ACKNOWLEDGEMENTS

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ABSTRACT

This project is the design and implementation of a geological data management system for Conoco, Inc.'s exploration department in the Corpus Christi Division. The database replaces manual record keeping of geological and well production data, integrates data supplied by outside vendors, and automates data transfer to computer mapping programs. Use of the system will ensure consistent data management for each exploration project in the division. A menu-driven interface allows the geologists to perform routine data management tasks with minimal computer training and technical support.
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INTRODUCTION

Geologists in Conoco, Inc.'s Corpus Christi Division are assigned to oil and gas field development projects in south Texas. These projects incorporate extensive subsurface geological, geophysical, well test, and well production data. The data are derived from multiple sources, both in-house and from outside vendors. Data management, typically in paper or simple computer spreadsheet form, constitutes a substantial portion of the project time. The conversion of these data to a format compatible with computer mapping programs is also a time consuming task, and typically involves the help of a computer technician. Conoco lacks a standard for geoscience information management, resulting in considerable variation between projects.

There are three critical areas of data management in the development projects. First, the geologist must organize and record subsurface geological data which are interpreted during the course of a study. A typical project will entail hundreds of well bores, miles of geophysical (seismic) data, and multiple formations of interest. Currently, these data are manually posted on maps, or recorded on paper or computer spreadsheets.

Second, well test and well production data must be integrated. Production data includes such things as total oil and gas production to date, production rate, and pressure data, all of which vary with time. These data are retrieved online from commercial vendors, and can be output as a printed report, or viewed on the terminal. For more extensive queries, the production data are downloaded to files on a microcomputer. Linking of production data to geological data (to determine which formations are oil and gas reservoirs) is performed manually by posting data on a map.
The GDMS was developed to run on stand-alone, IBM PC or compatible microcomputers operating under MS-DOS 3.2 or higher. Program modules were written using Nantucket Inc.'s Clipper database development software. Import and export file-format conversions were written as Clipper-compatible C functions, and compiled with the Microsoft QuickC compiler. This system was created for the exploration group in Conoco, Inc.'s Corpus Christi Division office.
LOGICAL DESIGN

The Geological Data Management System (GDMS) was constructed around the relational data model first described by Codd (1970). The use of the relational model with petroleum-oriented geological data was briefly discussed by Leonard and Coskey (1990), and a proposed standard relational design for the petroleum industry was reviewed by Rhynes (1990).

The two principle entities in the GDMS data model are the wellbore and the geological formation. These two entities have a many-to-many relationship: each well penetrates many formations, and each formation is penetrated by many wells (figure 1). In fact, there are numerous relationships between wells and formations, each of which has its own attributes and therefore can be treated as an entity. These relationships describe the state of the formation at a particular point and time (figure 2).

For the purposes of this system, the attributes used to describe a well were limited to only those items of concern to the geologists, principally the well name, location, and depth. The wells are uniquely identified by a 14-digit number (API number) that is assigned by the Texas Railroad Commission.

A formation can be defined simply as a mappable rock stratum. As defined herein, the attributes of a formation are only those items that remain constant over the map area, such as formation name and geologic age. Formations are uniquely defined by a formation code, which is user assigned in the GDMS.
WELLS ← FORMATIONS

Each well penetrates many formations. Each formation is penetrated by many wells.
WELL ATTRIBUTES
OPERATOR
LEASE NAME
WELL NUMBER
LOCATION INFORMATION
TOTAL DEPTH
SURFACE ELEVATION

FORMATION ATTRIBUTES
FORMATION NAME
FORMATION AGE

ATTRIBUTES OF THE WELL–FORMATION RELATIONSHIP

STATIC
DEPTH (TOP)
SUBSEA ELEVATION
THICKNESS

DEPTH VARIANT
POROSITY
PERMEABILITY
ROCK TYPE

TIME VARIANT
PRODUCTION VOLUME
PRODUCTION RATE
PRESSURES
All other properties of a formation vary over three-dimensional space and time, and are treated as attributes of the well-formation relationships (figure 2). These properties can be divided into four types:

1. **Static** - vary only in the XY direction. Examples are depth to the top of the formation and the formation thickness.

2. **Depth Variant** - vary in the XY and Z direction. Examples are porosity, permeability, and formation rock type.

3. **Time Variant** - vary in the XY direction and in time. Examples are oil and gas production, and subsurface pressures.

4. **Depth and Time Variant** - vary in the XYZ direction and in time. An example is the water saturation of the formation at some depth, which increases over time as hydrocarbons are produced.

Each of the relationship types must be implemented as a separate table with different primary key fields (figure 3). Static data items are uniquely identified by the formation code and XY location (the well id number). For those properties that vary vertically within the formation, such as porosity, depth becomes a primary key. Time-variant formation attributes are related to oil, gas and water production, and require the date of measurement as another primary key.
IMPLEMENTING THE RELATIONS

WELLS

<table>
<thead>
<tr>
<th>WELL_ID*</th>
<th>OPERATOR</th>
<th>LEASE</th>
</tr>
</thead>
</table>

FORMATIONS

<table>
<thead>
<tr>
<th>FORMATION_ID*</th>
<th>FORMATION_NAME</th>
</tr>
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</table>

WELL-FORMATION (STATIC)

<table>
<thead>
<tr>
<th>WELL_ID*</th>
<th>FORMATION_ID*</th>
<th>DEPTH_TOP</th>
<th>THICKNESS</th>
</tr>
</thead>
</table>

WELL-FORMATION (DEPTH VARIANT)

<table>
<thead>
<tr>
<th>WELL_ID*</th>
<th>FORMATION_ID*</th>
<th>DEPTH*</th>
<th>POROSITY</th>
</tr>
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</table>

WELL-FORMATION (TIME VARIANT)

<table>
<thead>
<tr>
<th>WELL_ID*</th>
<th>FORMATION_ID*</th>
<th>DATE*</th>
<th>GAS_PRODUCTION</th>
</tr>
</thead>
</table>

*DENOTES PRIMARY KEY: FIELDS REQUIRED TO UNÍQUELY IDENTIFY A RECORD IN THE TABLE.
The other significant entity in the GDMS model is the fault, which has the same many-to-many relationship with wells as does the formation. Faults also have a many-to-many relationship with formations; this relationship was established in the fault table by including the formation code as an attribute.

Minor entities are represented by the reference tables, which link a code value with an extended name or description. For example, geological codes are used throughout the system as attributes of various entities; these codes are then tied to a more extensive geological description in the reference table.

The entity-relationship model (figure 4) summarizes all the tables in the system and their association with one another. Entities are shown in boxes, and the relationships (which also have attributes) between these entities are shown as diamonds within boxes.

Overall, the number of entity tables was kept to a minimum to keep the scope of the project manageable. The design is such that it is upwardly compatible with more extensive descriptions of geological entities. For example, the core table as now defined consists of attributes which describe the formation. Cores, however, have their own attributes, such as core type and analysis type, which would require a separate table to maintain normality.

Several of the data tables contain the same key fields, and conceivably could be combined into one table and still maintain normality. For example, formation thickness data and formation depth data (figure 4) both contain static attributes of the formation, and have the same key fields. Such tables were broken out into logical groupings of related attributes to optimize space usage within the
files. There will be many more records with depth data than with thickness data. Combining these attributes into one table would leave an excessive number of null fields.

A zone-code field is provided as an optional key in several data tables. This field allows the geologist to subdivide a formation into several overlapping intervals. A descriptive zone name can be associated with this code in the zone reference table.