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3D geological model based interpretation of poor quality 2D seismic data: **Case study from Himalayan Foothills, Northwest India**

Abstract

Seismic data interpretation of poorly imaged structurally complex areas is a challenging task. While trying to make meaningful sense out of the signal and noise mayhem, one ends up holding on to the proverbial straw. Modern utility tools in state-of-the-art interpretation software provide scope for innovative applications to find solutions to such problems and to increase the confidence levels during interpretation workflows. The present paper deals with a case study involving the frontal Himalayan fold thrust belt of Northwest India and discusses how such innovation helps in better interpretation of 2D seismic data inhibited not only with poor signals but also comprising of a sizeable data gap area. The technique involves construction of a robust 3D geological model through integration and detailed analysis of all available geoscientific data of the area as a first step. The model is constrained by the limited available subsurface data and by the surface geological data. The 3D geological model is then sliced along the profile of interest to create a 'predictive' geological cross section which guides the final interpretation along that profile, thus resulting in geologically consistent interpretation in sync with the accepted geological understanding of the area.

Keywords

3D geological model, 2D seismic interpretation, Himalayan Foothills

Introduction

Interpretation of seismic data of fold thrust belts has been a perennial challenge especially because of the poor to extremely poor quality of the acquired seismic lines. It is often observed that consolidation of the stratigraphic horizons and their composition, the quantity of deformation these units have been subjected to, orientation of the seismic lines in strike, dip or oblique direction, accessibility and logistics for seismic data acquisition, the variable constraints for proper processing of seismic data, etc. are some of the factors that contribute significantly to the quality of the seismic data that is ultimately available for interpretation. With the technological advancements in modern interpretation software and the advantages afforded by the plethora of utility tools available therein, innovation in interpretation workflows often lead to workable solutions that are not only accurate but also predictive in nature.

In the present paper, application of a 3D geological model developed through detailed structural analysis of a part of the Outer Himalayan fold thrust belt in interpretation of poor quality seismic data of the area is discussed as a case study so that such innovative practices can be made a regular component of interpretation work-flows in similar areas.

Study Area

The Udhampur-Riasi sector of the Jammu & Kashmir Outer Himalayan belt comprise the study area for this work (Figure-1). It lies in the Northwest part of the Indian sub-continent within the latitudes 32°30'N and 33°30'N and longitudes 74°30'E and 75°30'E. The Outer Himalayan Belt comprises the Proterozoic Bilaspur Limestones overlain unconformably by the Eocene Subathu Formation, the Paleogene Dharamsala Group and the Neogene Siwalik Group of sediments. The structural style comprises south verging thrust sheets which are progressing towards the foreland resulting in NW-SE trending structures consisting mainly of faults and related folds.

The objective of this work was to generate a 3D geological model of the study area lying in a complex fold thrust belt set-up after detailed structural analysis and subsequently to interpret a poor quality seismic data of the area by using a 'predictive' cross section along it obtained from the 3D geological model.

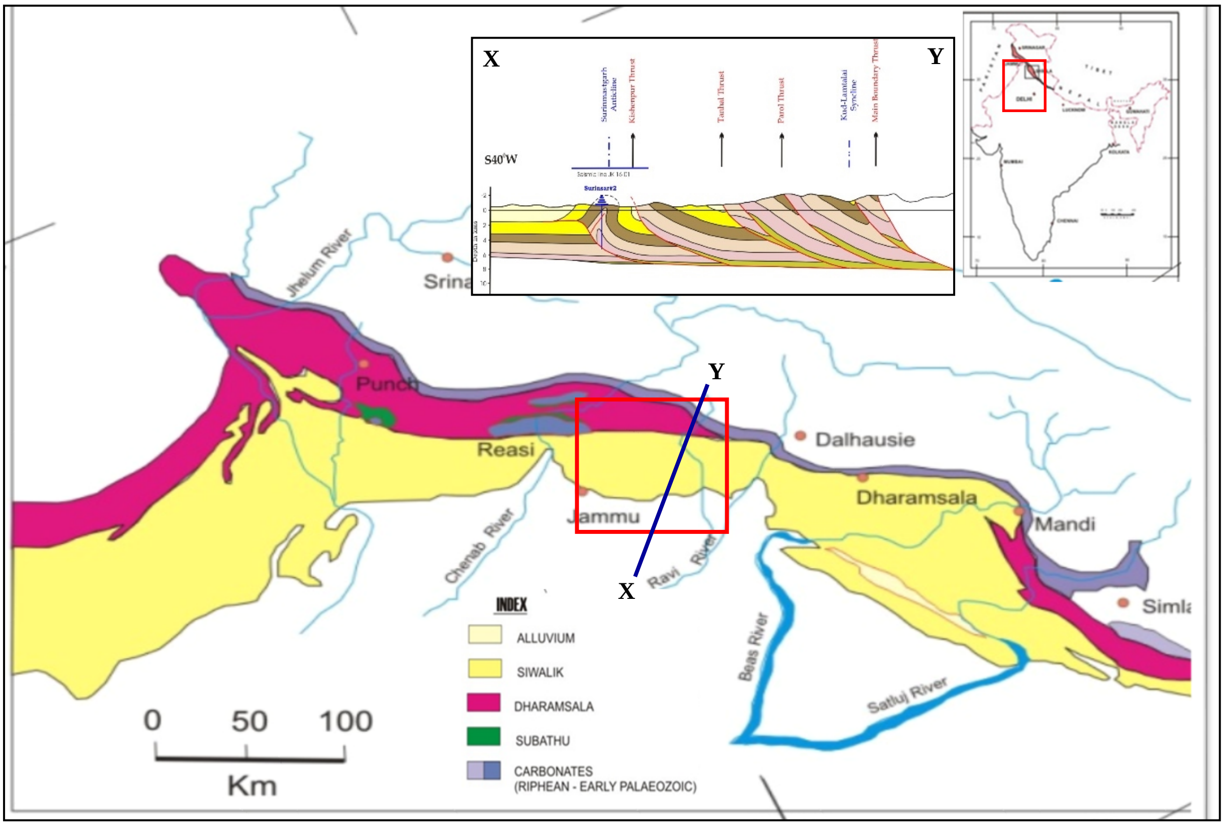

Figure 1: Study area indicated by red square (Inset: Structural style of the area along profile XY)

Data availability

The study area has good exposures of surface geology and detailed geological maps are therefore available. Geological interpretations along a number of strategic cross sections are available in the form of legacy data (Bhandari et. al., 1961, Krishnan et. al., 1965, 1966, Rao et. al., 1966, 1968, and others). Subsurface data is available only in sectors where exploration activities have been focused. Thus limited seismic data are available in Suruinsar area (Figure-2). However, except a few regional seismic profiles, all other profiles are so short that they do not even fully cover the Suruinsar anticline. Drill data are available for two deep exploratory wells drilled on the Suruinsar Anticline.

Main Boundary Th.

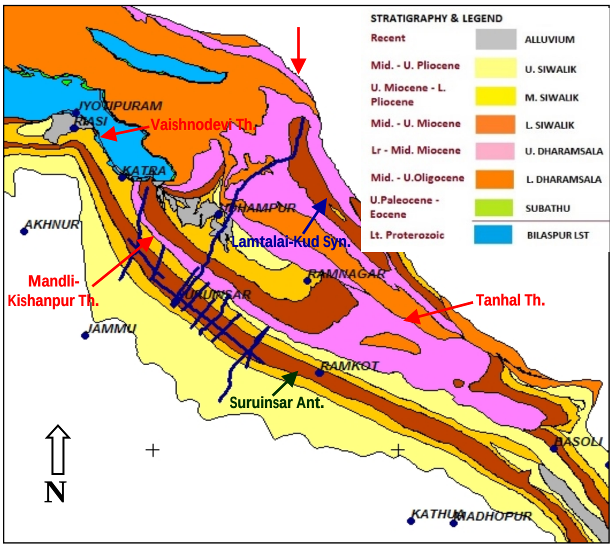

Figure 2: Availability of seismic data

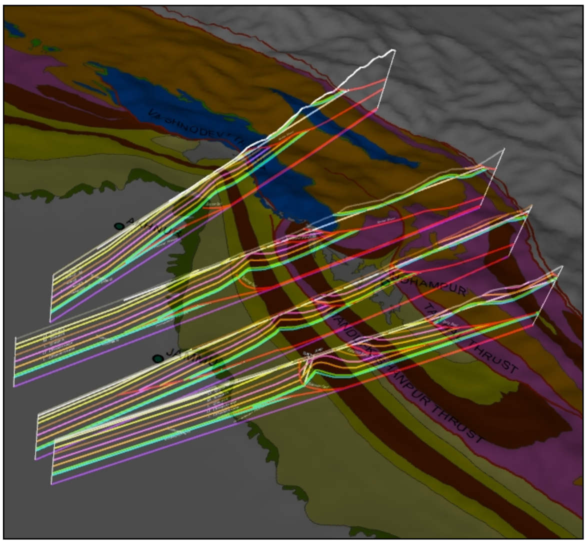

Figure 3: Construction of serial cross sections

Construction of 3D geological model

All available geological and geophysical data, including manually interpreted geological cross sections of earlier workers and the Digital Elevation Model of the area were integrated in MOVE software.

After detailed analysis of all integrated data, fresh interpretation of subsurface structures was carried out along four cross sections (Figure-3) across the area, following which a 3D geological model of the study area was generated (Figure-4).

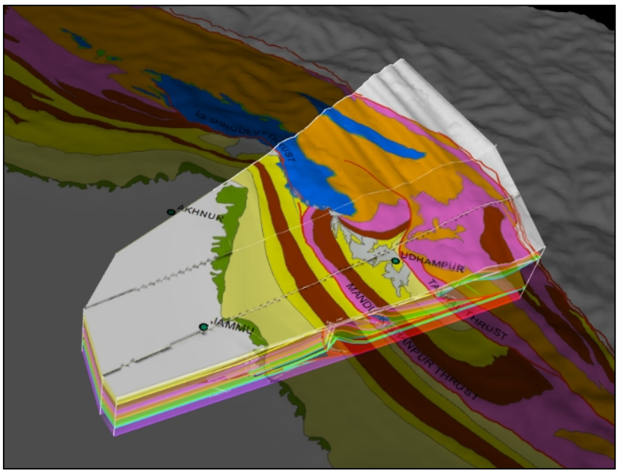

Figure 4: 3D geological model constructed from the cross sections

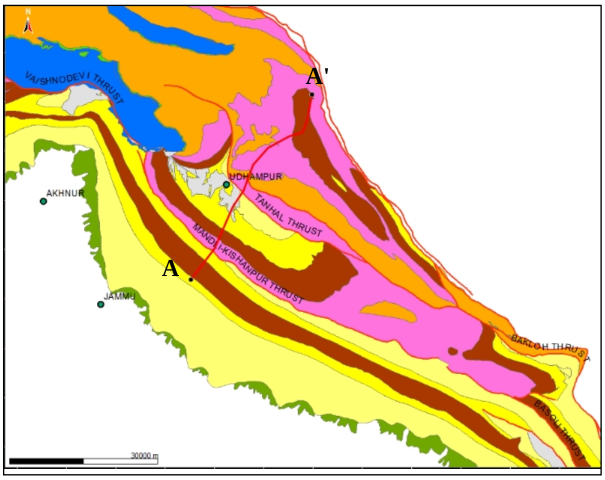

Figure 5: Construction of section trace along sinuous seismic line

The 3D model facilitates viewing of the geological details of the area in totality as deciphered from integrated analysis. For all practical purposes therefore, this model is convenient as a tangible object for understanding and conveying concepts about subsurface geometries and architecture of the area to management.

Use of 3D model for 2D seismic interpretation

The 3D geological model generated as above was then used as a valuable constraint for interpreting the poor quality seismic data of the area in the following manner:

A section trace AA' was digitized over the seismic line on the map (Figure-5). Part of this section trace lies outside the newly generated 3D geological model (Figure-6). A view of the internal geometry of the 3D geological model vis-a-vis the section trace, depicting the seismic profile, is shown in Figure-7.

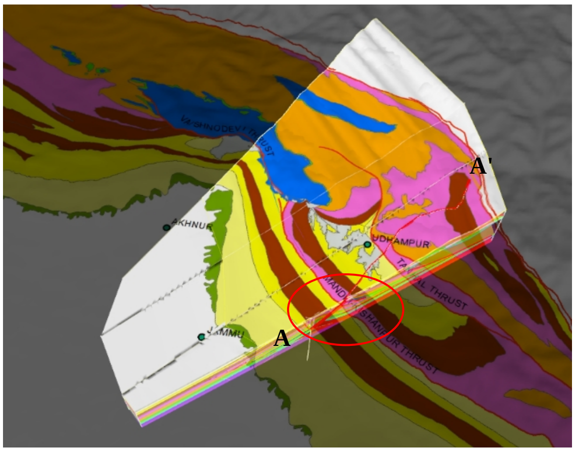

Figure 6: Part of section trace lying outside 3D model

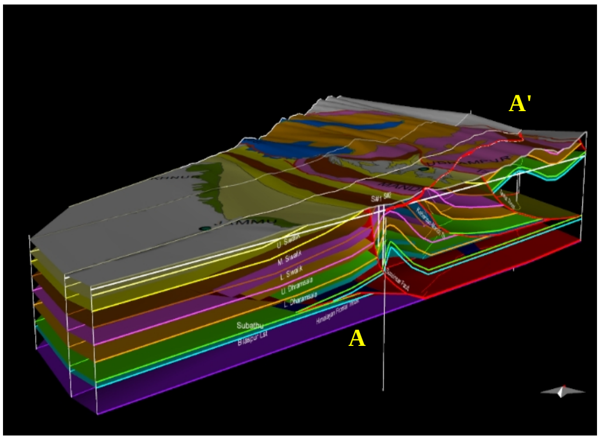

Figure 7: View of section trace with 3D geological model

All horizon, fault intersections and topography surface intersections were collected along this section line from the 3D model as far as it extends, while the area beyond it did not have any information and therefore led to the creation of a 'data gap' on the southern extremity of the 'interpreted' section trace (Figure-8).

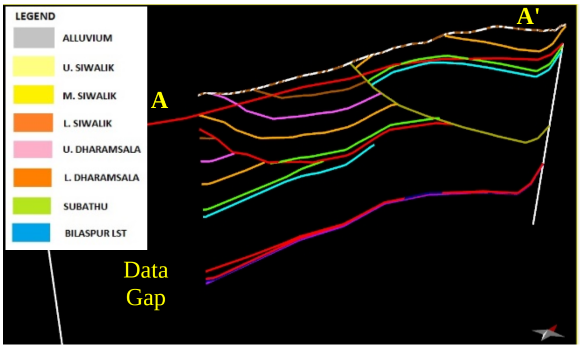

Figure 8: Collection of intersections of horizon and fault surfaces along section trace AA' representing sinuous seismic profile

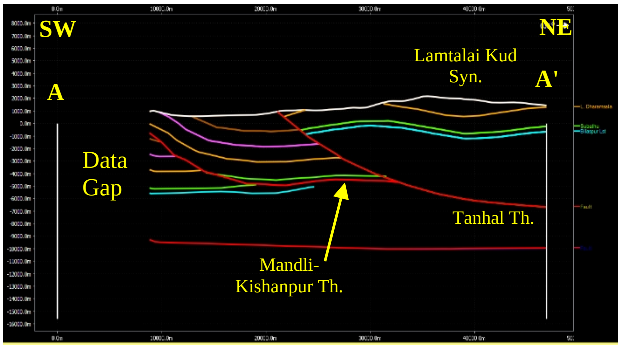

Figure 9: Predictive interpretation along seismic profile AA' obtained from 3D geological model

A 'predictive' model-based geological interpretation along the identified section trace, which is consistent with the accepted geological understanding of the area, is thus quickly obtained (Figure-9).

The seismic line to be interpreted not only is of poor quality but also contains a significant data gap (Figure-10, upper part). However, these difficulties could be convincingly overcome during the interpretation of this profile because it was effectively guided by the predictive interpretation available along it after it was carved out from the 3D geological model.

SW **NE** Suruinsar Ant. Lamtalai-Kud Syn.

Data Gap

Tanhal Th.

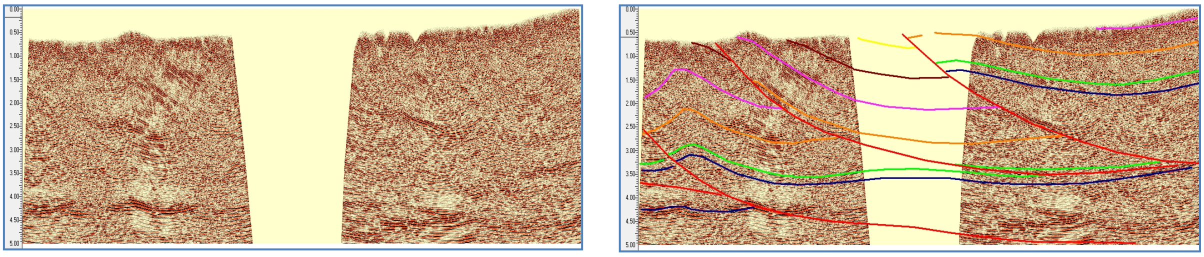

Figure 10: Uninterpreted (above) and Interpreted (below) versions of the selected seismic line across the study area

At the end of the exercise, a better constrained interpretation of a poorly imaged 2D seismic profile was achieved (Figure-10, lower part). This interpretation convincingly addresses key issues of being consistent with the known geological model and the structural style prevalent in the study area.

Discussion

In areas of poor seismic imaging such as the present area belonging to the frontal Himalayan realm, conventional methods of 2D seismic interpretation seldom escape subjectivity. Areas of data gap compound the problems manifold, especially in areas where the inter tectonic-unit disturbances are higher and more frequent in occurrence. In gradational lithologies with no marker horizons to guide seismic mapping, the interpreter is at an unenviable position.

In such situations 3D geological models may be firmed up over an adjacent area having better control on horizon thicknesses, fault geometries, structural styles, etc. which may be revealed by better seismic images. The geological model may then be extended to include areas with lesser subsurface controls. Then from this model, predictive geological cross sections can be carved out along any desired section orientation and length corresponding to our interest, as shown in the present case.

This will allow quick-look interpretation across any chosen profile, in any shape (straight or sinuous) and orientation (along dip, strike or oblique directions) across the area of interest.

In the absence of other robust controlling parameters this method of extracting 2D section data from 3D geological model will help to provide the limiting constraints to the interpretation process so that consistency of the accepted geological understanding and known structural style of the area is maintained.

The technique allows different virtual scenarios to be tried out for a properly designed seismic acquisition campaign, so that optimum coverage of structural elements is made possible.

In addition this method has the capability to quickly provide geological model across any desired profile for various analysis such as up-hole surveys, ray-trace modeling, velocity modeling, seismic data processing, mechanics and inversion studies, etc.

Conclusions

Well-constrained interpretations in apparently unusable seismic data sets are possible through innovative use of utility tools available in modern day interpretation software. The case study discussed in this paper amply demonstrates the potential of 3D geological model based interpretation of poor quality seismic data for meaningful exploration.

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Suruinsar Fault
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References

Bhandari, L.L., Venkataraman, S. and Ganju, J.L., 1961, Report on the geology of Suruin-Mastgarh anticline, Jammu, Kathua and Udhampur districts, (J&K state) and Gurdaspur and Kangra districts (Punjab state) (Field Season 1960-61), Part-II, ONGC (unpub.).

Krishnan, P.V., Varadarajan, K., Khanduri, R.V. and Singh, A., 1965, Geology of the Tertiary belt in the Udhampur-Ramnagar area (Jammu & Kashmir) (Field Season 1964-65), ONGC (unpub.).

Krishnan, P.V., Saxena, I.P. and Singh, A., 1966, Geology of the Tertiary belt in the Udhampur-Riasi area, J&K state (Field Season 1965-66), ONGC (unpub.).

Rao, V.S., Dhar, C.L. and Kumar, Suresh, 1966, Report on the geology of a part of the Suruin-Mastgarh anticline, Jammu and Kashmir State (Progress Report for 1965-66), ONGC (unpub.).

Rao, R. Prasada, Khan, Aijaz and Singh, Akhileshwar, 1968, Geology of part of the inner Tertiary belt, North and Northwest of the Chenab River (Field Season 1967-68), ONGC (unpub.).