EXECUTIVE SUMMARY

Exploration for hydrocarbons involves number of diverse and sophisticated technologies dealing with collection and analysis of voluminous amounts of geological, geophysical and geochemical data. One of the significant geo-physical tools used in exploration is the seismic technology that makes use of reflected seismic waves for delineation of subsurface geological structures and subsequently yields relevant information to aid in discovery of possible hydrocarbon reserves. Seismic exploration involves acquiring raw seismic data in the form of amplitudes of reflected waves along with two way travel time, and processing these to generate seismic maps. These are presented in the universally accepted SEG-Y format. These seismic maps, upon skillful interpretation, provide useful information concerning subsurface geological structures.

This interpretation is, to a large extent, dependent on interpreter's individual skill and expertise which is derived from experience. The interpreters draw conclusions based on their mental database of rules whose nature is largely heuristic and has a fair amount of uncertainty associated with it. A seismic map representing complex geological formation may be interpreted differently by different seismologists for the same reason.

In an attempt to overcome this uncertainty and also to minimize the dependence on seismic experts, a computer-based expert system has been developed as part of this work. The experience, the mental database and the heuristic knowledge of the seismic experts are translated into a set of rules which have been built into the developed expert system christened as 'SeisExpert'.

A commercially available Win-Prolog based expert system shell 'Flex' from Logic Programming Associates, UK was used to develop SeisExpert. The rules of thumb, heuristics and analytical procedures used for interpretation of seismic snaps were collected from various sources such as available literature and interviews with interpretation experts. These were converted into rules in '*if…then*' format and over 120 rules were added to form the knowledge base in 'Flex'. The

system acquires the information needed to fire rules, through question-answer modules. The questions have been designed and made part of the user-interface of the expert system. Each question has been associated with the explanation-text that provides information regarding ‘why the question is being asked?’ and also provides the clues regarding ‘how the question is to be answered?’

The rules have been broadly divided into two categories, namely the manual interpretation rules, and the analytical interpretation rules. The manual interpretation rules are primarily concerned with the information that can be obtained through visual inspection of the seismic maps, much in the same way as the routine interpretation procedure followed by the human experts. The analytical interpretation rules are based on the analytical results obtained by the analysis of seismic data. This part of knowledge-base is applied subject to the availability of seismic data along with the seismic snaps.

The rules have been categorized into rulesets and chained in a forward-chained manner, so as to appropriately fire. In this process, from the information so gathered step-by-step, a line of reasoning is developed and finally the interpretation is built and displayed.

SEG-Y file holding the seismic data in the form of reflected wave amplitude as a function of time has been used as the starting point of developed analytical procedures. Apart from the primary attribute, amplitude, few of the other derived seismic attributes such as ‘instantaneous phase’ and ‘reflection strength’, which are strong indicators of the subsurface structures, have also been used in the analytical procedures. These procedures have been developed in C++ programming language and incorporated in the “Application Programs” part of expert system.

One of the analytical techniques used was cross-correlation, for tracking reflecting horizons by cross-correlating the amplitudes of the adjacent traces, across, a user-specified time window. The technique tracked the reflecting horizons by following the maximum amplitude value within the time window. Instantaneous phase and reflecting strength, at any time are calculated for a given amplitude value and can be plotted within the expert system on demand along a reflection horizon using a time window approach similar to cross-correlation.

The observation made was that this technique fairs quiet well when tracking continuous horizons, but fails when tracking across discontinuities. The seismic attributes ‘instantaneous phase’ and ‘reflection strength’ are characteristic of the reflecting horizon and are more or less constant for a given reflection horizon. These attributes were computed from the available amplitude-time data and used for tracking the horizons with discontinuities. The techniques developed using these attributes, were found to track reflecting horizon accurately across a discontinuity such as fault. In order to fine tune the location of a fault, another technique of tracking the faulted horizon from either side has also been developed.

The GUI of the expert system has been developed in user-friendly visual programming language Visual Basic which forms the front-end of the system. ‘Flex’ has been linked with front-end through a software package called Intelligence Server. This mainly constitutes a set of files which make the connection and communication between these two parts of SeisExpert possible.

SeisExpert presents itself to the user in the form of an opening screen, which after authentication, offers the expert system services to the user. The system allows the user to choose from, a list of available seismic snaps for interpretation. The seismic data corresponding to the seismic map is also loaded based on its availability within the system. The provision to add a new seismic record to the available list is also part of the provided features of the system. The amplitude data corresponding to the section can also be uploaded so that analytical procedures can be used over it during interpretation.

An 18-character naming scheme was developed and used to identify each seismic map with details such as area code of area surveyed, sub area code, year of survey, time interval of recording, distance between geophones, serial number. New entries are also given code names on receipt of information and stored for easy retrieval in future.

The association of seismic snaps and corresponding data along with their file names and paths are stored in a database in Ms-Access. This database is accessed by the front-end using ActiveX Data Objects (ADO) that facilitate, authentication and connection to the database (data source). The desired data are requested by the ADO in the form of a query which is responded by passing the data to the front-end. Fresh data records can also be received by the front-end and passed to the database through ADO for persistent storage and later recall.

SeisExpert allows for interpretation of available seismic snaps both manually and analytically. The manual interpretation displays the seismic snap, allows visual inspection and gathers relevant information through question-answer module. Based on the responses provided by the user, the manual interpretation rules from the knowledge-base in the background, fire. The gathered information is used to build the interpretation of the given seismic snap.

SeisExpert is capable of doing the analytical interpretation of the seismic map subject to the availability of seismic data. The analytical interpretation starts with visual inspection of the seismic map and proceeds in the same manner as manual interpretation. The resultant interpretation obtained is further reconfirmed and fine-tuned by inviting the appropriate analytical procedures and invoking the analytical interpretation rule-base.

Context-sensitive help modules have been developed and included at appropriate places to facilitate smooth operation of the expert system. There is a fully developed 'help manual' which has been coupled with the product that helps in displaying the relevant help on any feature that is chosen by the user.

SeisExpert has been packaged into an installable setup program along with its dependencies, which can be deployed on any stand alone windows machine.

Using this expert system at least 30 horizons were successfully tracked across seismic traces in four different seismic maps. Both manual and analytical methods were used. Cross-correlation confirmed all the structures except faults. While traversing across a fault plane, the correlation almost invariably picked a wrong horizon which happened to be juxtaposed with tracked horizon before the fault. However, the derived attributes, 'instantaneous phase' as well as 'reflection strength' when plotted as a function of time, showed the shifting of the horizon across the fault correctly, establishing the efficacy of the package.