Towards Integrated Oil and Gas Databases in Iraq

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Introduction

The oil and gas industry has to deal with huge amount of data throughout the lifecycle of the exploration, drilling, logging, production, refining, transportation, distribution and marketing of crude oil and gas, and has a voracious appetite for data. Exploration and Production (E&P) departments acquire Tera (10^{12}) Bytes of seismic data which is processed to produce new projects, creating exponential growth of information. Furthermore, this data is increasingly acquired in 3 or 4 dimensions, creating some of the most challenging archiving and backup data management scenarios of any industry. The international oil industry has traditionally been at the forefront in the utilization of state-of-the art information technology tools for all aspects of its processes and operations, to manage the manipulation, storage and access of this data. This data covers:

- Surveys data
- Geological maps
- Seismic data
- Drilling and completion data
- Wells data including logs
- Reservoirs data
- Production information
- Infrastructure information
- Crude oil analysis data
- Leases

This paper focuses on the vital importance of establishing and maintaining integrated oil databases for the oil industry in Iraq covering upstream activities. Much of the oil and gas data presently exist in various formats such as paper, maps, computer tapes, photographs, and computer disk files. These data are seriously under threat due to the age of some documents, maps, photographs and even electronic records, and the fact that much of the data are scattered in various locations so they are difficult to access centrally and by different technical roles in the E&P organizations. They are also so important to be easily accessed for planning and operational purposes. Further, these data are national assets that need to be protected.

An initiative was made by the Ministry of Oil in Iraq several years ago on such a project but unfortunately for various reasons it was apparently abandoned.

Main processes and resulting data in upstream oil and gas industry

The upstream oil and gas industry includes all the activities that happen in the field, such as:

- Identifying prospects
- Shooting seismic surveys
- Drilling and servicing wells
- Cementing, perforating and fracturing wells
- Testing well production
- Engineering planning and development
- Producing crude oil and natural gas

Geological maps have traditionally been kept on paper and probably most of the existing maps in Iraq are on paper, but the advent of digital geologic mapping by which geologic features are observed, analyzed, and recorded in the field and displayed in real-time on a computer or portable device has changed the scenery. The primary function of this emerging technology is to produce spatially referenced geologic maps that can be utilized and updated while conducting work.

Seismic reflection data is used by petroleum geologists and geophysicists to map and interpret potential petroleum reservoirs. The size and scale of seismic surveys has increased alongside the significant concurrent increases in computer power during the last 30 years. This has led the seismic industry now to routinely acquire large-scale high resolution 3D surveys. Previously, seismic data were stored on 9 inch magnetic tape reels (140 MByte capacity) due to their size but with the availability of cheap high capacity DLT (Digital Linear) and other digital tapes (with capacity up to 1.6 Tera Byte), large magnetic discs and optical storage they are now largely used to store seismic data.

Well logging, is the practice of making a detailed record of the geologic formations penetrated by a borehole. The log may be based either on visual inspection of samples brought to the surface or on physical measurements made by instruments lowered into the hole (*geophysical* logs). Well logging can be done during any phase of a well's history; drilling, completing, producing and abandoning. Logging tools developed over the years measure the electrical, acoustic, radioactive, electromagnetic, nuclear magnetic resonance, and other properties of the rocks and their contained fluids. Logging during drilling and after well completion produces a lot of data normally stored now as computer files, but previously held on paper.

- **Exploration Surveying**
  - In the first stage of the search for hydrocarbon-bearing rock formations, Geological Maps are reviewed in desk studies to identify major sedimentary basins. Aerial surveys may ensue.
  - A seismic survey is the most common assessment method and is often the first field activity undertaken. It is used for identifying geological structures and relies on the differing reflective properties of sound waves to various rock strata, beneath terrestrial or oceanic surfaces. (Seismic Reflection Data)
- **Drilling and Appraisal**
  - Once a promising geological structure has been identified, the only way to confirm the presence of hydrocarbons and the thickness and internal pressure of a reservoir is to drill exploratory bore holes.(Core data and logs)
- **Reservoir Simulation**
  - Computer simulation of the reservoir using finite difference method to design best oil recovery (Pressure, Volume, Temperature data)

Reservoir models are constructed to gain a better understanding of the subsurface that leads to informed well placement, reserves estimation and production planning. Models are based on measurements taken in the field, including well logs, seismic surveys, and production history. Petroleum engineers use reservoir simulators to predict the evolution of pressure, temperature, and the saturation of water, oil, and gas during reservoir production. The results are then used to help make production decisions.

Seismic to simulation enables the quantitative integration of all field data into an updateable reservoir model built by a team of geologists, geophysicists, and engineers. Key techniques used in the process include integrated petrophysics and rock physics to determine the range of lithotypes and rock properties, geo-statistical inversion to determine a set of plausible seismic-derived rock property models at sufficient vertical resolution and heterogeneity for flow simulation, stratigraphic grid transfer to accurately move seismic-derived data to the geologic model, and flow simulation for model validation and ranking to determine the model that best fits all the data.

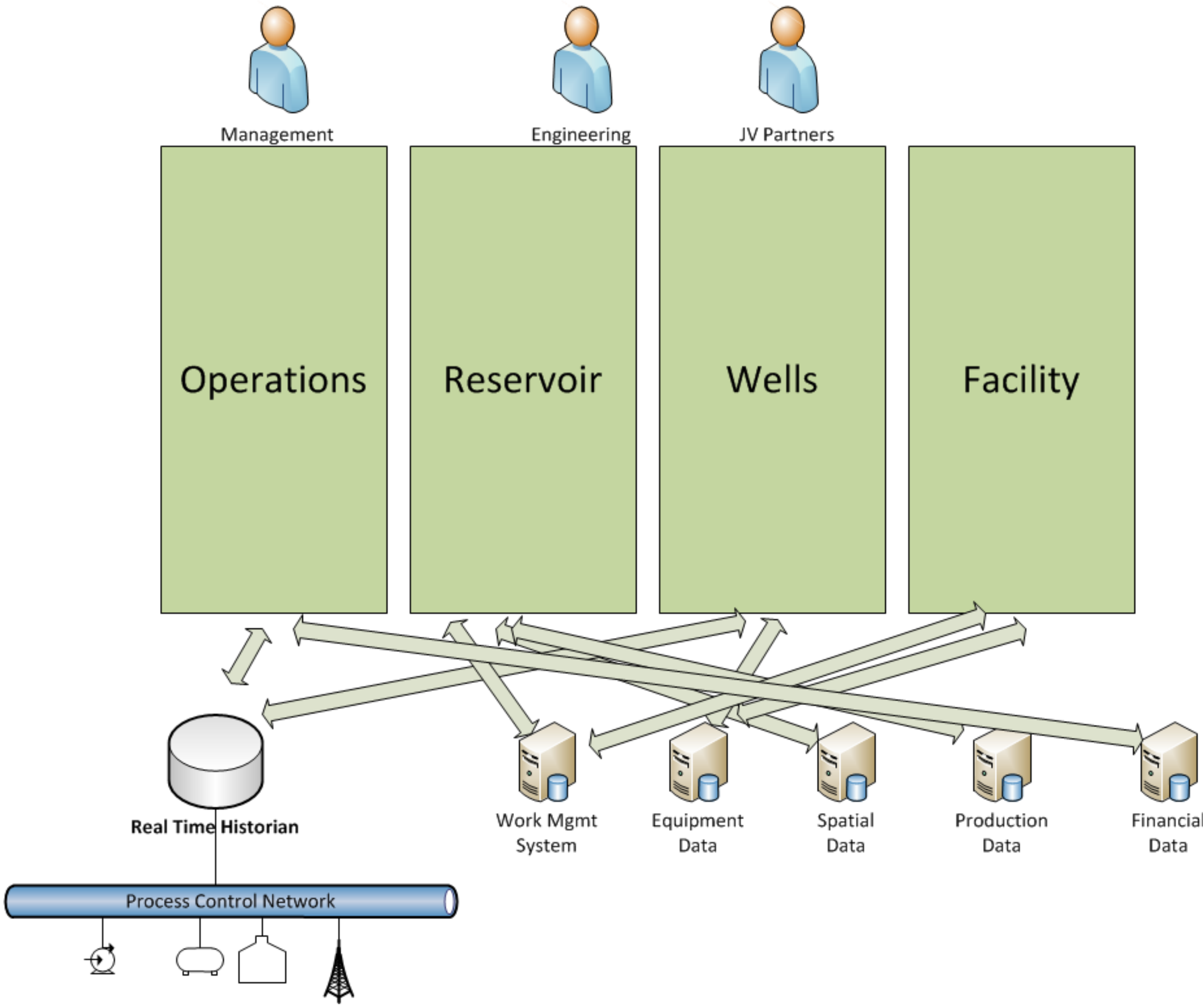
Reservoir software simulators are implementations of the laws of conservation of mass, conservation of energy, and energy transport equations. These models are simulated using parallel computational algorithms (usually using finite difference method) with high performance computers. Reservoir database may include rock and fluid characteristics, discovery well, production and reserves, oil-in-place and gas-in-place, and post-primary recovery method.

- **Development and Production**
  - Having established the size of the oil field, the subsequent wells drilled are called ‘development’ or ‘production’ wells. (well logs data, production data)

Once the oil/gas in place is identified and production wells are drilled and completed, well logs are collected and analyzed. When all necessary surface field infrastructure is developed, production can proceed and, production and sensory data are collected on continuous basis.

Upstream Oil and Gas Data

The data used and captured throughout the lifecycle of the oil and gas upstream processes are multi-faceted and complex. They are also in variety of formats including paper, digital data, analogue photographs, maps, graphs, and aerial photos. They are huge to store and access and would easily run into Peta (10^{15}) Bytes. The various categories of data pertaining to exploration, drilling and production are considered.



Exploration Data

Discovering and assessing oil or gas deposits requires integration of information culled from geology, geochemistry, drilling, Geographical Information Systems, seismology, electro-magnetic surveys, potential fields, and other disciplines. Exploration data include general well information, locations, and deviations; stratigraphic and well-interval data; well completions (perforated intervals); daily drilling results; and well-log and seismic data.

Aeromagnetic data have long been used by the petroleum industry to map structure and to estimate depth to magnetic basement. In the 1960s computers began to be used for processing and interpreting geophysical data. One application that became popular was estimation of depth to basement from potential field data, particularly aeromagnetic data. The second application, that of mapping basement structure, was not automated and was used by a dwindling number of practitioners.

Use of gravity methods has continued to expand, based on their contribution to reliable evaluations (and recent discoveries) in deeper, more challenging environments such as sub-salt structures.

Satellite and airborne Remote Sensing technology aids in the selection and development of oil and gas exploration areas around the World. Through geological and geophysical seismic interpretation and use of orthorectified satellite images, it provides insight on the selection of areas to plan 2D or 3D seismic surveys for an exploration drilling program as well as aiding in the process of environmental and operational safety hazards to minimize the health, safety and enviornment risks. There is currently no other technology that matches or exceeds the capabilities of remote sensing and its necessity in the oil industry.

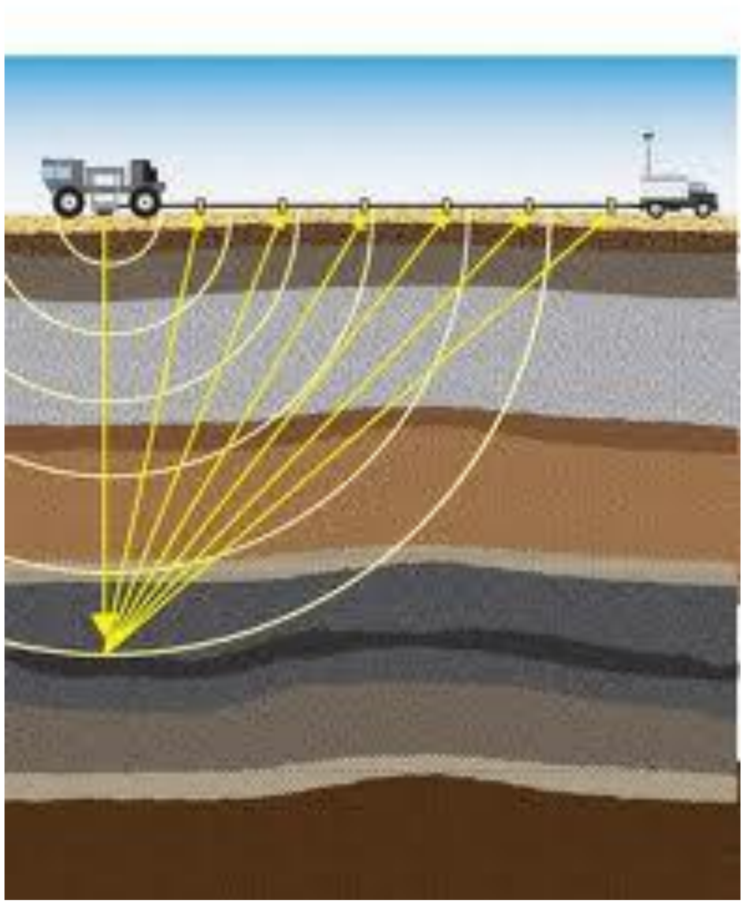
Exploration for oil and natural gas typically begins with geologists examining the surface structure of the earth, and determining areas where it is geologically likely that petroleum or gas deposits might exist. By surveying and mapping the surface and sub-surface characteristics of a certain area, the geologist can extrapolate which areas are most likely to contain a petroleum or natural gas reservoir.

The geologist has many tools at his disposal to do so, from the outcroppings of rocks on the surface or in valleys and gorges, to the geologic information attained from the rock cuttings and samples obtained from the digging of irrigation ditches, water wells, and other oil and gas wells. This information is all combined to allow the geologist to make inferences as to the fluid content, porosity, permeability, age, and formation sequence of the rocks underneath the surface of a particular area.

Once the geologist has determined an area where it is geologically possible for a natural gas or petroleum formation to exist, further tests can be performed to gain more detailed data about the potential reservoir area. These tests allow for the more accurate mapping of underground formations, most notably those formations that are commonly associated with natural gas and petroleum reservoirs.

Accurate geological mapping is of critical importance in oil and gas exploration. The risk and costs involved in establishing where to build infrastructure are simply too high to leave to inaccurate information. Digital geologic mapping is the process by which geologic features are observed, analyzed, and recorded in the field and displayed in real-time on a computer or portable device. This is gradually replacing the paper maps.

Seismic data is generated by using vibrations to capture a two or three-dimensional picture of the rock layers beneath the surface through the recording and interpretations of the reflected waves from the rock layers (see diagram below). The interpretation of seismic data allows the scientist to make an estimated picture of the rocks beneath the surface without drilling or digging trenches. The collection of vibrations which, when coupled with time elements, represent the rate of transmission of energy through a material. Scientists have measured many different materials and have a portfolio of data which allow them to interpret the type of material, the structure of the material, and the depth below the surface of the material, all based upon the nature of the vibrations. In a properly migrated 3D seismic data set, events are placed in their proper vertical and horizontal positions, providing more accurate subsurface maps than can be constructed on the basis of more widely spaced 2D seismic lines, between which significant interpolation might be necessary. In particular, 3D seismic data provide detailed information about fault distribution and subsurface structures. Computer-based interpretation and display of 3D seismic data allow for more thorough analysis than 2D seismic data. Data are usually captured on digital magnetic tapes or disks. There are now very sophisticated programs for interpretation and display of seismic reflection data.

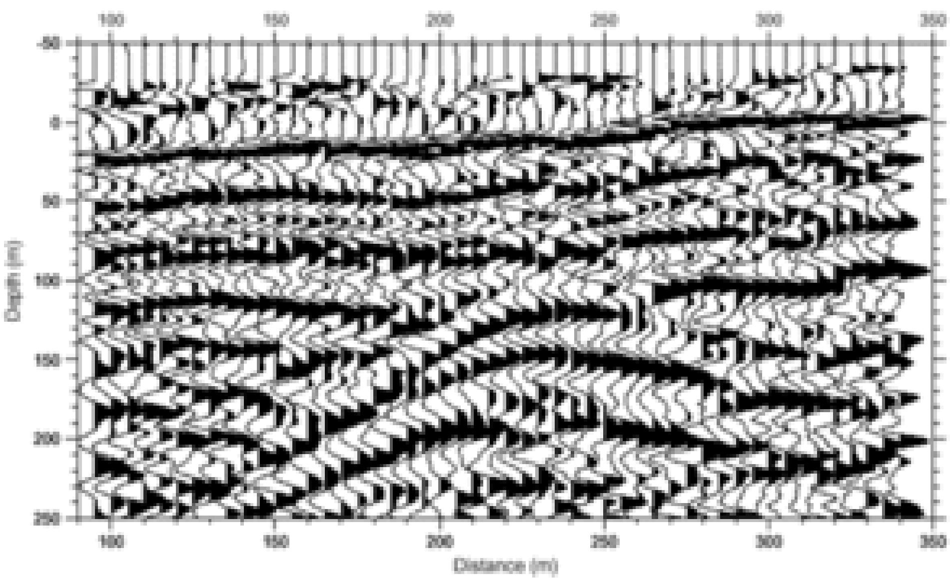


- Surveys data
  - Aeromagnetic surveys
  - Gravity surveys
  - Satellite imagery

- Geological maps
  - Traditional maps
  - Digital geologic mapping
- Seismic data
  - Huge reflection data
  - Captured on magnetic media
  - Displayed graphically

Seismic Reflection

A typical seismic reflection migrated plot.



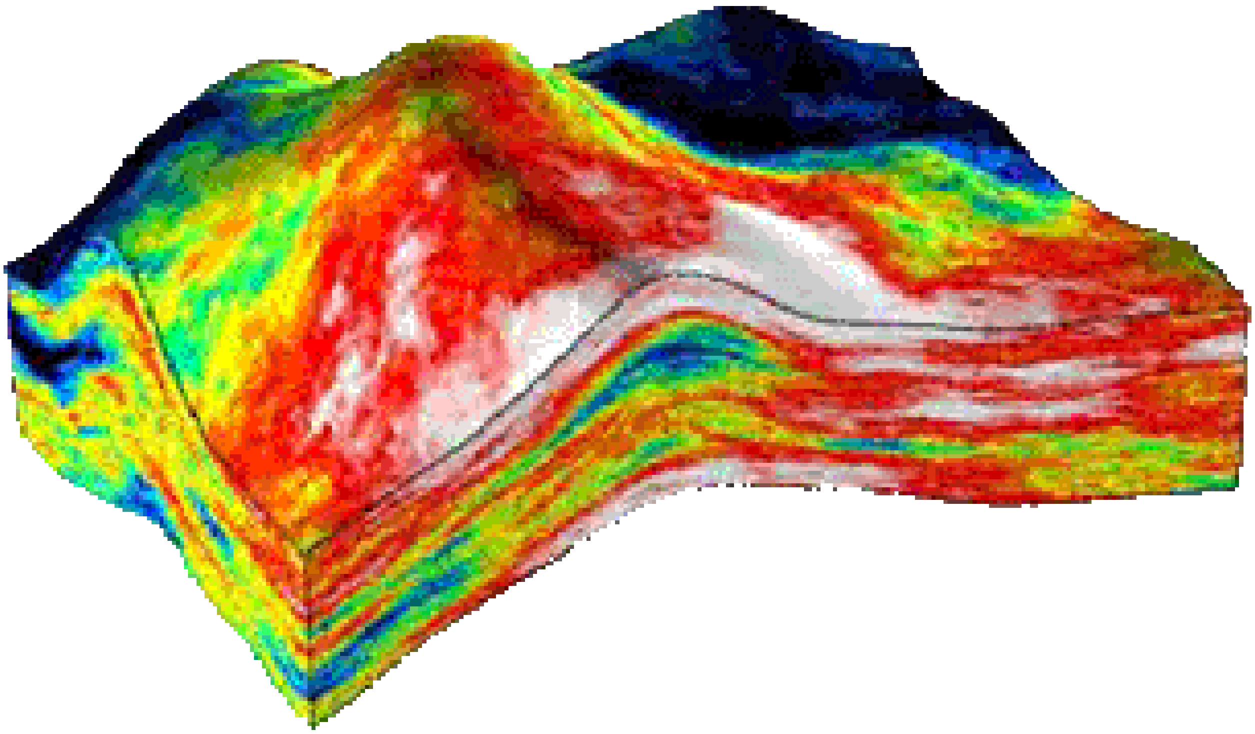
Reservoir Modeling Data

Converging technologies have brought high-end interpretation, modeling, and simulation to desktops. Two primary components of E&P decision making—seismic interpretation and reservoir modeling—have recently undergone rapid transformation due to the following four convergent information technology advances including the development of enterprise-class, volumetric seismic interpretation and reservoir modeling applications based on the relatively inexpensive and widely available Windows platform, the increased accessibility of high-availability desktop computing platforms with the CPU power necessary to drive data-intensive interpretation and modeling applications, the creation of data storage and management systems and software that can handle Peta Bytes of information while providing improved data sharing and the ready availability of GigaBit Ethernet via fiber-optic cable for connectivity between data storage systems and workstations.

Reservoir software modeling is also typically run on supercomputers, but some software can even run now on PCs or powerful workstations with the right hardware. Dynamic visualization of the reservoir can also be run on workstations or even supercomputers to gain better understanding of the reservoir behaviour and recovery under different production scenarios.

- **Reservoir identification** variables like: Unique field identification code, field name, and state/district code, Reservoir age rank and formation code, Reservoir composition and number of pools
- **Reservoir volumetric** variables like: Thickness, Area, Porosity, Initial oil, gas, and water, saturations, Formation volume factors of oil and gas, Gas compressibility, Temperature, Initial pressure
- **Other reservoir rock** variables such as: Lithology, Depth to top, Permeability, Tight formation indicator, Natural drive mechanism, Residual oil saturation, Well spacing and number of developed spacing units, General and specific trap type
- **Reservoir fluid** variables like: American Petroleum Institute gravity of fluids, Crude oil viscosity and pour point, Crude oil sulfur content, Gas-oil ratio, Gas gravity and heating value, Composition of reservoir gases, Resistivity of formation water

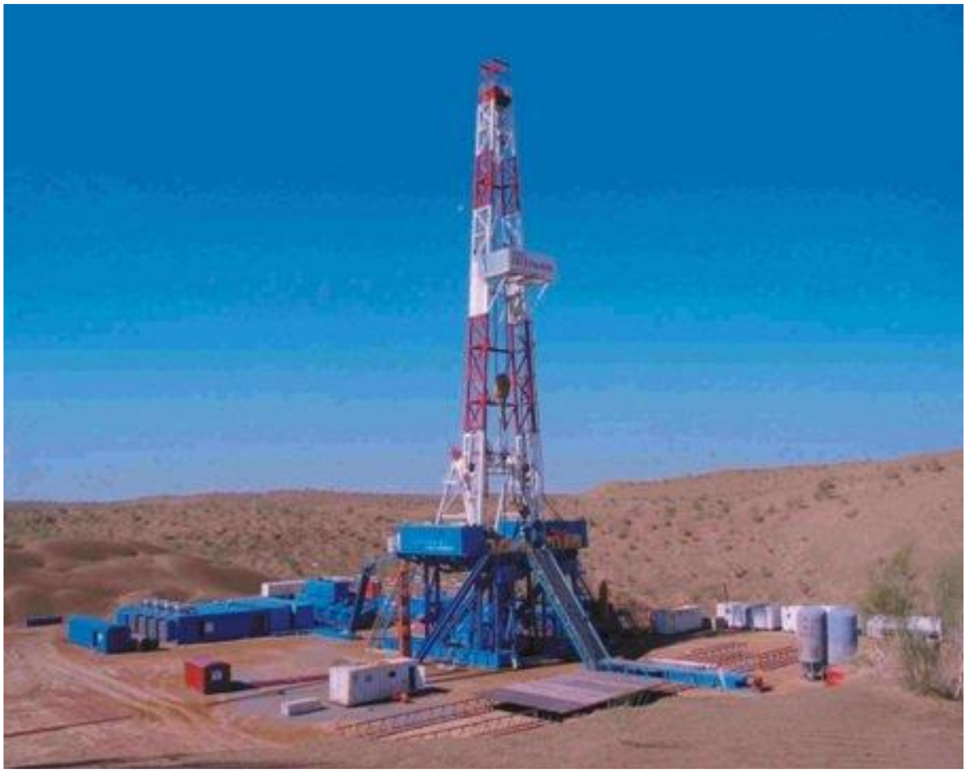
Rendering of the reservoir model is done now with excellent graphical software giving the reservoir engineer a clear picture of the subsurface formation and the location of the oil and gas, see diagram below which is colour coded for different rock layers.



Drilling and Completion Data

Collaboration between drilling and completion groups leads to a better understanding of complex reservoir conditions. The importance of tackling unstructured data across the drilling and petroleum engineering group, where significant use of a proper workflow and a state-of-the-art data management application system is made, should be highlighted. Variety of data is routinely collected during the drilling and completion processes.

- Detailed data on well location, rig, bits, casing
- Depth, performance, mud
- Core analysis



Wells Logging Data

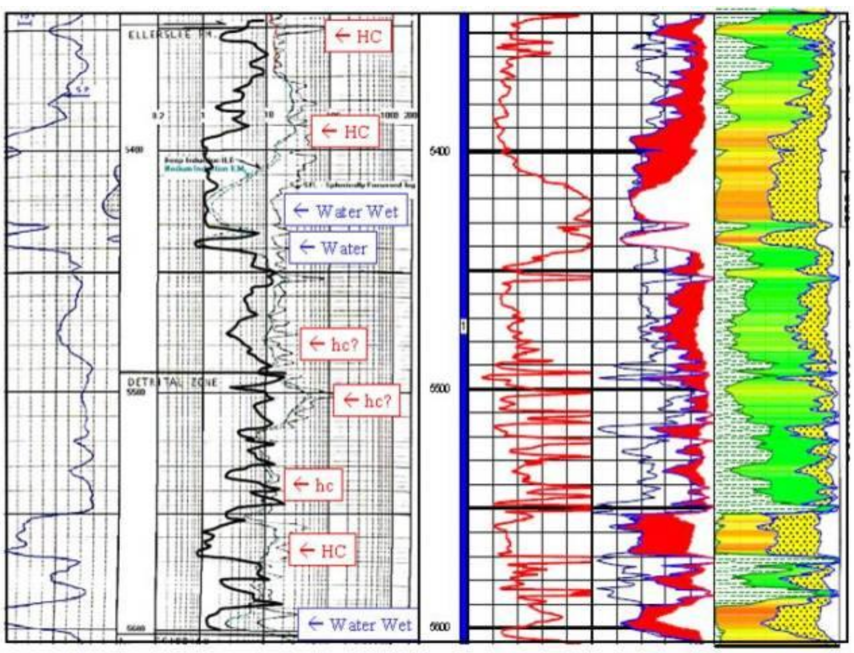
Well logging, also known as borehole logging is the practice of making a detailed record of the geologic formations penetrated by a borehole. The log may be based either on visual inspection of samples brought to the surface (*geological* logs) or on physical measurements made by instruments lowered into the hole (*geophysical* logs). Well logging can be done during any phase of a well's history; drilling, completing, producing and abandoning. Well logging is performed in boreholes drilled for the oil and gas industry. Types of logs include:

- Electrical Logs
- Resistivity
- Image Log
- Porosity Logs
- Density
- Neutron Porosity
- Sonic

- Lithology Logs
- Gamma Ray
- Self/Spontaneous Potential
- Caliper

Several types of well logs are performed such as

- Electric well Logging
- Gamma ray logging
- Caliper logging
- Sonic logging
- Coring and mud logging
- Many of the logs are in image format



Production and Infrastructure Data

Production data comprises production and injection history, test and sample data, workover information, and completion and reservoir data. Such data may include daily production data of oil and gas by wells, reservoir, region, Carter Coordinates, and other parameters including well locations. It can also include water or steam injection data for injection wells.

- Well by well production history
- Reservoir production history
- Water or steam Injection data
- Crude oil analysis data
- Well head equipment data
- Degasing equipment data
- Pipelines data

Storage and Transportation Data

Storage and transportation data comprise crude oil and gas flows and inventory.

- Real-time storage farms inventory data, on a tank by tank basis.
- Pipes flows using SCADA (supervisory control and data acquisition) systems
- Tanker loading terminals data

Data Management for Big Oil and Gas Data

There are now excellent processor hardware and database management software tools to deal with very large (Peta Bytes) databases so that seismic, maps, logs data can be loaded and accessed. Supercomputers with Peta Flop (10^{15} Floating Point Operations per second) speeds as well other high speed workstations, are now available for reservoir simulation work. Portable computer (and mobile phones) devices offer effective wireless connectivity and processing power to carry out meaningful database access and update. Large data storage has come down in price making it possible to duplicate storage and ensure data safety.

- Very large databases are now possible to be run with high availability
- Data storage has become very cheap
- Powerful computer processors make it possible to run complex reservoir simulation and analysis

- Excellent portable devices such as tablet computers are now available

The Business Case for Databases Integration

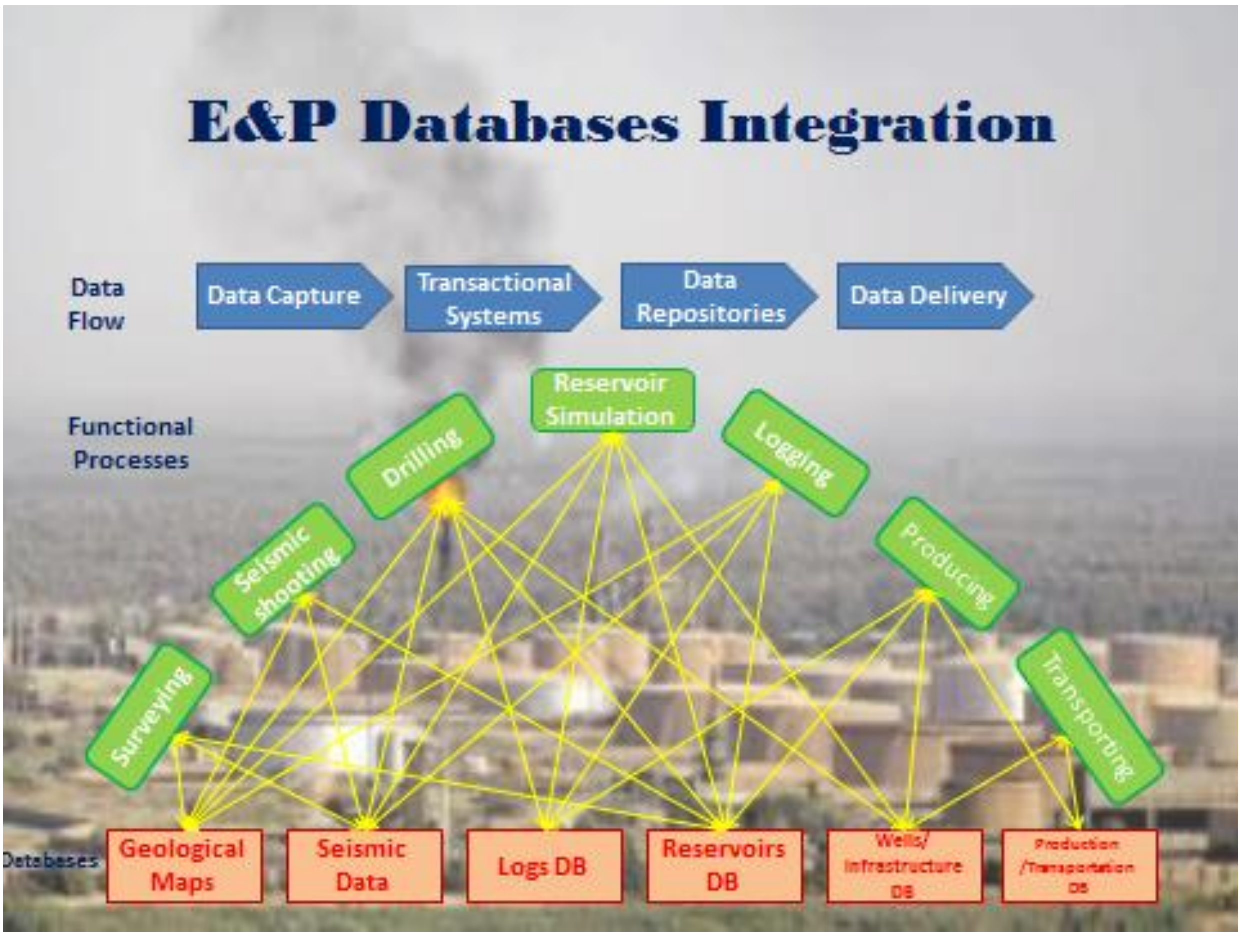
Integration in E&P information management is much more than just combining pieces of data pulled from various sources. It is equally important to clearly understand and adequately define the different roles within the organization that impact, or are impacted by, the data that are integrated from one process to another (e.g., the roles of Geology and Geophysics scientists, reservoir or production engineers) as the well moves through its concept-to abandonment life cycle. These people, process, and technology integrations are also dictated by a set of rules (i.e., workflow, which defines how a company wants to run its business). In a simple way, integration can thus be defined as successful communication between data, applications, process, people, and enterprises.

- Different roles in the E&P organization may access the same data
- Avoid data duplication
- Achieve data integrity
- Ensure protection of data and resilience
- Improve data accessibility and availability
- Ensure data standards are followed
- Reduce cost of holding data

E&P Databases Integration

The schematic below shows the interaction between the main functional E&P processes and the possible databases in a typical integrated E&P databases environment, and the data flow. The integrated approach should ensure that common data such as field, reservoir and well location and IDs are stored only once and used by all databases. This unified database model can enable workflow that span across exploration, engineering, development, production, economics, and other upstream oil and gas domains. It can also cater for unstructured data such as reports and studies.

A web portal that allows simultaneous access to all information from the integrated databases needs to be developed to allow access, update, data export, bulk data migrations, data analysis, data formatting, data modeling and transformations, report generation, statistics generation, graphical presentations, and printout. Metadata (e.g. unique identifier translation tables; data types, standards and lookup tables) across the databases should be maintained. Processes for developing and maintaining linkages across the databases and adding links to new databases have to be defined. Data quality control scripts should be run regularly to check the integrity of the databases.



A roadmap for integration of oil and gas databases in Iraq

It is proposed to initiate a large project to inventory all oil and gas data, design an integrated architecture for databases, capture, migrate and populate the new databases, and implement it with high availability, resilience and accessibility to be used for study, planning, and operational purposes by all stakeholders. This will be a multi-year project that should be implemented in phases. It would require the full participation and support of all oil sector players in Iraq coupled with political support. Full use of competent contractors with previous expertise in such projects should be made. The main activities of this project will include:

- Develop project statement of work and budgetary requirement
- Obtain the backing of stakeholder management including all new lease operators if possible
- Develop detailed project plan and assemble project team
- Inventory the existing data including type, location, size and format
- Identify the stakeholders/users of data, their locations and their precise data requirements
- Ensure definitions of each type of data in agreement with all operators; agree on data standards
- Develop the appropriate information architecture for the integrated databases
- Develop strategies to capture non-computer data in digital format
- Develop strategy for data migration from existing databases and ensuring data quality
- Design, acquire computer and networking hardware
- Design, build and test the new databases
- Load the data into the new databases including migration from existing databases
- Design, build and test the portal to connect to all the existing databases as well as the new databases, and provide easy access, processing and visualization tools
- Train users on the new environment
- Deploy the databases in a phased manner
- Review the implementation and make any necessary changes

Information Technologies to make use of for the project-Hardware

The pace of hardware change is hardly slowing down, and notable hardware useful for this project will be:

- Parallel high performance computers
- High availability computer servers
- Storage Array Networks
- High resolution colour graphical workstations
- Portable mobile phones, tablets and laptop PCs
- Wireless computer networks
- Wireless sensors
- SCADA Systems

Information Technologies to make use of for the project-Software

Similarly, there is an excellent range of software available for this project covering:

- Powerful database management systems suitable for large databases
- Enterprise Content Management System
- Middleware (applications server)
- Advanced operating systems supporting high availability, scalability and virtualization
- Geographical Information Systems (GIS) software
- Graphical rendering software
- Interpretation and Analytics software
- Statistical software

Conclusion

The integration of upstream oil and gas databases should be a high priority project for the oil and gas industry in Iraq. The project needs to be initiated and funded with a strong political and executive management support and a multi-disciplinary capable team representing all stakeholders. The return on investment for this project is very high in terms of optimizing recovery, raising productivity, and improving operational efficiency.

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