



Quantification of Quality An Approach towards Real Time QC Monitoring in the Field

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Summary

The optimum quality geophysical data is key input to the explorationist in oil industry. To fulfill the aspirations of explorationist, acquiring the desired quality seismic data had been a concern and prime objective of field Geophysicists. Various Quality Control (QC) norms and techniques had been developed to monitor and improve the quality of data at acquisition stage. Since the damage caused to the data at this stage cannot be recovered afterwards by processing or interpretation. In this direction, the authors have made an attempt to further sharpen the QC tools by developing Quantification of Quality. In this methodology, the primary elements contributing to the quality of the data are identified at acquisition stage and each identified element is assigned a weightage factor. Adding all these compounded weighted factors, the total Quality Control weightage for each shot is computed. The weighted information is tabulated for each shot and data quality is represented in the form of various contour maps viz. composite QC map, Frequency content map, Optimum Depth / Drilled Depth map etc. The information is prepared and upgraded on daily basis resulting in real time quality monitoring in field. The weaker quality zones are analyzed to find out the reasons for deterioration of data quality and remedial measures are taken in the field itself. These maps help not only to monitor and improve the quality on day-to-day basis but would immensely help in processing and interpretation of the data.

Introduction

In the quest for mapping of sub-surface features precisely, tremendous advancements have taken place in technology front in data acquisition, Processing & Interpretation. In spite of advent of sophisticated tools for processing and interpreting data, the good quality data at acquisition stage had been key input to the explorationist as no technology can provide desired result with poor quality data. Seismic data quality is said to be optimum if it has good amplitude (S/N ratio), better resolution (wider frequency band width) and has uniform foldage throughout the area of operation.

The responsibility of acquisition crew is to acquire quality data, which can fulfill the exploration objective in cost effective manner. This is achieved through efficient monitoring of data quality at acquisition stage. Well-defined quality norms exist in the geophysical Industry and are followed by the seismic field parties which are defined in “Land and Marine Seismic Data Acquisition”

Manual (LAMSDA) of ONGC. Still, effective tools are required to be developed for daily monitoring of quality of data and suggesting mid course corrections, if required. For effective monitoring of data quality, approach of quantification of quality can provide befitting solutions. Quantification of quality is nothing but assigning the weightage factors to various elements contributing to the data quality, tabulating the information and display of the information in the form of contours. Such approach was applied in Olpad-Dandi area of Western Onshore Basin in Gujarat, for quality monitoring. This methodology has not only helped in monitoring and improving data quality on day-to-day basis but has created vital information in the form of data base for surface and near surface variations which may be of great help in future.

Area of operation:

The area of study forms a part of Narmada tectonic block of South Cambay basin (Fig-1). The major part of the operational area lies mainly in Olpad



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gas field falling in the transition zone along Gulf of Cambay on the Western coast of India. This area is highly prospective from hydrocarbon exploration point of view. The wells drilled in and around this area are producing mainly gas from Tarkeshwar sands. The shallow gas exploration from Kand formation has further accentuated the prospectivity of this area. Integrated study of the available geo-scientific data has revealed a sub-surface picture in the area with regard to extension and disposition of various pay sands. Further, 3-D seismic survey is carried out to understand the disposition of various pay sands and entrapment environment for deciding exploration strategy. From the prospectivity point of view the quality of seismic data acquired needs to be exceptionally good.

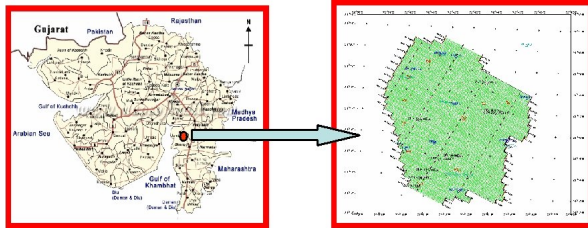


Figure-1: Area of operation of the study

Elements of Quality:

Seismic section is collection of different stacked traces. Therefore, the basic unit of seismic data is nothing but a single seismic trace. For a field geophysicist, the ultimate product of data acquisition is a Seismic trace and all his efforts are to improve this trace. The improvement in data quality is possible only when one fully understands the basic parameters constituting this trace. The seismic trace is defined as:

$$\text{Trace} = \text{source pulse} * (\text{reflectivity} (\text{earth's filter} + \text{noise})) * \text{detector response} * \text{recording instrument response}$$

In the above definition of trace, the reflectivity is function of earth's filter (which is area dependent and is subject of processing) and noise (environmental and is subject of acquisition). From this definition, it is clear that the basic elements are SOURCE, RECIEVER AND RECORDER. Apart from these factors, there are other factors like recovery shots, transmission error etc which have negative impact on data quality. The details of contributing parameters and their controlling factors in a shot (collection of traces) are given in table 1.

Table-1: definition of trace and controlling factors

Seismic trace	Defining parameter
Trace = source pulse*	<ul style="list-style-type: none"> Charge depth & size Impedance contrast (area dependent)
(reflectivity *(earth's filter+noise))*	<ul style="list-style-type: none"> Behavior of Earth's filter during propagation of energy (subject of processing)
detector response*	<ul style="list-style-type: none"> Receiver distribution (field geometry) & condition of receivers (percentage of good noise free receivers)
Recording instt. Response	<ul style="list-style-type: none"> All recording parameters within spec.

From the above discussions on quality of seismic data, following attributes are required in seismic data:

- Good S/ N ratio which can be achieved by enhancing amplitude and / or minimizing noise
- Proper resolving power i.e. proper band width
- Uniform fold distribution i.e. all offsets in each bin which can be achieved by minimizing skips, dead channels and recovery shots.
- Monitor record display without AGC to see reflection hyperbola, patchy reflection events and energy in far channels.
- Data is recorded within specifications of all equipments.
- Assignments are completed within stipulated time frame without data gaps.

To achieve the above objective attributes of data, following factors/ parameters are required to be set right and are quantified:

- Shot hole depth and charge size to decide proper shooting media through Near Surface Modeling (NSM) data.
- Percentage of good channels (eliminating dead and noisy channels).
- Frequency band width in the data.
- Type of shot (regular or recovery).
- Appearance of monitor record without AGC
- Transmission error during recording

Though, performance of the recording instrumentation is also a key element of data quality, it is not quantifiable as it cannot be changed during field season. However, all the instrument test must be taken daily (as per LAMSDA QC standards) before data recording so as to ensure that all the instrument parameters are within specifications.

The above mentioned parameters are assigned the maximum & minimum weights as given in table-2.



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the weights in between maximum & minimum are distributed linearly.

Table-2 : Assigning weights to various parameters

parameters	Source of information	Maximum weightage factor (out of total 1)	Min. weight
Shot depth	Observer sheet	0.3 for depth within +/- 2 m (as per LAMSDA)	0 if DD<50 % of OD
% of good channels	After data editing on (MPU)	0.3 for > 98 % good # (as per LAMSDA)	0 If good #, 50 %
Freq. band width(Fmax-Fmin) at -12 dB	From Frequency Spectrum processed on MPU	0.3 for > 45 htz (based on earlier data in the area	0 If band width < 50 % of max. bandwidth in the area
Hyperbola/ energy in far #	From visual display on MPU	0.1 for good looking monitor	0.05
Regular/ recovery shot	Observer sheet	-0.1 for planned recovery	0
Transmission error	Observer sheet	-0.1 for TE in any arm	0

The maximum weightage for any shot is taken as 1.0. sum of all these weights gives total quality weight for any particular shot. For grading shot Quality on a scale of 0 – 1, The quality of each shot is rated and plotted as per the following color scheme. The color scheme is optional and may be changed as per the user's convenience.

The available information is tabulated and updated daily on day to day basis. A sample format is given in table-3.

QC weightage	QC rating of shot	
0.96 – 1.0	Excellent	Dark green
0.65 – 0.95	very good	Light green
0.76 – 0.85	good	yellow
<0.76	fair	Light red

Table-3: Table showing inputs for QC analysis

line	Shot information				Channel Information			freq.(-12 DB;W:200-1000ms		Recovery shot	Events visible	TE(in arms)
	SP	OD	DD	dead	noisy	% good #	Fmin	Fmax				
190	514	20	19.2	116	30	77	15	70	n	y	0	
191	514	20	21.3	116	30	77	19	68	n	y	0	
192	514	20	18.8	116	30	77	19	63	n	y	0	
197	558	21	19.5	28	11	94	16	54	n	n	0	
190	562	22	20.6	33	12	93	15	47	n	y	0	
191	562	22	20.8	33	12	93	14	47	n	y	0	
192	562	22	20.2	33	8	94	15	51	n	y	0	



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utilized for preparation of various maps using **surfer** software. These maps are shown in figures 2, 3

Preparation of maps:

The available information from table-3 is further utilized to compute the weighted factors for each shot as shown in table-4.

Table-4: table showing weight functions for each shot and quality rating

Line	Pks.	Quality weights							total	quality rating,ex cell, v, good, fair, poor	remarks
		Wdd	Wch	WF	W/c	Wr	Wse				
190	530	0.3	0.3	0.3	-0.05	0.1	-0.25	1	Wb-0.95	bad	
191	530	0.3	0.15	0.1	0	0.1	0	0.65	fair	bad	
196	530	0.15	0.15	0.3	0	0.1	0	0.7	fair	low	
197	530	0.3	0.15	0.3	0	0.1	0	0.85	very good		
196	558	0.3	0.3	0.2	0	0.05	0	0.85	very good		
197	558	0.3	0.3	0.2	0	0.05	0	0.85	very good		
191	562	0.3	0.3	0.1	0	0.1	0	0.8	good		
190	570	0.05	0.05	0	0.1	0	0	0	poor	skip	

Information available in table-4 is further

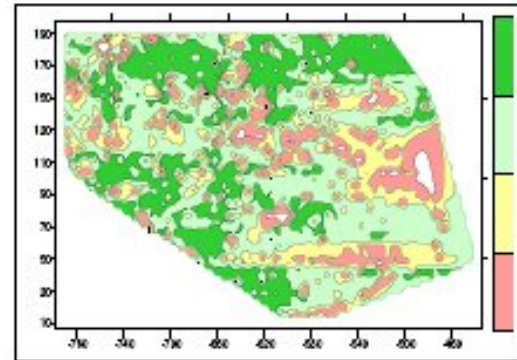


Figure-2 : composite QC map on a scale of 0-1

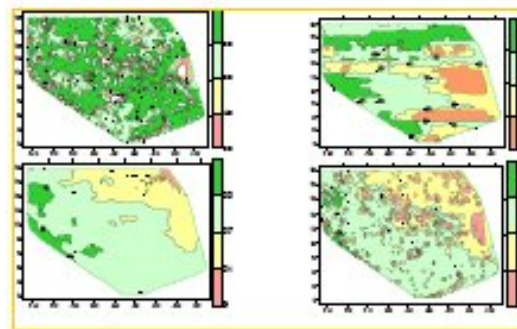


Figure-3 showing effect of various factors on quality; good channels(top right), OD(bottom left) & DD(bottom right)

Analysis of these maps showing quality of data and frequency distributions can demarcate the zones of better quality of data and higher frequency contents. It acts as a guiding tool for diagnostics and further remedial measures to improve upon data quality. This quantification of quality is of immense use if utilized to improve the data quality by taking mid course corrections. For this purpose, the identification of reasons affecting data quality is essential.

The QC analysis carried out on above data could bring out the total no. of shots with poor quality and the reasons for the same. This is depicted in figures 8. the aim of this analysis is to minimize the percentage of weak quality shots and to maximize the good quality shots by repeating the out of OD shots, minimizing TE and recovery shots., maintaining the inputs to make them function within specifications, attacking logistics to minimize skips and bad channels. Monthly Variation of bad shots is given table-5. the contribution of various



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factors towards weak quality shots at the end of Field Season is given in Figure-4.

Table -5: monthly percentage variation of weak quality shots

As on date	skips (%)	Out of OD (%)	Bad channels (%)	Poor freq	Others (%)
6/4/07	6	2	4	1	1
31/3/07	6	2.8	4	1.1	1.2
28/2/07	6.4	3.2	4	1.8	2.1
31/1/07	6	4	2.5	2.5	2.5
31/12/07	6	4	3	3	2.6

processing while picking the velocities shows good resemblance (Figure-5). This resemblance confirms the validity of Quantification methodology adopted in this study for quality monitoring. This analysis further confirms that the poor quality data affect the velocity picks which has a bearing on the output quality i.e stack section will be of degraded quality. Effort must be made to effectively monitor and improve the quality of data at acquisition stage itself.

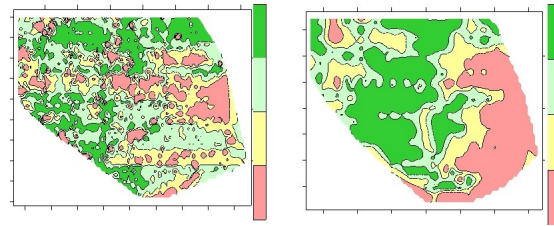
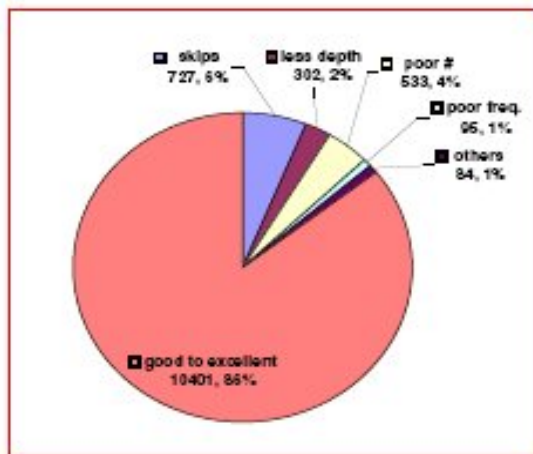


Figure-5 : comparison between Shot QC and Velocity QC maps



Benefits from the study:

Methodology developed in this study helped in reviewing the OD at various stages based on the study of QC and Frequency maps. After modifying OD quality of data specially freq. content in the data has improved.

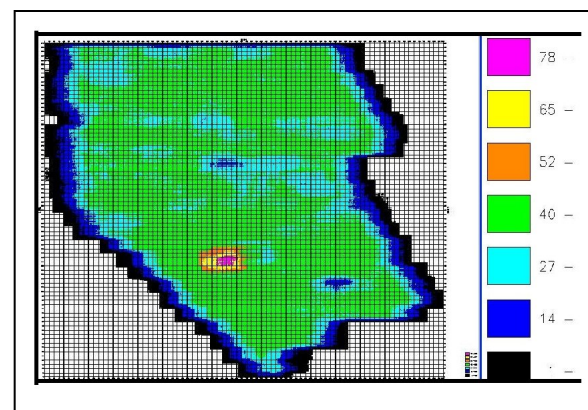
The study could mark the zones of tough logistics based on the good channel percentage map and skip shots. It has helped in improving the ratio of good channels and reducing the skips through strategic planning. This ensured the quite fair distribution of fold (Figure-6). Further this map will help in future field work in the area so as to overcome the logistic hurdles if possible.

The study has helped in minimizing the no. of out of OD shots, recovery shots and transmission errors while acquiring data by repeating the shots, avoiding unnecessary recoveries and rigorous repairing and checking of ground electronics inputs.

This study has definitely helped in acquiring better quality data if compared with 2D data acquired in earlier vintages (Figure-7, & 8).

Validation of Quantification approach:

Theoretically, the damage done to the data at acquisition stage cannot be recovered fully during processing stage. The zones of week quality should affect the velocity picks during processing since the velocity picks in seismic is highly dependent on S/N ratio. We may commit mistake while assigning weights, but energy in semblance used for velocity picks cannot be enhanced. So based on semblance quality, a separate QC map had been prepared while picking velocities on Mobile processing unit in the field. A comparison between two QC maps prepared using quantification approach during acquisition and the one prepared during





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Figure 6: Fold map generated in the field from Brute stack

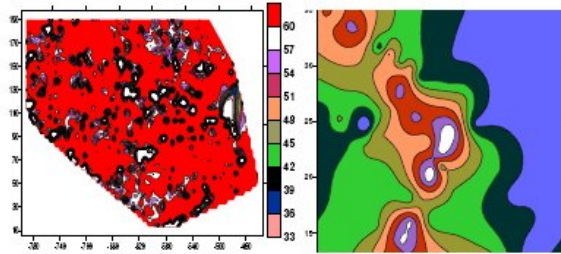


Figure-7.: Fmax maps generated from current data(left) and earlier data(right)

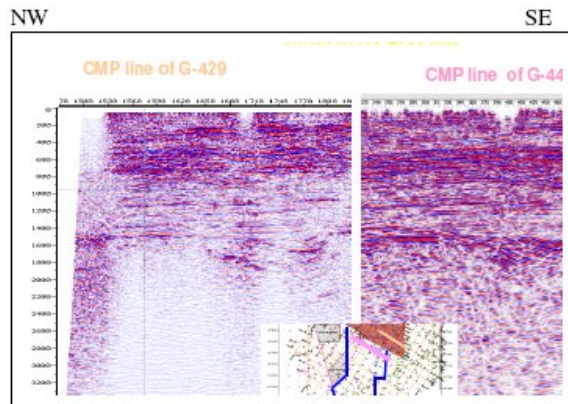


Figure-8: stack section from earlier data(left) and current data (right)

Conclusion:

The study carried out using Quantification of quality approach has clearly made a break through in effective monitoring and improving the quality of data in the field. Still there is a scope for refining the weights and hence for fine tuning the methodology. Some of the parameters are area dependent like band width and near- surface irregularities. These parameters required to be fine tuned to make the methodology universal. This is the first study when a detailed analysis of quality has been carried out. Once it is accepted universally, it will bring out a revolution in quality monitoring for taking mid-course corrections in the field.

References:

1. Operational Reports on 2-D Seismic Surveys under investigation nos. G-228, 252 and 400, Unpublished Reports of ONGC, Baroda.
2. Operational Reports on 3-D Seismic Surveys under investigation nos. G-429 and 439, Unpublished Reports of ONGC, Baroda.
2. Gupta, T., C., et al, 1990, Interpretation Report on CDP Reflection Survey in Olpad- Tapti area, Unpublished Report of ONGC, Baroda.
3. Cordsen, A., et al, Planning land 3-D seismic surveys, Geophysical Development Series No. 9, SEG.
4. Hornman, K., & Vermeer, G., 2000, Introduction to a 3- D design problem, First Break, 18.5 May 2000, EAGE.
5. QHSE manual of ONGC on QC procedures

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<p style="text-align: center;">Trace = source pulse*</p> <p style="text-align: center;"><i>(reflectivity</i> <i>*earth's</i></p> <p style="text-align: center;"><i>filter+noise))*</i> detector response*</p> <p style="text-align: center;">Recording instt. Response</p>	<ul style="list-style-type: none"> • Charge depth & size • Impedance contrast(area dependent) • Behavior of Earth's filter during propagation of energy (subject of processing) • Receiver distribution (field geometry) & condition of receivers (percentage of good noise free receivers) • All recording parameters within spec.

From the above discussions on quality of seismic data, following attributes are required in seismic data:

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Quantification of quality

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The maximum weightage for any shot is taken as 1.0. sum of all these weights gives total quality weight for any particular shot. For grading shot Quality on a scale of 0 – 1, The quality of each shot is rated and plotted as per the following color scheme. The color scheme is optional and may be changed as per the user's convenience.

QC weightage	QC rating of shot	
0.96 – 1.0	Excellent	Dark green
0.65 – 0.95	very good	Light green
0.76 – 0.85	good	yellow
<0.76	fair	Light red

The available information is tabulated and updated daily on day to day basis. A sample format is given in table-3.

Table-3: Table showing inputs for QC analysis

Shot information	Shot information		Information channel		freq. -		Recovery shot	Events visible	TE(in arms)			
	line	S P	OD	DD	dead	noisy				% good #	Fmin	Fmax
190	190	514	20	19.2	116	30	77	15	70	n	y	0
191	191	514	20	21.3	116	30	77	19	68	n	y	0
192	192	514	20	18.8	116	30	77	19	63	n	y	0
197	197	558	21	19.5	28	11	94	16	54	n	n	0
190	190	562	22	20.6	33	12	93	15	47	n	y	0
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Preparation of maps:

The available information from table-3 is further utilized to compute the weighted factors for each shot as shown in table-4.

Information available in table-4 is further utilized for preparation of various maps using software. These maps are shown in figures 2, 3 surfer

Table-4: table showing weight functions for each shot and quality rating

Lineine	Pkt.	Quality							total	Wt>	quality(0.95,V.good, rating,excel,good,fair,poor	remarks
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191	530	0.3	0.15	0.3	0	0.1	0	0.85	verygood			
196	530	0.15	0.15	0.3	0	0.1	0	0.7	fair	lowfreq		
197	530	0.3	0.15	0.3	0	0.1	0	0.85	verygood			
196	558	0.3	0.3	0.2	0	0.05	0	0.85	verygood			
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190	570	0	0.05	0.05	0	0.1	0	0	poor	skipline		

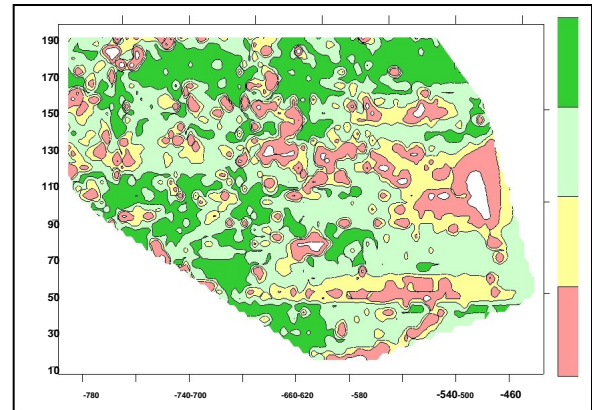


Figure-2 : composite QC map on a scale of 0-1

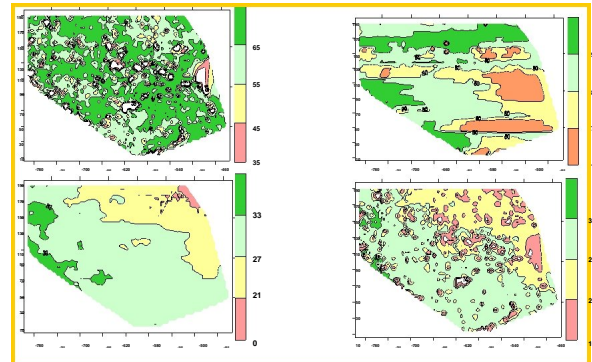


Figure-3 showing effect of various factors on quality; good channels(top right), OD(bottom left) & DD(bottom right)

Analysis of these maps showing quality of data and frequency distributions can demarcate the zones of better quality of data and higher frequency contents. It acts as a guiding tool for diagnostics and further remedial measures to improve upon data quality. This quantification of quality is of immense use if utilized to improve the data quality by taking mid course corrections. For this purpose, the identification of reasons affecting data quality is essential.

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of this analysis is to minimize the percentage of weak quality shots and to maximize the good quality shots by repeating the out of OD shots, minimizing TE and recovery shots., maintaining the inputs to make them function within specifications, attacking logistics to minimize skips and bad channels. Monthly Variation of bad shots is given table-5. the contribution of various factors towards weak quality shots at the end of Field Season is given in Figure-4.

Table -5: monthly percentage variation of weak quality shots

A s on date	S kips(%)	O ut of OD(%)	B ad channels(%)	P oor freq	O thers(%)
6/4/07	6	2	4	1	1
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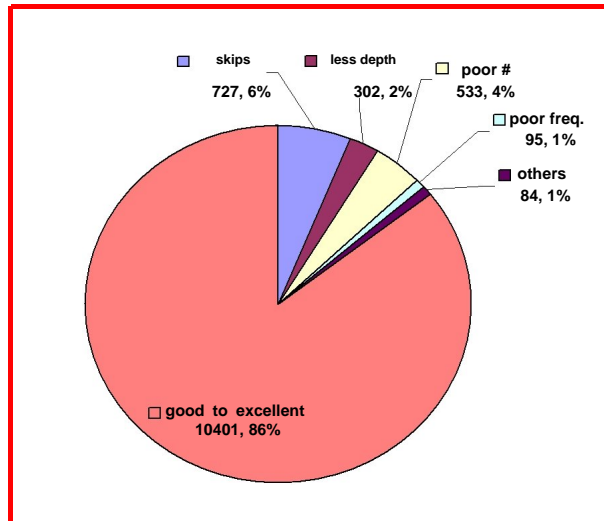


Figure-4 weak quality shots as percentage of total shots

Validation of Quantification approach:

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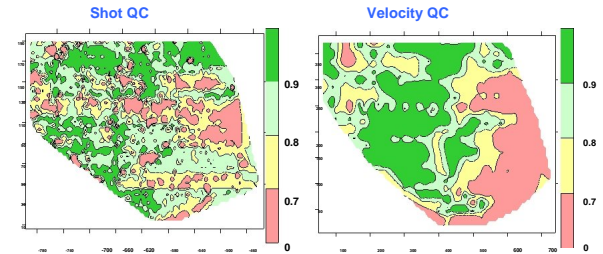


Figure-5 : comparison between Shot QC and Velocity QC maps

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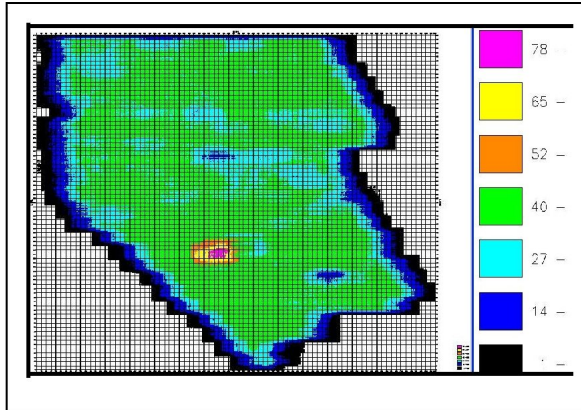


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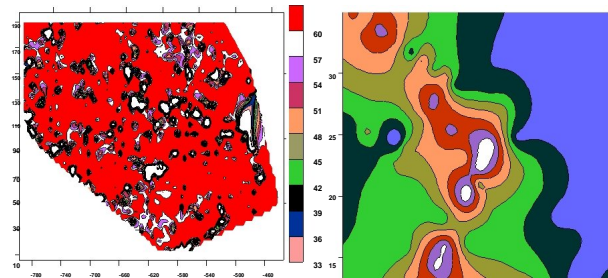


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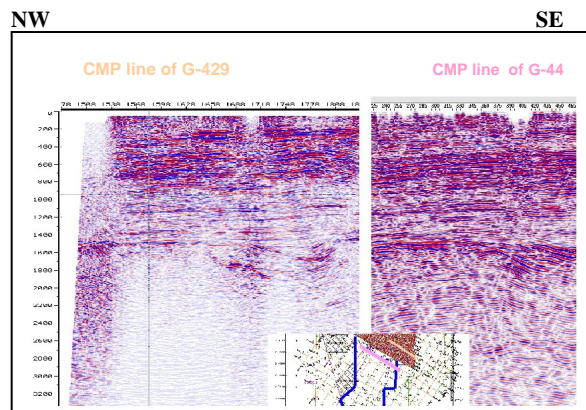


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References:

- Operational Reports on 2-D Seismic Surveys under investigation nos. G-228, 252 and 400, Unpublished Reports of ONGC, Baroda.
- Operational Reports on 3-D Seismic Surveys under investigation nos.G-429and 439, Unpublished Reports of ONGC, Baroda.
- Gupta, T., C., et al, 1990, Interpretation Report on CDP Reflection Survey in Olpad- Tapti area, Unpublished Report of ONGC, Baroda.
- Cordson, A., et al, Planning land 3-D seismic surveys, Geophysical Development Series No. 9, SEG.
- Hornman, K., & Vermeer, G., 2000, Introduction to a 3- D design problem, First Break, 18.5 May 2000, EAGE.
- QHSE manual of ONGC on QC procedures

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