SPE
Society of Petroleum Engineers

SPE 18375

HESPER: An Expert System for Petrophysical Formation Evaluation

by R.C.A. Peveraro* and J.A. Lee, Britoil plc
*SPE Member

This paper was prepared for presentation at the SPE European Petroleum Conference, London, UK October 16–19, 1988.

1. ABSTRACT

A prototype expert system for formation evaluation is introduced and discussed, beginning with the rationale for its development, and presenting briefly qualitative assessments and tests of its performance.

The background and definition of petrophysical formation evaluation is clarified, and the specific geological frame of the Permian Southern Basin of the North Sea, in which the system operates, is presented, with indications of future developments.

The different modules of the system are discussed in some detail, and the interaction between modelling, advice-giving, and the user interface is clearly shown to be a crucial factor. Of particular importance is the ability of the system of presenting the reasons for its choice of solution in a clear text and in a user-intelligible fashion.

Tests and performance of the system are discussed from a qualitative viewpoint, rather than after rigorous benchmark tests. This is considered appropriate at this stage, since the system is by no means in its final configuration.

The conclusion has been reached by Britoil that the system has demonstrated that the application of expert systems design and technology to petrophysical formation evaluation is both feasible and desirable, and further development would therefore be beneficial.

References and illustrations at end of paper.

2. DEFINITION OF THE PROBLEM

The HESPER system (or Heuristic Expert System for the Petrophysical Evaluation of Reservoirs) attempts to emulate the manual process of Petrophysical Interpretation.

The system takes wireline log data, along with drilling coring and other data, and allows the petrophysicist to build and manipulate a geological model of the formation. Using petrophysical equations, synthetic logs can be generated from this model and compared, both visually and by the program, with the real logs recorded in the borehole. When a reasonable match is obtained with all pertinent logs, the model can be taken to represent adequately the formation under evaluation. This statement can be shown in diagrammatic form as a flow diagram (Fig. 1).

Note that we have separated the process into two distinct phases, a data capturing phase, and a data interpretation phase. As indicated in the diagram, HESPER concerns itself with the data interpretation phase. The reasons for this are both conceptual and practical. Data obtained at the wellsite (wireline logs, cores, cuttings, drilling logs, etc.) are in general supplied to the client by different service companies, at different times, using different systems. Often they are in a mutually incompatible format, and in general they all have to be reduced to a common, corrected version, eliminating the influences of the drilling environment, borehole, tool response, etc. In other words, the "raw data signals" have to be processed and deconvolved into "formation response signals".

The different service companies supply data using proprietary instruments and systems, and the client does not know in general enough details about them to perform a satisfactory correction job. We decided therefore to eliminate the data analysis, editing, and correcting procedures from HESPER, although they are an integral and important part of formation evaluation. These steps are performed separately somewhere else, either by the service company supplying the data, or by our own conventional petrophysical analysis system.

The output consists of corrected data, that represent genuine formation measurements and responses, and can be inverted in HESPER to produce a model of the formation, with all its characteristics and properties, which is compatible and coherent with the geological and geophysical knowledge available.

At all times, the petrophysicist has on display his data, synthetic logs and a pictorial representation of the model itself. He can manipulate the model in a highly interactive manner, displaying the effect on the synthetic logs of changing the model structure or of changing the petrophysical equations used.

The system stores geological and petrophysical knowledge in the form of rules and model relationships, and is capable of making inferences based on that knowledge, generating advice for the petrophysicist.

It is designed to enable the petrophysicist to request advice at any time, and will generate a list of preferred options, based on evidence from the data and the state of the model. The petrophysicist may request an explanation as to why a particular piece of advice was offered, and is free to accept or reject that advice.

As attractive and seductive as it may have initially appeared, it was also clear that a system able to process data from any geological province and environment would have been impossibly complicated and, in fact, also technically unfeasible from the viewpoint of the software and hardware available. We decided therefore from the outset that we would select an area and an environment that could be easily defined in geological and petrophysical terms, that would be sufficiently well and widely known for the basic model knowledge to be freely available, but that would be sufficiently ample and complex to be representative of the tasks and problems to be solved. Furthermore, it had to be of genuine, current technical interest, so that it could be tested with real data, and its answers could be evaluated in the proper context of day-to-day operations rather than purely on academic research achievements. We selected therefore the province of the Southern North Sea gas fields basin, or more accurately, the Southern Permian Basin at the stages of Rotliegend and Zechstein deposition.

Because of its importance in the establishment of the knowledge base and of the modelling rules, as will be shown in the following sections, we present here a brief outline of the geological model, with explanations of the terms used.

2.1 The General Geological Model (after Glennie)

In the Southern Permian Basin, sandstones of the Upper Rotliegend form the most important reservoir rocks for gas, containing some 4.1×10^{12} m^3 of proven recoverable reserves, of which 1×10^{12} m^3 are in offshore fields of the Southern North Sea and 2.4×10^{12} m^3 are in the giant Groningen gas field in the Netherlands. The source for all this gas is the Coal Measures of the underlying Carboniferous and the seal is provided by the overlying Zechstein sequence.

The Upper Rotliegend is made up of four distinctive rock types, which have been interpreted as the products of deposition in fluvial (wadi), aeolian or desert sand dunes, sabkha or intermittent desert lake, and lacustrine environments. An artists view of what the basin might have been before the Zechstein sea flooding is shown in Fig. 2.

The Zechstein transgression, which is responsible for the formations providing the seal for the gas reservoirs, probably started because a world wide rise in sea level permitted oceanic water to flow along a pre-existing fracture system. The surfaces of the Permian basins were probably well below the level of the open ocean, so that once the water began to flow south along the fracture the transgression continued until the level of the Zechstein Sea matched that of the ocean (Fig. 2).

With this geographical/historical/geological picture in mind we can summarise our model as follows.

Any given well in the South Permian Rotliegend Basin is likely to traverse a sequence of rock consisting of sandstones of different quality, determined by their origin within a depositional model.

The sandstones may or may not contain gas. We may also encounter mudstones and other non-reservoir rocks. Finally, the uppermost (shallowest) rock formation will be a thick section of Zechstein salts and carbonates, providing the seal.

Our interpretation process consists therefore in finding the rock sequence that best fits all the data, and model each formation so that the synthetic logs match the original logs as best as possible. Formation properties such as porosity, fluid type and content, mineralogy, etc. will be varied within each rock type according to rules and guidelines proposed by the general geological and depositional model, eg. if this rock is a Zechstein carbonate, it is most unlikely to contain gas.

2.2 HESPER and Its Relation with the Computing Environment

As part of the HESPER project, we considered it of great importance to design and develop a computing environment which would improve the way in which our petrophysicists work, by making data access and processing friendly, fail-safe, and easily understandable, if not self-explanatory. This was to be achieved by designing the interface in a way that mirrored the working practice of the petrophysicist, in terms of data presentation and manipulation. At the same time well-known and proven routines and algorithms were to be retained. The knowledge and experience of senior staff would be made more generally available and accessible by incorporating them into the knowledge base, and in fact by assigning senior staff part-time to the project, so that the transfer of information could take place most efficiently. This allowed the retention in the system of the "flavour" or "style" of the Britoil approach and working practice, and makes the system more friendly to the users.

Finally, we wanted to obtain an example of expert system technology and gain experience of these techniques for use in other areas within Britoil.

The project was to retain as much as possible of the existing hardware and software, and in fact, the ultimate goal was to integrate HESPER fully within the existing computing environment.

The initial system, based on the Southern Permian Basin, had to be able to be developed to whatever other area it was deemed desirable, eg. the East Shetland oil fields basin. This meant that it was acceptable to operate initially on limited knowledge and data bases, but the bases themselves had to be easily expandable, and all the logic tools and inference engines had to be in place and capable of being applied to other environments.

If possible, extension to other areas related to but away from petrophysics, ie. purely geological and geophysical applications, was borne in mind.

3. STRUCTURE OF HESPER

Fig. 3 shows the overall structure of the system.

There are three main modules, as follows:-

- The Modelling Module, which contains code to maintain the data structures which represent the geological model, the procedures to manipulate and view this model and those to derive synthetic log responses from the model.

- The Interface Module, which contains the code to display the data and model, and to handle all interactions between user and system.

- The Advice Module, which contains the code to generate advice for display to the user, based on the data and the current state of the model.

3.1 The Model

The emulation of the manual process of Petrophysical Interpretation can be thought of as three steps, around which the user will iterate while constructing a plausible model of the formation being analysed. These are:

- Zoning, where the user breaks the formation vertically into a number of discrete zones, each of which may be modelled in a different way;

- Modelling, where the user constructs and manipulates sets of components and their properties, each of which represents the formation at a given depth;

- Simulation, where synthetic logs are generated from the model, for comparison with recorded data.

3.1.1 Zoning

Zones would be created by the petrophysicist to represent vertical sections with similar characteristics, for example a broadly similar lithology or sections of high permeability. Within HESPER, these zones are represented as a tree structure, the leaves of the tree representing the Zone Map - the zones on display. One of the zones in the map is nominated as the Selected Zone - the zone to which all modelling operations apply. The system provides the user with a number of facilities to manipulate this zone structure. Zones can be divided to form a number of sub-zones, which may themselves be divided and so on.

A typical strategy might be to first isolate all intervals exhibiting the characteristics of sandstone. These would then be further sub-divided into, for example, dune and wadi sands. Once models to represent the two sandstones had been set up, the last division operation might be undone, and the sandstone re-zoned on the basis of porosity or permeability. The intervals so chosen would then be modelled in greater detail.

3.1.2 Modelling

Although HESPER will normally be used to model the formation on a zone-by-zone basis, it contains sufficient flexibility to operate on a single depth. To provide this flexibility, and to permit the zoning operations outlined above, requires the model to be fully represented at each depth, rather than on a purely zonal basis.

In HESPER, the model is represented at each depth by a tree, whose structure depends on the lithology being modelled. Each of the five rocktypes which may be represented - sandstone, claystone, siltstone, carbonate and evaporite - has a default structure, but potentially many variations are possible to represent, for example, the way in which the lithologies were altered through time (diagenetic processes).

Fig. 4 shows the default structure used to represent a sandstone. Each node in the tree is a component with a set of properties - density, resistivity etc. - and a set of valid inferiors - eg. oil cannot be an inferior of cement or matrix. A tree structure was chosen to represent the model, in preference to a flat list of components, to embody some knowledge of geological constraints within the system.

The method of constructing a model would typically be as follows: The user would first broadly describe the lithology by setting the depositional environment - eg. aeolian, the facies - eg. dune and the rocktype - eg. sandstone. He would then proceed to construct the model by adding and removing components to change the structure of the tree, and by varying the volumes of components present, relative to their siblings. The latter can be achieved by setting the volume of the component to a specified value, by varying it by a specified amount, or by "driving" its volume with a selected log. The user is also free to vary the properties of a component, for example its density, to change the synthetic log response generated by the model.

Finally, one of the most powerful features of the system is the ability to add Prototypical Components. These are partial component structures, complete with relative volumes and properties, stored within the system to represent, for example, a typical aeolian dune sandstone. The addition of such a component structure will allow a solution to be approached more rapidly.

3.1.3 Simulation

After each change to the model, the system will re-simulate automatically all synthetic logs which could have been affected by the change made. This is done using a set of petrophysical equations stored within HESPER. These equations require a number of simulation parameters, which relate to the formation in question. Within HESPER, the user is free to modify these parameters, and prototypical values, often obtained by experiment or by direct measurement, are stored for different lithologies.

3.2 The Advice-Giving System

The advice-giving system within HESPER is the part of the system which, when requested, prompts the user on the next most appropriate action(s) to take to further the evaluation. The philosophy behind the advice-giving system is that of a "dual pipeline", as illustrated in Fig. 5. The first pipeline deals with operations, which are abstract entities, such as "build an initial model" or "check simulation equation settings". The second deals with steps, which are more concrete entities, such as "introduce the dune gas sandstone prototype" or "select the Archie equation for resistivity". This approach allows the user to choose a general topic of interest before the system generates any specific advice. In this way, the system will not use resources on investigating topics in which the user has no interest at that time.

The lists of operations and steps generated by the system can be pruned on request to suggest only those that the system concludes are more appropriate at that time.

Each piece of advice offered has associated with it a full explanation of the evidence found to support that advice. The system makes no attempt to judge the relative importance of pieces of evidence. Rather, the user is left to decide whether sufficient evidence has been found to justify the particular piece of advice offered.

The advice-giving system is built around a general-purpose goal-directed rule-interpreter, which was developed as part of the project. The associated rule language is a full logic programming language, similar in many ways to Prolog, but with a good interface to LISP, to allow rules to interrogate the model and data.

One hallmark of an expert system is the ability to explain its own reasoning. In HESPER, this is done by building up an English-like explanation as rules are fired, then making it available to the user, allowing him to display whatever depth of reasoning he requires. It is felt that this approach offers advantages over the more conventional approach of stepping through rules, since it offers a less "stylised" explanation and allows the programmer more freedom in the expression of knowledge in rule form.

3.3 The User Interface

The Interface to HESPER consists of a single screen, split into a number of independent interaction panes, each of which is responsible for displaying a particular set of data and for permitting related interactions with the system. Interaction with the system is almost exclusively through a three button mouse, the keyboard being used only to enter scale values. The system is menu-driven, all menus being context-dependent, only displaying options which are valid at that time. Control is via a central process which awaits mouse clicks and other messages in a shared buffer, then dispatches a message to the appropriate pane.

Fig. 6 shows an example of the interface with six logs on display, a fairly complete model of part of a well, showing sandstone, claystone and evaporite zones, a set of core data and two crossplots.

The model is constructed using a window which can display each possible component structure as a mouse-sensitive tree. By clicking on components in this tree, the user can add them to the model, remove them and change their volumes. An example of this display is shown in Fig. 7.

Advice is displayed using a window which is divided into two panes, to display the list of generated operations or steps, and those selected by the system as being most appropriate. Through the use of icons, the mouse can be used to display greater or lesser levels of reasoning. An example of this display is shown in Fig. 8.

3.4 Implementation

HESPER has been developed on a Symbolics LISP-based workstation, networked to a central VAX cluster over Ethernet. The system is written entirely in LISP, and comprises approximately 40,000 lines of code. It makes heavy use of object-oriented programming techniques and also uses logic programming techniques for rule handling. The display is on a high resolution bit-mapped screen with hardcopy on a VAX-connected electrostatic plotter.

4. TESTS AND PERFORMANCE

As already stated, HESPER was developed as an integral part of the petrophysicist's computing environment. Tests and performance were therefore designed to address three areas: ease of operation and accuracy of results (the petrophysicist's viewpoint), program efficiency (the artificial intelligence expert's viewpoint), and integration and expansion within an existing environment (the system manager's viewpoint).

From the petrophysicist's viewpoint, the first thing the user notices is the great flexibility of the presentation on the screen: all the available and relevant data are presented in an independently addressable form.

Log data, core description, core analysis results, cuttings description, mud and gas analysis, and in general the entire body of evidence is immediately visible and accessible, with the result that the user is almost obliged to keep the entire evidence in mind, rather than concentrate only on single immediately available pieces, one at a time.

The task of manipulating the data is also made much simpler by the use of the mouse for selection and display: scale changes, presentation, shading, etc. are performed by moving the selection arrow/indicator to the appropriate option and clicking a button.

Keyboard input is almost non-existent, and the user can therefore literally follow his/her train of thought on the screen, without having to worry about spelling or typing mistakes, or indeed without having to bother with the position of the keys at all.

The generation of new models of formations and of their responses in the form of synthetic logs is perhaps the most powerful aspect of the interface with the user: the model formation can be changed gradually so as to minimise or eliminate the difference (errors) between the model logs and the real logs, and when a satisfactory match has been obtained, the model can be said to be a true or at least plausible and acceptable representation of the real formation.

In summary, the ability of displaying the entire body of data evidence, to manipulate the individual elements easily and clearly, to investigate changes, and to observe the results in the model make the interface a very powerful and user-friendly tool.

The generation of synthetic logs takes place by applying well-known and tried models and algorithms. As already stated, the only assumptions made are that the logs used for input have been corrected elsewhere for all environmental effects, ie. that they are genuine formation responses and that the formation responses from the individual measurements are either linear as regards the contributions of the individual components, or linearisable in some way, over a range of values. This requires some ingenuity in the use of appropriate models, particularly for sonic and resistivity logs, and HESPER uses simple, but reliable, models.

It is interesting to note that modelling and simulation are activities that can take place independently from the expert system for advice giving. This means that the - hopefully experienced - user can use the modelling and simulation parts of HESPER in areas where no knowledge and advice is available from the system, and still get useful results, in the same way as he would with a conventional interpretation system.

HESPER offers selection and advice in all three processing steps: zoning (the selection of a depth interval of interest), modelling (the selection of the most appropriate environment), and simulation (the selection of the most appropriate algorithm for the selected environment).

By far the most important point is that the body of advice is so constructed that it continuously uses the geological environment and model as the overall guide. In other words, it eliminates from any further consideration all those solutions that are not consistent or compatible with the geological model selected.

This is of course of tremendous impact in the interpretation: it means that it is not any more sufficient that the results make sense algebraically (eg. non-negative porosities and water saturations), but even before numbers are produced, the appropriate set of geological boundary conditions is selected, explained, generated, and finally applied, so that the results make sense geologically and petrophysically.

The user is of course free to accept or reject the advice: this is of particular value when exploring "what if" cases, where particularly subtle effects are being investigated, or when constructing new formation models. For routine evaluation in a well-behaved environment, the system will present and offer the best and most consistent advice. The user following that advice will be sure that he has optimised the use of all the data.

To the more experienced user, some of the advice will not be necessary, or will be used only as some sort of monitor/quality control: since it is called upon on demand, no processing time penalty is incurred.

The body of advice is contained in a "knowledge base" that is both general, and easily expandable: it should therefore be possible to use the same system for other applications and to extend HESPER to other environments from those available at the moment.

As regards speed of response, the system performs reasonably well. Two classes of response can be envisaged: the simple case, where the user clicks a mouse button and expects an immediate response from the system, and the more complex case, where the system is perceived to be doing useful work and the user is prepared to wait a little longer.

In the first case, almost all requests are handled immediately. The only exceptions are options which re-configure the screen, as these cause the machine to page heavily, which is in turn a function of it being memory bound (only 4 megabytes).

In the latter case, there are two types of operation: those to update the model and requests for advice. The slowest modelling operation (by its very nature) is that of driving the volume of a component with a log. In the most complex such case, response times have been found for an average zone to be around 10-15 sec, which is perfectly acceptable. In the case of the advice-giving system, each request for advice takes of the order of 30 sec to complete. This is probably at the upper limit of acceptability and has only been achieved by splitting the advice-giving process into a number of short steps. The time taken is due to three factors: poor paging performance, the speed of the rule interpreter and the time taken to query the model and data. The paging performance could again be improved by increasing the memory of the machine.

The other two factors should be considered together. The use of a commercially available interpreter would significantly speed up rule-execution. However, such a package would be unlikely to have such a good interface to LISP and there would therefore be performance penalties when querying the model (which amounts to a significant portion of the total time taken). This will be the subject of further investigation.

As regards integration with the existing Britoil computing environment, the situation is more complex. The range of hardware and software available for this type of application is under continuous development, as machine performance increases and memory costs decrease. The final decision as regards the hardware on which a production HESPER system will run has not yet been made, but work is ongoing to integrate the current hardware and software with the Britoil computing environment, and no major problems have been encountered, nor are any foreseen.

5. CONCLUSIONS

In the phased approach followed by Britoil for this project, conclusions at this stage can only be provisional, and of a more qualitative nature than we ourselves would wish: HESPER has not reached yet its final stage, and considerable changes and extensions are planned.

There is, however, little doubt that the prototype stage of the HESPER project has shown that the philosophy, overall design and technical implementation are correct and successful, and there is significant scope for expansion.

The modelling - feedback - advice philosophy implemented has proved to be successful, and understandable by the users, because the tools and the communication channels used are familiar to them.

It was remarkably satisfactory to note that we had to overcome somewhat less problems than initially feared: the good and productive programming environment offered by the hardware gave the system analysts and programmers the opportunity of exercising their skills to the fullest, with very good results. This was particularly apparent in the way the interface could be developed, and the very quick response time.

The very successful blending of talents and dedication in the development team was perhaps the most salient characteristic, and was without doubt at the root of the success of the project. The seed planted by the original team fell on very fertile ground, and the project is being continued entirely within Britoil, almost without outside staff. Technology transfer and training of staff has made it possible to confidently carry on with the development.

The original objectives of demonstrating the feasibility, desirability and usefulness of expert systems in petrophysics as representative of an earth sciences discipline, of providing a better environment, for our petrophysicist to work, and of acquiring direct experience and expertise of these technologies within Britoil have been successfully and comprehensively achieved.

6. ACKNOWLEDGEMENTS

In a project of this kind, we must recognise the crucial role that our senior Corporate and Function management (Petroleum Engineering, Information Services, and Research and Development) played in firstly very critically and thoroughly examining the whole project, and then just as thoroughly and enthusiastically supporting it: it made us think and re-think and re-shape our ideas, until the project was water-tight and well-controlled.

The development team was composed of staff from Britoil, and from the main contractor, Oilfield Expert Systems Ltd., who appointed the specialist consultants in artificial intelligence and in computing hardware and systems (from Marconi Underwater Systems Ltd. and Scientific Computers Ltd.). They put an incredible amount of hard work, professional expertise, and enthusiasm into the project: the credit for the success of the project is entirely theirs. Finally, the authors would like to thank Britoil for permission to publish this paper.

7. REFERENCES

We did not find, or use, specific papers of relevance, but made use of relevant textbooks on the subjects of reservoir rocks, sandstones, petrophysics, well logging, artificial intelligence, LISP programming, etc. We found the following textbooks most useful, and group them in the two categories of Earth Sciences and Computing.

7.1 Earth Sciences Books

1. Berg, R.R.; Reservoir Sandstones 1986, Prentice-Hall, Inc.

2. Doveton, J.H.; Log Analysis of Subsurface Geology - Concepts and Computer Methods 1986, John Wiley & Sons

3. Glennie, K.W.; Desert Sedimentary Environments Developments in Sedimentology 14 1970, Elsevier Publishing Company

4. Glennie, K.W. (Editor); Introduction to the Petroleum Geology of the North Sea First Edition, 1984, Blackwell Scientific Publications

5. Hearst, J.R. and Nelson, P.H. Well Logging for Physical Properties 1985, McGraw-Mill Book Company

6. Hobson, G.D. (Editor); Developments in Petroleum Geology-1 1983, Applied Science Publishers

7. Hobson, G.D. (Editor); Developments in Petroleum Geology-2 1983, Applied Science Publishers

8. Pettijohn, F.J., Potter, P.E., Siever, R.; Sand and Sandstone Second Edition, 1987, Springer Verlag

9. Tittman, J.; Geophysical Well Logging 1986, Academic Press, Inc.

7.2 Computing and Programming Books

1. Abelson, H. and Sussman, G.J. Structure and Interpretation of Computer Programs 1985, MIT Press

2. Bratko, I.; Prolog Programming for Artificial Intelligence 1986, Addison-Wesley Publishing Co.

3. Clocksin, W.F. and Mellish, C.S. Programming in Prolog Second Edition, 1984, Springer-Verlag

4. Cox, B.J.; Object-Oriented Programming: An Evolutionary Approach 1986, Addison-Wesley Publishing Co.

5. Steele, G.L. Jr.; Common LISP: The Language 1984, Digital Press

6. TI Engineering Journal (AI Issue) Jan-Feb 1986, Vol. 3, No. 1

7. Winston, P.H. and Berthold, K.P.H. LISP Second Edition, 1984, Addison-Wesley Publishing Co.

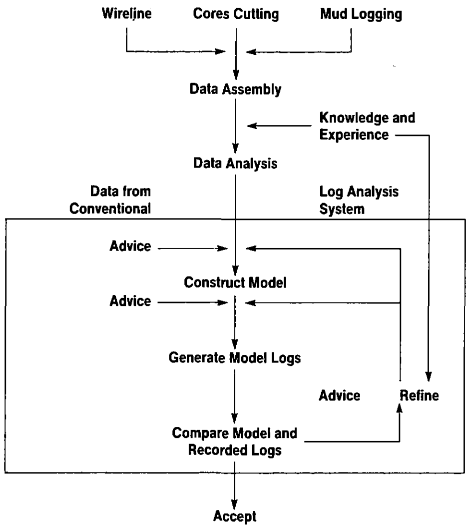
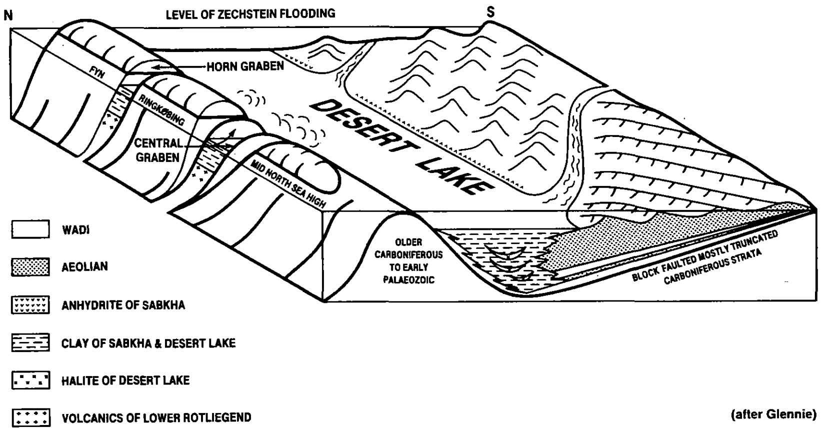
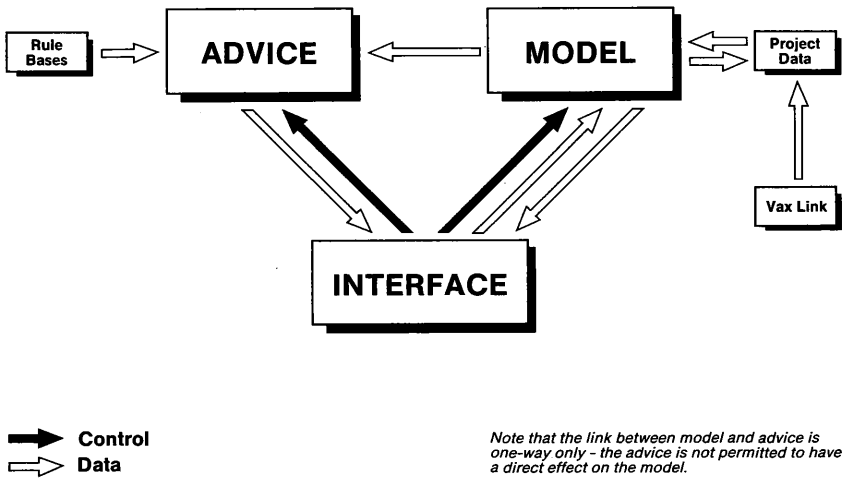


Fig. 1—Process of petrophysics.



(after Glennie)

Fig. 2—Conceptual diagram of the southern Permian Basin.



Note that the link between model and advice is one-way only - the advice is not permitted to have a direct effect on the model.

Fig. 3—System diagram.

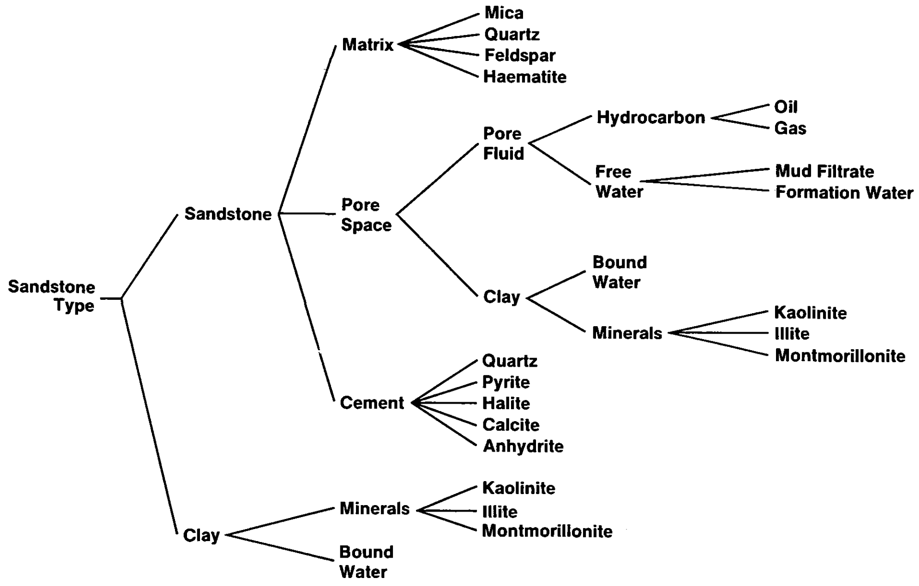


Fig. 4—Sandstone tree.

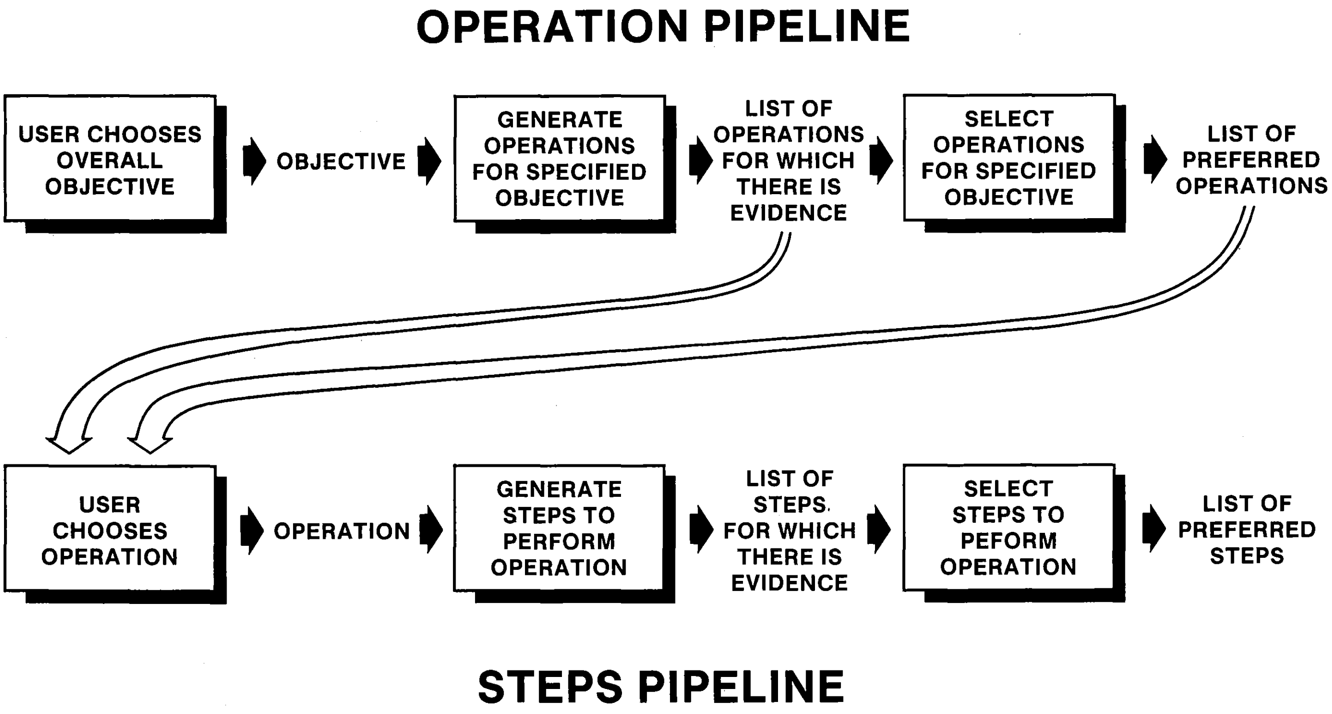
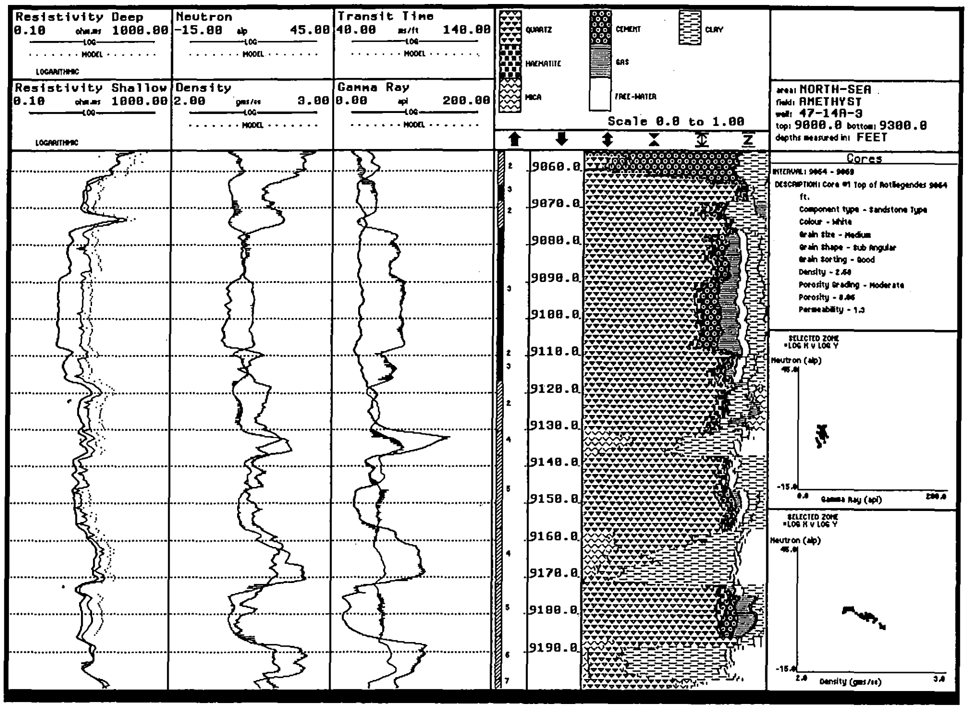


Fig. 5—The advice-giving system.



area: NORTH-SEA
field: AMETHYST
well: 47-14A-3
top: 9000.0 bottom: 9300.0
depths measured in: FEET

Cores

INTERVAL: 9064 - 9069
DESCRIPTION: Core #1 Top of Rotliegendes 9064 ft.
Component type - Sandstone Type
Colour - White
Grain Size - Medium
Grain Shape - Sub Angular
Grain Sorting - Good
Density - 2.60
Porosity Grading - Moderate
Porosity - 0.06
Permeability - 1.3

Fig. 6—The user interface.

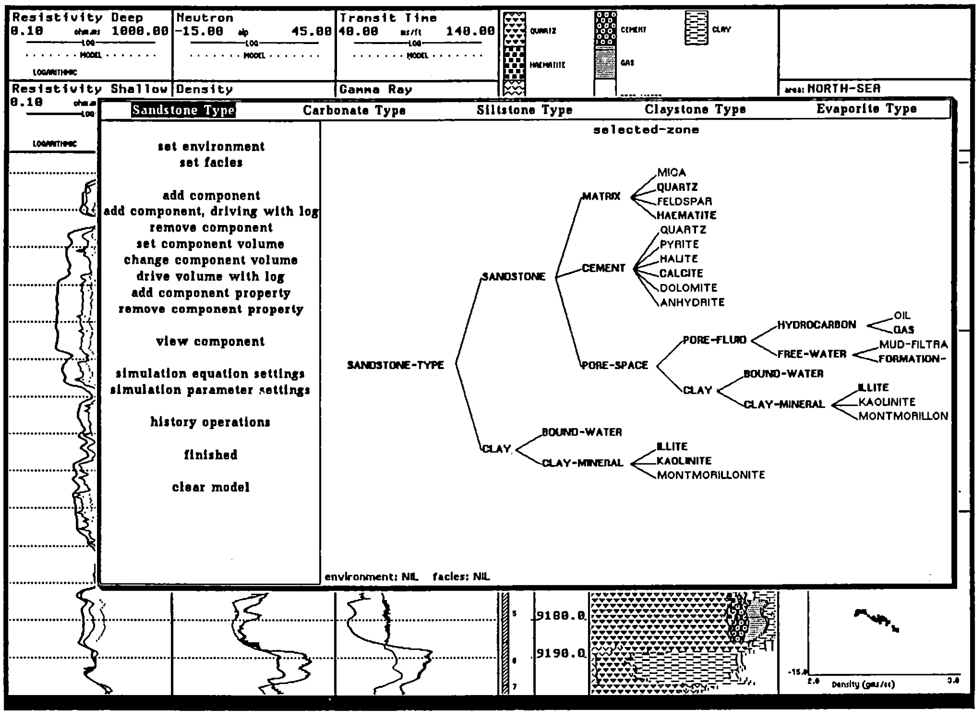
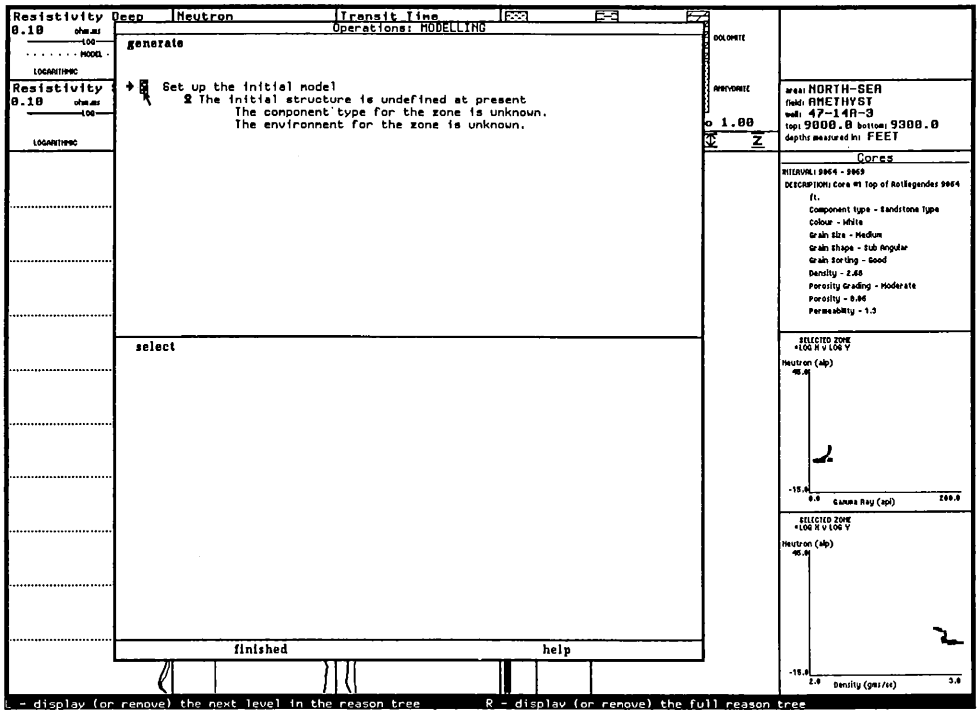


Fig. 7—Manipulating the model.



Set up the initial model
2 The initial structure is undefined at present
The component type for the zone is unknown.
The environment for the zone is unknown.

area: NORTH-SEA
field: AMETHYST
well: 47-14A-3
top: 9000.0 bottom: 9300.0
depths measured in: FEET

Cores

INTERVAL: 9064 - 9069
DESCRIPTION: Core #1 Top of Rotliegendes 9064 ft.
Component type - Sandstone Type
Colour - White
Grain Size - Medium
Grain Shape - Sub Angular
Grain Sorting - Good
Density - 2.68
Porosity Grading - Moderate
Porosity - 0.06
Permeability - 1.3

L - display (or remove) the next level in the reason tree
R - display (or remove) the full reason tree

Fig. 8—The advice interface.