Bridging Seismic Data Gaps: A Curtain Raiser for Future Recoveries

T.K.Prasad*, B.K.Barve, P.V.Subba Rao, S.Viswanathan, Y.M.S.Reddy
GPS,WO,ONGC,Baroda.
E-mail: tkprasadongc@hotmail.com

Summary

3-D seismic data acquisition is an important tool in Hydrocarbon exploration, and has always been a challenging task to carry out 3-D land seismic survey in logistically difficult areas. For better subsurface imaging and precise mapping, a good 3-D volume is a prime requirement with respect to fold, better offset distribution and wide azimuth. Due to increasing industrialization and urbanization, missing of source and receiver locations is rather menacingly increasing, and making the task still more complex and challenging. Ground patches of varying sizes, in the area of survey not amenable for placement of planned source and/or receivers due to various logistics need to be looked upon as obstacles in our path of seismic coverage of the given area. Seismic data acquisition encounter various types of obstructions small, big, wide, time variant, elongated, irregular shape and size. Villages, ponds, roads, oil wells can be categorized as small obstructions, where as town, industrials areas, salt pans, oil installations and time-variant obstacles such as tidal areas can be considered as major obstructions in seismic data acquisition. Data gaps due to the missed out locations, in the final processed outputs confront the processor and interpreter more or less alike, in execution of their respective studies confidently. Seismic events may not be confidently correlatable across, especially over the large data gaps. The compulsion to bridge the data gaps is thus obvious in completing the image of the subsurface below the obstacle area. This leads to the concept of filling the data gaps by recoveries, in an attempt to make the data loss good. To fill the large data gap over the larger obstructions, meticulous planning and execution are required in both technical and other logistical support aspects. This paper deals with planning and execution of recovery plans to illuminate the subsurface across the obstacles.

Introduction

In Hydrocarbon exploration, seismic imaging of the subsurface by 3D is a proven technique. As the structural prospects have already been explored, there is a need to go for exploring more difficult strati-structural / subtle traps. Delineation of thin sands, lenticular sand bodies and deep reservoir are the present day exploration challenges. 3D seismic surveys are being planned in more logistically difficult areas, which were left out earlier (Fig-1).

These challenges are being met with available 3D technology with improved survey design. This include symmetric sampling, smaller bin size, wider azimuth recording etc.. Excellent results can not be obtained on these attributes, if uniformity of fold is not maintained; it may otherwise result in false amplitude anomalies. In order to carryout advance studies like AVO and Inversion successfully, it is necessary that 3D volume to be more homogeneous in terms of fold, offset and azimuth distribution over the survey area. In the recent times land seismic data acquisition has become more difficult, due to rapid growth in industrial sector and fast land developing trends in urbanization. The obstacles in the survey area are

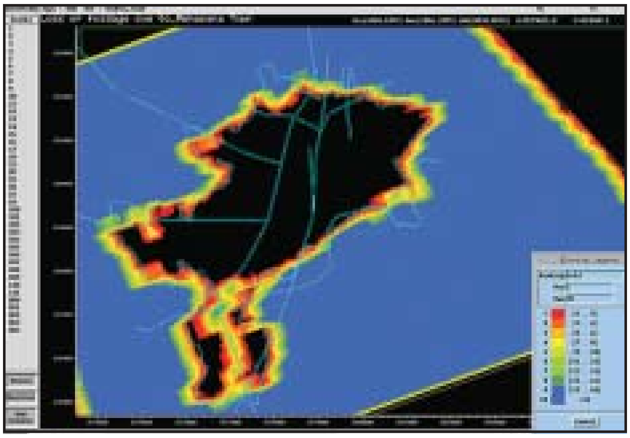

Fig-1: Loss of fold due to a larger town

causing loss of fold, missing offsets and azimuths, resulting in an uneven coverage and data gaps, which may lead to unreliable data interpretation. In case of 2D seismic, the task is relatively simpler. After a detailed survey the 2D lines can be oriented in such a way that the effect of the obstacle will be minimum without deviating much away from the objective of the survey. If the obstacle can not be avoided by shifting the line, a low angle deviation can be taken making an arc around the obstacle (Fig-2).

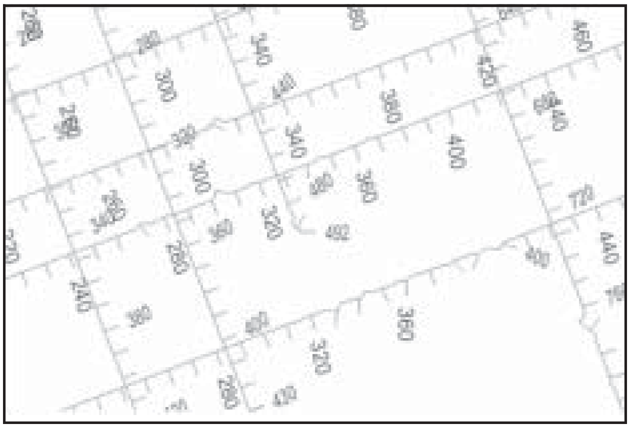

Fig. 2: Due to obstacle 2-D line making an arc around the obstacle

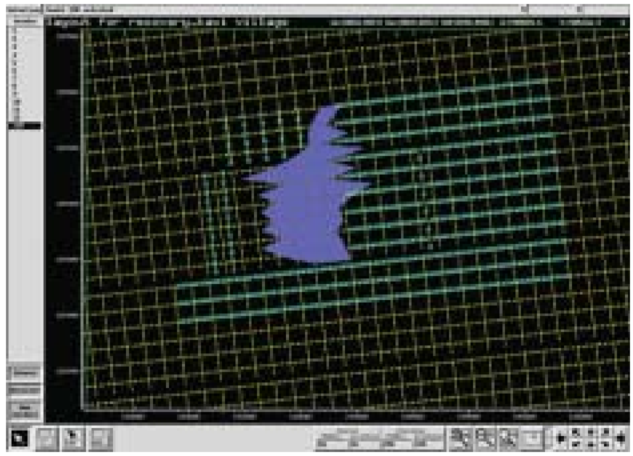

Fig. 3: Infill and additional shots from adjacent swaths for a recovery plan

Undershooting technique (by placing the receivers and sources on either side of the obstacle), can be applied if the shape of obstacle is elongated along the line, however, near offsets may not be recovered. In case of obstacle having longer extent across the line but shorter along the line, additional inline shots can be planned in between the regular shot intervals on either side of the obstacle. In case of 3D seismic data acquisition, the handling of obstacles is not so simple. By early 80's the 3-D data acquisition was developed and became wide spread in early 90's. A distinct advantage of 3-D surveys over 2-D surveys is to provide a detailed subsurface imaging. Carrying out 3D survey in logistically difficult areas is becoming tough, as the planned receiver and source positions can not be occupied in the normal course due to obstacles, resulting in an uneven fold, missing of offsets and poor azimuth. Generally 3-D designs consist of large number of channels. Loss of coverage is lesser in case of missing of receiver stations as compared to that of the missing of source stations. The data gap created by smaller obstacles will be smaller and can be recovered by infill shots (Fig-3) that are placed between the regular shot arms, on either side of the obstacle making use of the receiver lines of the regular swath shooting or with small recovery plans.

This type recovery can be planned along with regular swath shooting which saves time and money. The bigger obstructions such as towns, salt pans, big fish ponds and oil installations, generate large data gaps (Fig-4a) which are not desirable in 3-D volume.

To fill these data gaps an approach, *Recovery Planning*, is to be adopted meticulously, taking both technical and ground logistics into account. The concept of filling the data gaps by recoveries, in an attempt to make the data correlatable. (Fig-4b) To design a suitable geometry, study its attributes, estimating the loss of fold and designing of recovery plans to fill the gap, interactive software is a prime requirement. GEOLAND, MESA, OMNI, etc., are some of the commercial softwares, are being used in the industry. GEOLAND and MESA softwares have already been established in most of the Geophysical parties in ONGC. There is no unique solution for filling the data gap due to the obstruction in seismic data acquisition. No software will give a design, which is best suited for recovery planning and its execution. An extensive and rigorous study to be made to design the recovery plans keeping the logistics of the area in mind. In oil installations keeping the source in the vicinity can be ruled out and the only option left is identifying safe zones for receiver locations and by the method of undershooting the data gap can be filled up effectively. In case of time variant obstacles, scheduling of operations is an important aspect because of its unpredictable nature. The survey design should include a time schedule for recording in the low tide period, in case of tidal affected areas. Network of roads is common feature in salt pan area, make use of these roads and lay the receiver lines along the roads and source can be placed randomly with available locations. With this the salt pan area can be filled up, but the case is not simple in case of towns, because of large and densely populated localities. The various aspects of recovery planning especially for bigger towns, nontechnical, as well as technical, and its execution, will be discussed in this paper.

Methodology

Non technical planning

In case of recovery of a town, it is necessary to create an amicable environment across the town with proper

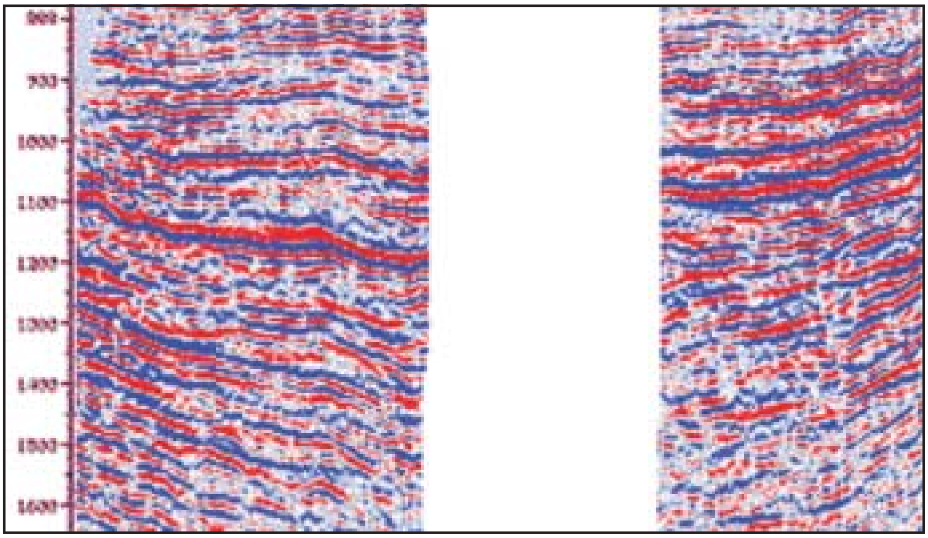

Fig. 4a: Data gap due to a larger town

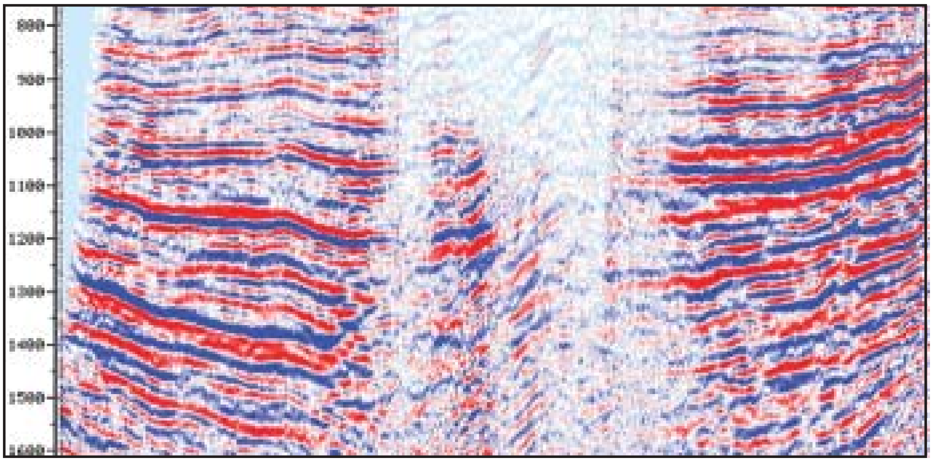

Fig. 4b: Data after recovery plan execution across a larger town

communication with the civil authorities and public in advance. All the necessary permissions must be obtained to work in the town preferably in the nights. Police escort is a must in case vibrators are to be operated on the streets. Resources such as vibrators, additional ground electronics/ equipment and work force is to be arranged and mobilized in time. Advertisements in local news papers, through PR section, to be issued in advance for mass awareness and dispelling their apprehensions about the intended survey work.

Survey

The foremost job is precise mapping of the obstacle by DGPS, the various obstacle boundaries for its size and shape, followed by detailed mapping of highways, roads, streets, lanes, by-lanes, open grounds, culverts, under ground sewage, water, gas pipe lines, cables, etc., are to be mapped precisely(fig-5). Identification of source locations within the obstacle is one of the important aspects in planning these recoveries. The lanes, by-lanes, culverts are of great practical advantage in mending the recovery plans especially for laying of receiver lines and in planning movement and positioning of the source(vibrators). Satellite maps contain a wealth of information and will be very useful in planning seismic survey. The details of oil well locations, pipelines, and safe zone locations for plantation of geophones in case of oil installations. In salt pan areas lot of parallel roads are normally available; the detailed mapping of planning these roads will be of great help in laying receiver lines.

Fig. 5: Highways, lanes, open areas of a larger town

Recovery planning

Survey design

Swath Geometry plays a very important role in 3-D seismic data acquisition. Designing a suitable geometry, to meet the geological objectives is of prime importance in the seismic survey. The geometrical positions of source and receiver in a swath, define the basic 3D parameters like bin size, offset and azimuthal distribution. In order to select a suitable geometry to meet the survey objectives, various geometries are to be studied thoroughly. The zero or less coverage area due to the obstruction varies based on the swath geometry besides shape and size of the obstacle. As an exercise, keeping all parameters such as fold, bin, SLI (Shot Line interval) constant, and by changing the RLI (Receiver line interval), the area of less/no fold zone varies. However the near offsets may be affected by widening the RLI. Based on the geological objectives and operational convenience, proper swath geometry should be chosen for regular swath shooting which helps to lessen the burden in recovery planning and execution.

Resources

Based on the survey design the required inputs should be mobilized in good working condition. Radio telemetry such as OPSEIS is best suited for recoveries, which allows placing of the sensors randomly within the obstacle area, but considering the difficulty in obtaining the licenses for the desired frequency the system is not preferred for towns. However, other systems such as UL 408 is also very useful in recovery plan execution, because of its features such as snaking and detouring and handling of both energy sources, ie., dynamite and vibrator.

Energy source

The next important aspect of the resources is selection of type of the source. Dynamite can not be used within the obstruction areas such as the towns, oil installations, fish ponds, factories, etc., due to safety and environmental considerations. However, in tidal and river belt areas, dynamite can be used with proper precautions. Vibrators may be used as an alternative energy source in the towns, which should be operated at lower drive force with more number of sweeps avoiding low frequencies. A full set of experiments must be carried out in order to fix vibrator parameters keeping in view of the safety and environmental aspects in mind before deployment of the vibrators in case of town. Collection of data by occupation of the same source points of a spread by both vibrators and dynamite sources is important in designing matching filters at the time of processing.

Designing of recovery plan

Planning of layouts is an important feature in recovering the seismic data lost due to gaps. With the available basic information such as survey data, swath geometry, energy source, by including the obstruction, study the loss of fold. For all practical purposes the obstruction should be considered as ‘NO shot NO receiver Zone’ for desk calculations.

The first step is to acquire data on the peripheral part of the area along with regular shooting, by placing some additional source line/locations between the regular shot lines. In addition use some available source locations from the adjacent swaths in the vicinity of the obstacle boundary such that data gap gets filled on the periphery. After this exercise for all the swaths in the obstruction area, study the data gap that still exists. This particular process can be implemented along with the normal shooting of the swaths.

In the next step, compartmentalize the obstacle area into different sectors, based on operational convenience. Depending on the shape and size, each sector can be considered as a smaller obstruction. To fill the data gap in this sector, a rough estimate has to be made with the basic CDP concept in placing the receivers and source locations(Fig- 6).

Place the receivers preferably on the normal receiver lines either with a moving spread or a fixed one. If more roads or locations are available perpendicular to receiver

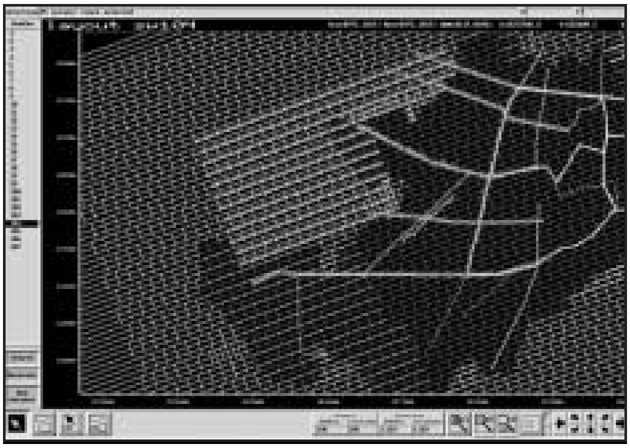

Fig. 6: Layout of a sector of a larger town

line orientation, these locations can be used as shot lines. Even crooked lines can also be made use of in recovery planning based on the logistic. After number of iterations, the recovery plan for the sector can be finalized. In the same manner, different recovery layouts can be finalized for different sectors. While finalizing the recovery layouts for different sectors, cumulative effect of the coverage and its attributes are to be studied simultaneously, to get an idea of fold and offset distribution. The desktop recovery plans are to be suitably modified with the data inflow of more survey information about the obstacle and ground logistics at the time of execution. User should design a plan which is best suited for operational convenience, and satisfy the technical requirements. For town recoveries a systematic day wise plan should be prepared with optimum number of source points

Execution

Occupying all the source and receiver locations as planned is the most important part in execution of the recovery planning. It is therefore necessary to confirm the practicability for occupation of all the envisaged source and receiver positions by physically inspecting the town in advance. The same possible shots zones especially within the town can be reoccupied again and again, for corresponding plans of different sectors. The feasibility study is to be done for reoccupying these zones repeatedly helps in filling of near offsets.

Another important aspect in recovery is to acquire the data within permissible limits of noise level. Data acquisition with in the town area in day time is not recommended due to high level cultural noise. As such the planned recovery must be executed during night time to have meaningful data.

After each day of execution the fold diagrams need to be updated and confirm the results as per the plan. It has been observed that in most of the areas in the town, geophones cannot be planted in the usual way due to hard surface conditions. It is recommended to either use raw clay bricks / bags for planting the geophones. Round the clock operations can be executed by carrying out shooting with dynamite in day time on the periphery of the town and vibrator operations in the night time to conclude the recovery in a shorter span of time.

All the safety norms must be observed stringently during the execution of recovery plans in the town areas. Time scheduling is an important aspect in recovery planning. As a precaution for oil installations, mufflers to be used to protect from the sparks comes out from the vehicles. Similarly, care should be taken in the movement of vehicles in salt pan areas which disturbs crystallization process in these areas.

The figures 7a-7e shows the various stages of recovery and its execution as an example of the recovery plan.

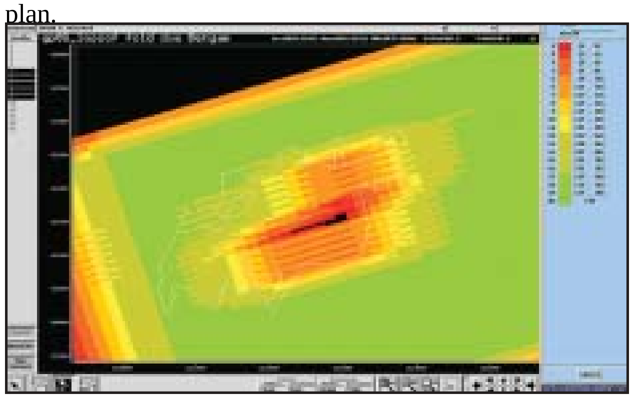

Fig. 7a: Loss of fold due to a town

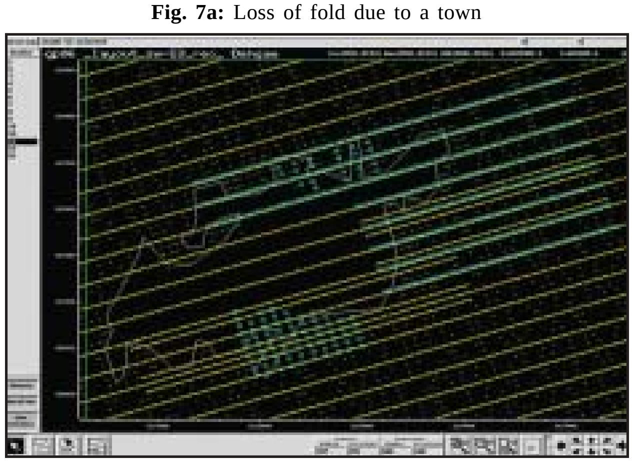

Fig. 7b: Recovery plan layout-1

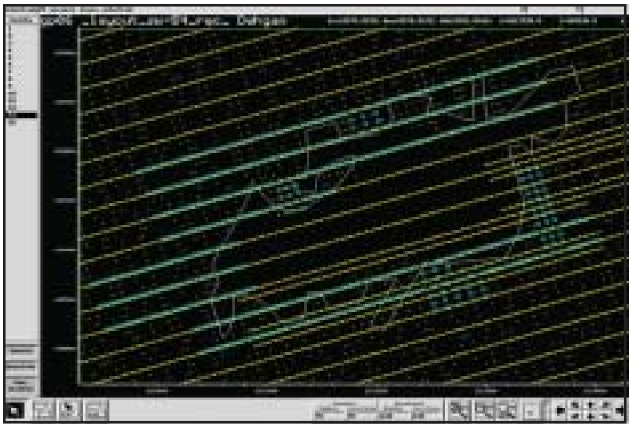

Fig. 7c: Recovery plan layout-2

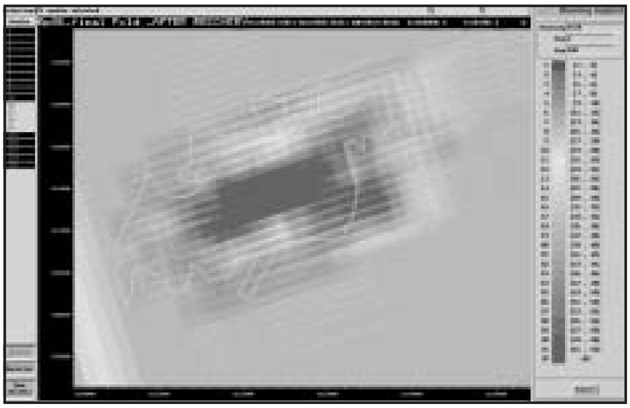

Fig. 7d: Fold map after recovery planning

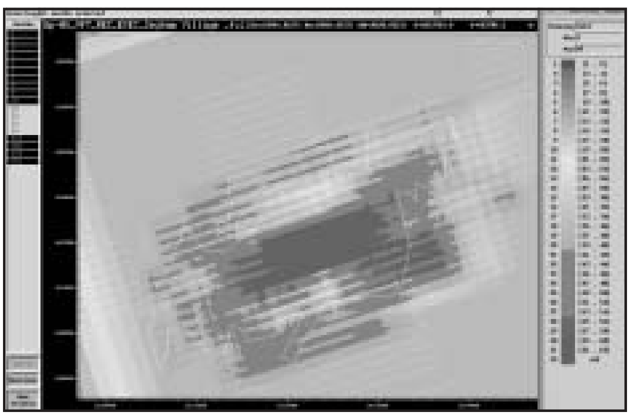

Fig. 7e: Fold map after recovery planning execution

Conclusions

For a successful recovery of the obstacle, prior collection of all relevant information about the obstruction area is of prime importance. Selection of proper swath geometry keeping in view of the geological objectives and operational convenience can not be ignored. Meticulous planning must be done using available software to acquire missing fold and offsets to the maximum possible extent.

The planning should be carried out on day-wise basis keeping in view maximum number of achievable source points. All the necessary permissions must be obtained prior to execution of the plan. All the safety norms must be observed stringently during execution of the plan. Day-wise monitoring must be done and if required mid course corrections should be effected to achieve desired results. The survey design should include a time schedule for carrying out day and night operations.

Missing near offsets is a common feature unless otherwise some source and receiver locations are available inside the obstacle area. This paper has been intentionally made more descriptive with the sole idea of providing broad practical guidance to the teams embarking on recovery plans for various obstacles commonly encountered in seismic data acquisition.

Acknowledgements

The authors are thankful Sh S.N.Singh,GM (Geophy)-Head Geophysical Services, Western Onshore, ONGC, Baroda for his encouragement and support to publish this paper.

Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.