to demonstrate these effects. Guidelines are given with respect to aspects of field survey design such that these designs will have minimal effect on data interpretability. The implications of recent techniques on survey design are also investigated. In particular, the introduction of DMO in the Radon domain has considerable impact on survey designs as it allows the use of wide azimuths and irregular offset sampling. Also, certain processing-induced artefacts are described, with suggestions given as to means of reducing or eliminating them.

Keywords: artefacts, 3-D seismic surveys, survey planning

INTRODUCTION

The ultimate use of 3-D seismic surveys is, of course, to interpret sub-surface geology. Increasingly 3-D seismic data are being used in ever more demanding situations where both structural and stratigraphic integrity are of significant importance. This paper deals with artefacts which relate to the manner of acquisition and processing and the interaction between these. These can be extremely confusing to an interpreter and, where a quantitative interpretation is being performed, very misleading. Some artefacts may be of equivalent or greater magnitude than the geological attribute being sought. An unfortunate aspect of such artefacts is that they are not always visible until the data are examined on an interpretation workstation.

Many artefacts can be minimised or eliminated by careful design and execution of the acquisition and processing. Others are not so readily dealt with. This paper presents a general overview with guidelines and examples. Specific known causes of artefacts are discussed and means of avoidance or amelioration discussed. The implications for 3-D survey design of new processing technology are discussed with the use of examples.

SOME CAUSES OF ARTEFACTS

Some of the more obvious artefacts are caused by the fold of the data, either by this being insufficient or by it being very variable. In considering fold, the target is of prime consideration and because this often lies within the mute zone, there will be a limit to the maximum offset for useful data. This may be even further limited if there is substantial noise, eg, channelled waves, which are difficult to attenuate, the normal processes being less effective because of the poor sampling. The field design will also place a limit on the minimum consistent offset. These factors leave a diminished offset range. The fold may be further reduced by the use of coarse sampling. It is not uncommon for short cuts to be made in this aspect of the design, as all the parameters which lead to improving fold, especially in the shallow region, have a direct and substantial impact on cost.

A commonly accepted rule is that 3-D fold should be about half that of 2-D fold. A formula has been presented (Krey, 1987) showing this fold relation to be a function of expected resolution both in terms of bin size and frequency. This formula usually indicates the need for higher fold than just half of 2-D fold.

From a practical viewpoint, there are startling examples (Hastings-James and Al-Yahya, 1996) of high-fold 3-D surveys showing improvements considerably greater than could be expected on a simple fold and signal to noise improvement basis alone. This is most probably due to the better pre-stack sampling. Apart from a better gathering and sampling of the source generated wavefield this also allows pre-stack processes to function more accurately, eg, statics and FK filters. It is worthwhile to note that such large fold need not imply a significant increase in cost if the areal source effort is kept nearly constant.

Another area where cost plays a significant role is in the total survey area. The need for adequate fold and migration aperture, or at least a Fresnel zone width, is well known. Somehow when the data reach the interpreter, there is a tendency to step outside the inner zone supposedly designed for them. Including the interpreter in the initial design can help with this. One aspect which is not often considered is the effect of migration at survey boundaries. This may well lead to noise migrating up from deep in the section to affect the shallow data, especially if a high dip migration algorithm is used. To some degree this can be solved by a careful edge and bottom tapering in processing.

Migration will also have an undesirable effect on sharp edges in a survey boundary. For example, omitting a patch of receivers on one side of the survey, as illustrated in Figure 1, will save time and money in acquisition. On the negative side it will also cause migration noise to appear within the interpreter's fully migrated data segment. There is often a large temptation to make such apparent savings but these detract from the usefuleness of the data.

Another edge-effect not often considered is the effect on multiples. Figure 2 shows a plot of maximum offset for an

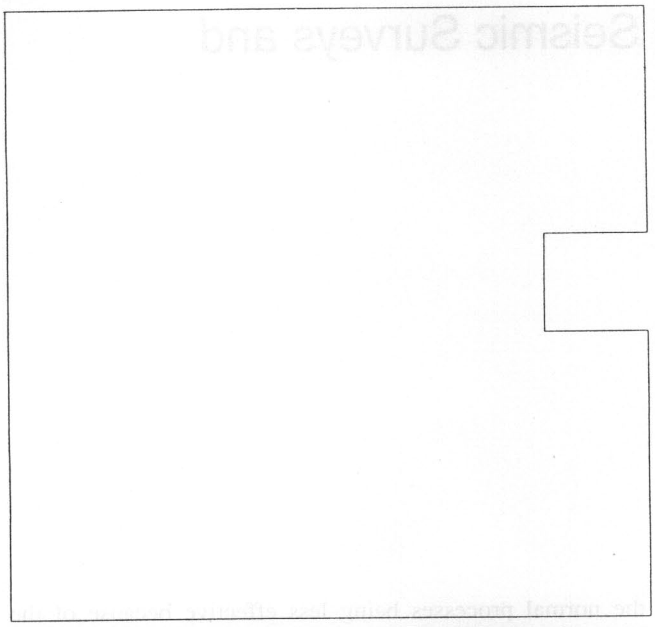

Figure 1. Omitting a patch at the survey edge causes migration artefacts.

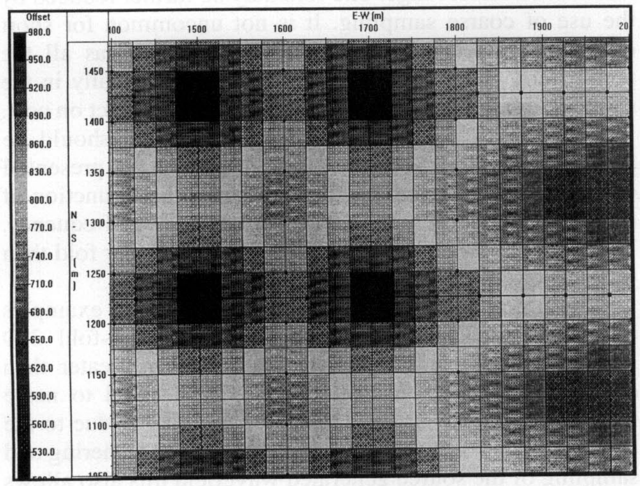

Figure 2. Loss of long offsets at survey edges leads to poorer multiple attenuation.

orthogonal survey with normal roll off. Full fold occurs at the vertical line marked as 1800. Beyond this the fold decreases largely, as the plot shows, through losing longer offsets. The effect of this is that there will be less multiple attenuation at this edge of the survey. The data will thus contain greater multiple content, which is likely to be of high amplitude (and quite possibly non-conformable with primary structure). This will migrate back into the survey area to give a plausible geological appearance, eg, of onlapping sedimentary rocks.

Another fold-related issue is the fold after 3-D DMO. This is a function of acquisition geometry, particularly of patch dimensions, ie, narrow patch design will not correctly image cross-line dipping structure. Much work has been done in recent years to compensate 3-D DMO algorithms. Performing 3-D DMO in the Radon domain (Wang, 1995) gets around many of these problems. A brief discussion of the theory for this new technique will be given along with practical examples. One implication of this technique is that wide azimuth surveys, ie, the use of large areal receiver layouts (be they land or marine), may be processed through DMO with little or no problem. This, combined with the

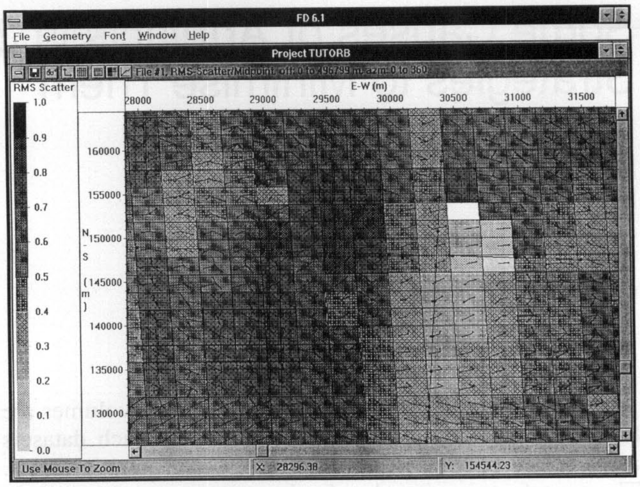

Figure 3. Normalised CMP Scatter and Tadpole plots illustrate grid irregularities which can cause striping.

findings of Hastings-James and Al-Yahya (1996), indicate that the use of many channels will help to reduce artefacts.

Artefacts can also be induced by apparently harmless processes. For example, a whole trace scaler may be used to bring amplitudes under control. If this is performed at too early a stage in processing before signal to noise has been improved then the noise will most likely control the scaling and the signal will have had an artificial variation imposed on it.

It is common practice to interpolate data post-stack. Such interpolation should be truly 3-D, since 2-D interpolators leave seams in the data which may become spread by subsequent processes. There is a case to be made for interpolating prestack using such techniques as wavefield reconstruction. Artefacts are frequently the result of undersampling, leading to poor stack performance in noise and multiple attenuation. Noise and multiple attenuation techniques are also less effective due to the poor sampling. It has been shown (eg, Mannin and Spitz, 1995) that prestack interpolation techniques can significantly improve older surveys. The deliberate planning for the use of such techniques will be discussed.

Yet another possible cause of artefacts is the scatter of CMPs within the bins. Figure 3 is a plot showing the normalised scatter of CMPs for a real land 3-D survey where shots and receivers were forced to follow the terrain. Such a tool may be used for determining the optimum binning grid in a graphical manner, a very difficult task to perform algorithmically but very easy to recognise by eye. In other words, simply move the binning grid until it visually "fits" the CMPs and reduces the scatter. This technique may also be used to fit an optimal binning grid to image complex structure when analysing CRP locations (Common Reflection Points in the sub-surface) generated by binning on sub surface events.

CONCLUSIONS

Several mechanisms for the creation of data artefacts in 3-D seismic have been presented. These artefacts have become a severe annoyance to interpreters as 3-D seismic data are increasingly used for quantitative analysis where amplitude, wavelet and structural stability are of paramount importance. It has been demonstrated that many such anomalies are avoidable. Careful survey planning and attention to detail during processing is very effective in reducing these anomalies. Recognition of such anomalies requires the viewing of data during processing in the same way as the interpreter will view it on the workstation. This requires something of a paradigm shift in QC methodology for processing. It is now necessary to examine the data in time and horizon slice form as well as vertical section form prior to delivery.

It has also been shown that the recently introduced technique of performing DMO in the Radon domain has a very beneficial effect on anomalies typically introduced by conventional DMO. There is no one solution to this problem, but a procedure which is ever mindful of the benefits of new technology is capable of producing 3-D datasets of more lasting value and supporting quantitative interpretation.

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