AN AUTOMATED APPROACH TO THE SEQUENCE STRATIGRAPHY OF THE NIGER DELTA BASIN, SOUTHERN NIGERIA.

BY

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CERTIFICATION

This project entitled "*AN AUTOMATED APPROACH TO THE SEQUENCE STRATIGRAPHY OF THE NIGER DELTA BASIN, SOUTHERN NIGERIA*" by S. O. Obaje meets the regulations governing the award of Post Graduate Diploma in Computer Science of the Federal University of Technology, Minna, Nigeria, and it is approved for its contribution to scientific knowledge and application of computer science to practical and technical problems.

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DEDICATION

This project is dedicated to my beloved wife and friend, Mrs. (Q/S) J. Obaje.

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ABSTRACT

The major goal of the project was to design an information system that will meet the operating requirements of petroleum exploration managers. The new system is dependable, reliable, efficient, accurate, secured and easily accessible. Following the cost-benefit analysis of the old and the new systems, the new system is an economical, feasible and justifiable alternative.

The system integrates field data from seismics, sedimentology, biostratigraphy and well logging. The system aids the description of the subsurface geological signatures of given wells for basin analysis, besides serving as a data support system to enhance the decision-making process of petroleum explorationists.

Using top down method, the Niger delta sequence stratigraphy was split to achieve modular decomposition. Methods such as clerical procedures flowcharts, data flow diagram and decision tables were used to described the various routines and processes in the system.

Chapter One

INTRODUCTION

1.1 Computer Application to Petroleum Exploration

The chief objective in acquiring knowledge of petroleum exploration is to obtain a guide that will aid in the discovery of new oil and gas deposits. The discovery is ultimately made by the drill, but the location of the drill hole is determined by co-ordinating many diverse elements, namely: geologic, economic and personal. To make such a decision, data must first be gathered from all available sources - for example, other wells, geophysical surveys, pressure and temperature surveys. These data must then be put together in a form that will reveal the underground stratigraphy, structures, and conditions which could be depicted as maps, tables, diagrams, etc. The early identification of both regional surface and subsurface geologic features a of an area in which a discovery is made can be of great economic value, not only because it will indicate the best method of exploitation of that area, but because it can also lead to the identification of new regions throughout which oil and gas occur in commercial quantities.

The areas of data generation are usually located far away from the headquarter of the oil company.

For example, Shell Petroleum Development Company Limited has its headquarter at Lagos while its petroleum exploration areas are scattered around Rivers and Delta States in the inland swamps or offshore. Most management decisions and data processing of petroleum exploration are made at the headquarters. The subsurface models, stratigraphy, structures and other vital information must be conveyed to the petroleum exploration sites.

Computers are useful for data / information transfer / communications. Via wide area network (WAN), the petroleum exploration site could be interconnected with the heaquarter.

This help to reduce bureaucratic bottle-necks, prompt relay of management decisions on the project to the areas of exploration.

Computer software such as autoCAD (computer aided design), seismic sections and subsurface maps could be designed and simulated. Computer enhance the processing and interpretation of petroleum exploration data. Therefore, human errors are eliminated, while more timely and accurate information is made available to exploration managers.

Computers help to integrate the various field data from geophysical surveys, sedimentology, biostratigraphy, well logging / evaluation, reservoir engineering and economics. This in turn, reduces the high risk factors usually associated with petroleum exploration projects.

1.2 Objectives of Present study

The research for oil in Nigeria was first initiated by Shell-BP Petroleum Development Company in 1937. Commercial oil production commenced in 1958 in Oloibiri and by September 1970 about 1800 accumulations of oil and gas had been discovered in the structural features (Weber, 1971). The stratigraphy, major sedimentary cycles, tectonic movements of the basement and various geological aspects of the Niger delta has been extensively researched.

The objectives of this project include the following:

* to process and integrate the data from seismics, well logging, palynology and faunal biostratigraphy;
* to describe the geological signature for basin analysis;
* to develop a data support system (DSS) to aid the decision - making process of petroleum explorationists / managers;
* to design a computerised system which will accept actual field data obtained from existing oil wells or newly drilled oil wells in the Niger delta;

* to aid the profit optimisation of exploration projects;
* to attempt stratigraphical correlation of petroleum wells;
* to delineate Niger delta Formation generated from input data.

1.3 Literature Review

Short and Stäuble (1967) identified three depositional cycles in the coaster sedimentary basin of Nigeria. They noted that the first cycle began with a marine incursion in the middle Cretaceous and that it was terminated by a mild folding phase in Santonian time. The second cycle included the growth of a proto-Niger delta during the Late Cretaceous and ended in a major Paleocene marine transgression. The third cycle, from Eocene to Recent, marked the continuous growth of the main Niger delta. A new threefold lithostratigraphic subdivision was introduced for the Niger delta subsurface, made up of an upper sandy Benin Formation, an intervening unit of alternating sandstone and shale named the Agbada Formation, and a lower shaly Akata Formation (Avbovbo, 1978).

According to Short and Stäuble (1967), these three units extend across the whole delta and each range in age from early Tertiary to Recent. Also, the units are related to the present outcrops and environments of deposition. A separate member of the Benin Formation was recognised in the Port Harcourt area, which was named Afam Clay Member and it was interpreted to be an ancient valley fill formed in Miocene sediments. The subsurface structures were described as resulting from movement under the influence of gravity and their distribution was related to growth stages of the delta. Rollover anticlines in front of growth faults formed the main objectives of oil exploration, the hydrocarbons were found in the sandstone reservoirs of the Agbada Formation.

Weber and Daukoru (1971) viewed the Niger delta as a large, arcuate delta of the destructive, wave dominated type in which a sequence of under-compacted marine clays were overlaid by paralic deposits, in turn covered by continental sands which were built up by imbricated superposition of numerous offlap cycles. Weber and Daukoru (1971) stressed on the impact of basement faulting in the delta development and sediment thickness distribution. They concluded that growth faults played very important role in the hydrocarbon distribution because they functioned as hydrocarbon migration paths from the over-pressured marine clays. In addition to the growth faults, their conclusion was also based on the depositional environments of the reservoir sands, which they emphasised influenced oil well productivity and recovery efficiency.

Weber (1971) dealt with growth faulting and the application of sedimentology to oil-field development of the Tertiary to Recent Niger delta sediments.

Orife and Avbovbo (1982) identified three major types of stratigraphic traps in the Niger delta such as:

a) crestal accumulation below mature erosion surfaces;

b) canyon-fill accumulations above unconformity surface; and

c) facies change traps.

According to these authors, several important oil discoveries in offshore south-eastern Nigeria were associated with crestal accumulation below erosional surfaces. They also noted that canyon-fill accumulations were found in offshore south-eastern Nigeria within the Qua Iboe Shale. Also, recent discoveries have been shown to accumulate within the Opuama channel fill in the western and central areas of the Niger delta.

Petters (1984) shew that an anomalous sequence of thick fossiliferous marine shale of late Oligocene to early Miocene age termed the Opuama Shale member occur in the subsurface of the western Niger delta. Petters (1984) based his conclusion on the age and environment of the Opuama canyon on findings from planktonic and benthic foraminifera (i.e., faunal biostratigraphy).

According to Burke (1972), re-entrants of the Niger delta are potential sits for ancient submarine canyons. Burke (1972) based his conclusion on the observation that the eastern and western re-entrants of the modern delta are areas where opposing longshore drifts converged and generate turbid currents which cut submarine canyons.

There is continuing controversy with respect to the exact nature of and stratigraphic position of the Niger delta source rocks and their maturity (Daukoru, 1983; Ejedawe, et. al., 1984; Lambert-Aikhionbare and Ibe, 1984; Ekweozor et. al.,1984; Nwanchukwu and Chukwuza, 1986).

Growth faults are considered to be major conduits in the Niger delta. Weber (1987) studied the relationship of fault-sealing capacity with the sand and shale thickness distribution and the systematic patterns of hydrocarbon distribution revealed in many oil fields. He observed that the occurrence of several thick under-compacted clay layers that locally form effective seals to vertical migration is also important. He concluded that though the lateral distribution of hydrocarbon over a series of fault blocks can be predicted fairly accurately, the structures with pre-dominance of thick sands and thin shales can trap large volumes of hydrocarbons, but only if they are unfaulted.

Chapter Two

SEQUENCE STRATIGRAPHY

2.1 Palaeontology

Palaeontology is the study of ancient life using its fossils or traces of its activity as recorded by ancient sediments. The study of fossil plants is known as palaeobotany. Palaeobioloogy is the study of the biological aspects of fossils, and it is usually correctly combined with the study of fossil communities which is referred to as palaeoecology. The study of small microscopic fossils is called micropalaeontology. This science has a special botanical branch called palynology, which is concerned with fossil spores and pollens.

2.2 Biostratigraphy

Stratigraphy is the study of the geometry, composition, and time relations of stratified rocks. Its special concern is with the history of these rocks, including their fossil components. Biostratigraphy is simply that branch of stratigraphy that is primarily concerned with fossils and fossil-bearing rocks. Perhaps the only basic stratigraphic principle is the "law" of superposition, which states that in any undisturbed sedimentary sequence the oldest bed is at the base and the youngest bed is at the top. Many principles of palaeoecology, evolution, sedimentology, and geometry are common to stratigraphic problems. For example, the so-called "law of biotic succession" often cited in elementary or historical discussions of biostratigraphy, states that biota have followed one another in an orderly succession through geologic time. This succession is simply the product of organic evolution and might properly be considered to be a part of evolutionary palaeontology borrowed by stratigraphy.

2.2.1 Rock-Stratigraphic Units

Stratigraphy deals with units, primarily units of rock and of time that are used to divide stratigraphic sequences and geologic history. The stratigraphic record is divided into three-dimensional rock bodies on the basis of lithology, the physical character of rock. Rock units, often called rock-stratigraphic units, are recognised without regard to time relations or fossil content, except insofar as fossils contribute to their physical and chemical composition. Units are recognised on the basis of lithologic uniformity, which is inevitably judged with a great deal of subjectivity. The basic rock-stratigraphic unit is the formation. Formations may be lumped into higher units called groups , or divided into smaller units called members. A single bed, or lamina, of sediment represents a single depositional event. Surfaces between beds or laminae then indicates gaps in the rock record, just as unconformities do on a large scale. Early in the twentieth century, the discontinuity of deposition has been recognised and the gaps due to short time periods of non-deposition or erosion were named the diastem.

2.2.2 Biostratigraphic Units - The Biozone

Superimposed on the rock-unit subdivision of the stratigraphic record is a system of subdivision based on fossil occurrences. The units of this subdivision, called biostratigraphic units, are also tangible rock bodies, but their boundaries are defined by various palaeontologic criteria, such as the appearance, maximum abundance and disappearance of fossil species or genera in various local rock sequences.

The fundamental biostratigraphic unit is the zone. Many sorts of zones have been recognised. We can envisage an abstract kind of zone known as biozone, which represents all rocks throughout the world that were deposited during the time interval in which a species lived. A biozone is an abstraction because we can never delineate it physically. No species is present in all rocks of its biozone.

It is instructive to examine the reasons that species have not filled their biozones. We can assume that many species have originated through evolutionary divergence of geographically isolated population of pre-existing species. The extent to which a new species arising in this manner has come to fill its biozone depended partly on how rapidly it spread throughout areas of the earth's surface that it could potentially inhabit. In a sense, we are comparing rates of evolution and rates of geographic dispersal.

If there were no effective barriers, most species would have spread over large geographic areas quite rapidly relative to rates of species evolution. There are additional reasons that no fossil evidence of a species is found in many parts of its biozone. Even within their geographic ranges, species can generally inhabit only certain types of local environments. Consequently, many fossil species are noted for their restriction to certain rock types. Such fossils may be known as "facies fossils". In most instances, their local distribution patterns reflect primary ecologic distribution. Furthermore, no species is preserved in all rock units deposited in environments in which it lived. Finally, a species may actually occur in a rock unit but may be misidentified because of inadequate preservation or confusion with another species.

Prevailing winds and ocean currents disrupt latitudinal temperature gradients in many parts of the world. Sharp temperature changes and abrupt physiographic barriers tend to confine groups of species to certain regions, which are called biogeographic provinces.

2.2.3 Correlation With Fossils

Given the partial representation of fossil species in their biozones, to what extent can the stratigraphic distributions of fossils be used profitably to determine relative geologic time ? From our previous discussions, it should be evident that biostratigraphic units can only be used in an approximate way to determine time relationships. Establishing the time equivalence of two spatially separate stratigraphic units is known as correlation. Unfortunately, the term "correlation" is also used by some workers to imply equivalence of rock type or fossil content without regard to time. It is less confusing to use terms like "lithologic equivalence" and "biostratigraphic equivalence" for the latter sorts of relationships.

Time correlation, though usually only approximate, can be undertaken by various methods, only some of which make use of fossils. Nevertheless, fossil represent by far the most important tools for time correlation. Establishment of biostratigraphic equivalence is the first step. This equivalence may then be interpreted as demonstrating approximate time equivalent, or correlation.

Taxa found to be especially useful in correlation are commonly referred to as index fossils, or guide fossils. The attributes of an ideal index fossil are; wide geographic distribution, ecologic tolerance, abundance, rapid evolutionary rate, and distinct morphologic features. Index fossils are especially useful for inter-regional and inter-continental correlation. Sudden morphologic changes within species and genera can be used profitably for correlation, especially of rocks and sediments of Cenozoic age. Among the most spectacular examples are those involving shell-coiling direction (dextral versus sinistral) in planktonic foraminiferans. Coiling reversal in globorotalia menandii has been widely used for recognition of the Pliocene - Pleistocene boundary in deep-sea- sediment cores (Raup and Stanley, 1978).

2.2.4 Time and Time - rock Units

Very early in the history of modern geology it became convenient to divide regional stratigraphic sequences into large units that could be distinguished from one another on the basis of fossil content. Thus, the stratigraphic systems, from Cambrian through Quaternary, came to be recognised over the course of several decades during the nineteenth century. Delineation of these did not proceed according to any well-planned scheme, nor were they established in order of their temporal relationships. There was a natural tendency for early workers to establish system boundaries at major fauna and floral breaks. Many of these boundaries seem especially well placed, even today, for some breaks that were chosen represent distinct evolutionary changes or extinctions that occurred during short time intervals on a world-wide scale. Geologic systems are still defined on the basis of type sections, which local stratigraphic sections in the type areas in which the systems were first recognised.

2.3 Sedimentary Environment and facies

Sedimentary environment is a part of the earth's surface which is physically, chemically, and biologically distinct from adjacent terrains. Examples include deserts, river valleys, and deltas.

The three defining parameters listed above include fauna and flora of the environment, its geology, geomorphology, climate, weather, and, if subaqueous, the depth, temperature, salinity, and current system of the water. These variables are tightly knit in dynamic equilibrium with one another like the threads of a spider's web. A change in one variable causes changes in all the others. A sedimentary environment may be a site of erosion, non-deposition, or deposition.

A sedimentary facies is a mass of sedimentary rocks which can be defined and distinguished from others by its geometry, lithology, sedimentary structures, palaeocurrent patterns, and fossils. In recognising facies, emphasis may be placed on lithologic features, or biofacies, based on fossil features. Facies may be found within rock units that are formally classed as groups, formations, or members (Raup and Stanley, 1978; Selley, 1985). A sedimentary facies is the product of a depositional environment, a special kind of sedimentary environment.

2.3.1 Relationship between Facies, Sequences and Stratigraphy

Sedimentary environments occur side by side across the earth in a predictable manner. Thus for example, an alluvial flood plain may merge into a tidal flat, which may pass laterally via a lagoon into a barrier island and so to the open sea. As the sea level rises and falls the shoreline may transgress and regress the continental environment. The result of this process may be the deposition of a series of conformable facies with gradational vertical transitions. The relationship between facies and environments is known as Walter's Law. This may be stated concisely as: 'A conformable vertical sequence of facies was generated by a lateral sequence of environments' (Selley, 1985).

2.3.2 Methods of environmental Diagnosis

There are many techniques which could be used to determine the depositional environment of a sedimentary rock. These vary considerably according to whether the study is based on surface or subsurface information. The techniques of environmental analysis can most conveniently be discussed under the five defining parameters of a facies: geometry, lithology, sedimentary structures, palaeocurrent patterns, and fossils.

2.3.2.1 Geometry

The over-all shape of a sedimentary facies is a function of pre-depositional topography, the geomorphology of the depositional environment and its post-depositional history.

The geometry of sedimentary facies may be relatively easy to determine where it crops out at the surface and where exposure is good. In the subsurface however this is impossible. Traditionally, the approach was to map the geometry of facies from borehole data; environmental interpretation being carried out on each well so as to locate the next one in optimum position. Nowadays, however, seismic surveys make it possible to map the geometry of facies long before any well has been drilled. Examination of seismic line often shows that it may be divided into a number of units. The geometry of these units may be mappable using the data from a complete seismic survey. Channels, fans, progrades and many other forms may be detected. The shapes of these seismic units are often environmentally diagnostic. The character of seismic unit boundaries may be important in establishing the geological history of the area.

2.3.2.2 Lithology

The lithology of a sedimentary facies is one of the easiest of parameters to observe and one of considerable environmental significance. This is truer of carbonates than sandstones since they are deposited at, or close by to, their point of origin. The lithology of sandstones gives less indication of their depositional environment since the sediment is introduced from outside the site of deposition and inherits extraneous characteristics due to previous history. Grain size, sorting, shape, and texture often reflect the energy level and process of the environment.

2.3.2.3 Sedimentary Structure

Sedimentary structures are very important indicators of depositional environment. Unlike lithology and fossil they are undoubtedly generated in place and can never have been brought from outside. Sedimentary structures are easy to study at outcrop where exposure is good. In subsurface work, however, only the smallest ones can occasionally be found in rock cores.

Sedimentary structures can provide evidence of whether an environment was glacial, aqueous, or sub-aerial. They give some indication of the depth and energy level of the environment and the velocity, hydraulics, and direction of the currents which flowed across it. Most sedimentary structures can be arbitrarily fitted into a genetic classification of pre-, syn-, and post-depositional categories.

2.3.2.4 Palaeocurrent Patterns

To determine the palaeocurrents of a facies involves not just the description, but also the interpretation of data. Palaeocurrents clearly reflect the depositional environment of a facies and cannot inherit features from outside the actual site of deposition. The palaeocurrent analysis of a facies involves the following steps:

a) Measurement of the orientation of significant sedimentary structures in the field (e.g., cross-bedding dip direction, channel axes, etc.).

b) Deduction of palaeocurrent direction at each sample point.

c) Preparation of regional palaeocurrent map.

d) Integration of palaeocurrent map with other lines of facies analysis to determine environment and palaeogeography. In some environment, palaeocurrents may indicate palaeoslope.

It would seem therefore that, though it must be interpreted with great care, palaeocurrent analysis is an important technique for recognising ancient sedimentary environments and their palaeogeographies.

2.3.2.5 Fossils

Fossils have always been one of the most important methods of identifying the depositional environment of a sediment.

The way in which fossils lived, behaved toward one another, and influenced and were influenced by their environment is termed palaeoecology.

To use fossils to identify the depositional environment two assumptions must be made:

* That the fossil lived in the place where it was buried.
* That the inhabitant of the fossil can be deduced either from its morphology or from studying its living descendants (if there are any).

Of all the different fossils that can be used in environmental analysis perhaps two of the most important types are micro-fossils and trace fossils. Micro-fossils have the great advantage over mega-fossils that they are recoverable from well cuttings, and that a small volume of rock may contain sufficient specimens to be used in statistical studies. There are many different groups of micro-fossils that may be used in environmental interpretation regarding depth, temperature, salinity, current turbulence and palaeo-climate. The most useful types include foraminifera, ostracods, microplanktons and palynomorphs.

2.3.2.6 Subsurface Environmental Interpretation Using Well Logging Data / Seismic Maps

The key to the subsurface diagnosis of terrigenous rocks lies in the study of vertical sequences: sequences of sedimentary structures in cores, and sequences of grain size which may be inferred from geophysical logs. After a borehole has been drilled the geophysical properties of the adjacent strata are measured by passing a series of electronic devices along the borehole. These can record many of the physical and chemical properties of a sediment, including resistivity, density, sonic velocity, and radioactivity. These logs can be used to correlate adjacent wells, to identify lithology, to measure the amount of porosity, and to calculate the amount of oil, gas, or water within the pores.

2.4 Origin of Petroleum and Choice of Petroleum Exploration Methods

2.4.1 Origin of Petroleum

Theories of the origin of petroleum may be divided into two groups as organic or inorganic. Early ideas leaned toward sources, whereas the modern theories, with few exception, assume that the primary source material was organic. The change was brought about by an increasing number of objections to the inorganic ideas; but, since these objections have not completely eliminated the possibility that inorganic substances - especially hydrogen - played some part in the origin of petroleum, inorganic theories still find occasional favour (Hedberg, 1964).

Some geologists hold that all petroleum was formed in place, either at or adjacent to the position of the present pools; others hold that petroleum has migrated from areas of origin to trap areas, and that the source area does not necessarily coincide with the accumulation area. Some theories assume that oil was transported along with circulating water, whereas others assume that it migrated independently of water movement. Some geologists believe that the source material was deposited in the shale formations or transformed into petroleum within them, and migrated from there into the reservoir rocks, while others believe that the source material, possibly in the form of colloidal or water-soluble organic matter, was concentrated in the reservoir rocks, or even in the places where the traps are now found, and was there changed to petroleum (Levorsen, 1985).

2.4.2 Inorganic Origin of Petroleum

The chief interest of the "inorganic theories" on the origin of petroleum is historical, for most of them have long since been abandoned. It was natural that they should develop, however, in view of what was known about the universe during the eighteenth century. The chief support for theories of inorganic origin lies in the fact that in the laboratory the hydrocarbons methane, ethane, acetylene, and benzene have repeatedly been made from inorganic sources. There has not been, however, any field evidence that the process have occurred in nature, while there is an expanding mass of evidence of organic origin.

Theories that uphold the inorganic origin of petroleum have few supporters today for several good reasons. In the first place, optical rotary power is a characteristic of petroleum, and especially of the intermediate boiling fractions

(100° - 140°C). As far as it is known, this phenomenon is almost entirely confined to organic matter and it is observed only where biological agencies have prevailed. Another serious objection to any inorganic origin is that several homologous series of hydrocarbon compounds, containing great numbers of individual members, are found in all petroleum.

All known compounds of this kind are of organic origin and could hardly be formed by inorganic agencies (Levorsen, 1985).

The lack of association of petroleum with vulcanise or its products, except in rare and anomalous occurrences, is another reason for doubting that there is any important relation between volcanic action and the origin of petroleum.

2.4.3 Organic Origin of Petroleum

Four compelling reasons favour the belief that the chief primary source material of petroleum - the "protopetroleum" - was organic:

1. The vast amount of organic matter and hydrocarbons now found in the sediments of the earth. Carbon and hydrogen predominate in the remains of organic material, both plant and animal. Furthermore, lesser but still important amount of carbon and hydrogen and hydrocarbons are continually produced by the life processes of plants and animals. An abundant and widely distributed source of the two essential elements of petroleum - carbon and hydrogen - is therefore provided by organic material.
2. The fact that crude oil had been found to contain porphyrin pigments and the fact that nearly all petroleum contain nitrogen, are more or less direct indication of the animal or vegetable origin, or both, of petroleum, because all organic matters contain both porphyrins and nitrogen.
3. Optical activity, the power to rotate the plane of polarisation of polarised light, is a property of most petroleum, and it is not known to occur in oil of inorganic origin or in inorganic substances or minerals with the

exception of cinnabar (HgS) and quartz (SiO_2). The power of optical rotation is not uniform throughout the distillation range , but it is usually at a maximum in the fractions having intermediate boiling points (100°-140° C). It is believed that the activity in most petroleum is due to the presence of cholestrol ($C_{26}H_{45}OH$), which is found in both vegetable and animal matter (Levorsen, 1985).

4. A wide variety of petroleum hydrocarbons, and even crude oil, have been found included in the organic material that is found in nearly all non-reservoir rocks, such as the shales and carbonates. The same types of hydrocarbons occur in both the fine-grained sediments and in crude oil. Nearly all shales and carbonates contain disseminated organic matter of three general kinds: soluble liquid hydrocarbons, soluble asphalts, and soluble kerogen. The hydrocarbons found in the non-reservoir sediments presumably have come directly, either wholly or partly, from the hydrocarbons that are found in living plant and animal matter. They may result, in part, from processes whereby organic matter, or petroleum-like hydrocarbon compounds in the organic matter, were converted through minor changes into petroleum hydrocarbons. This conversion must have occurred either before or during diagenesis of the sediments, for the petroleum content of shales and carbonate rocks is rather universally distributed (Levorsen, 1985). The intimate relation of the organic material and the petroleum in the sediments leaves no doubt that organic matter was the original source of petroleum.

2.4.4 The Choice of Petroleum Exploration Methods

Since 1958, the choice of petroleum exploration methods in Nigeria have been based on the theory of organic origin and continental / marine environment source rocks. Subsequently, the quest for microfossils which are indicative of marine environment or lithologic evidence suggestive of marine environment has continued to constitute one of the major exploration efforts.

In addition, applied geophysics, wildcat drilling and wells history from existing wells yield information on the subsurface geology detailing on issues such as reservoir geometry, traps, unconformities, etc.

The quantity of fossil fuel extracted from the Niger delta has corroborated with the organic origin of petroleum. All efforts to get petroleum from the Nigerian Basement Complex proved abortive and frustrating. Up till today there are no known petroleum occurrence in the hard rocks.

The choice and integration of petroleum exploration methods would yield a better picture of the subsurface geology. The subsurface geology of petroleum contributes immensely to the detection of traps that contain oil and gas pools, and once a pool is found, to bring to bear the geologic evidence and concepts that in turn aid most in petroleum development and production.

Chapter Three

SYSTEM ANALYSIS

3.1 Project Feasibility Study

The project feasibility study is, in effect, a miniature systems study. Facts about the present system are found and recorded, so that they can be analysed. An outline design of the new system can then be attempted. Estimates of the costs and benefits of the new system can be made. The three tests of project feasibility studied include: operational feasibility, technical feasibility and financial and economic feasibility.

3.1.1 Operational Feasibility

The proposed system is beneficial because it would eventually be turned into an information system that will meet the operating requirements of petroleum exploration managers. The proposed system would work when it has been fully developed and implemented.

There is sufficient support for the project from petroleum exploration management and also from the user departments. Many operating staff are looking forward to a more efficient computerised system instead of their present manual system. The current manual methods of processing are very tedious and errors-prone because large volume of data is constantly coming from the fields. Many of the oil staff are very co-operative especially in explaining their jobs operation and requirements, which are useful during the system investigation stage.

The new system will cause no harm. Rather, it will amongst other things produce:

* better results in any respect or area;

* improve the control result in any area;
* enhance better individual performance after implementation than before it;
* faster and efficient performance in any area.

3.1.2 Technical Feasibility

Most oil companies (indigenous and multinational) have sufficient technology to accommodate the proposed system. In addition, there is enough technical capability to hold the data required to be used in the proposed system. With proper implementation of the proposed system, the components would provide adequate and timely responses to inquiries or queries regardless of the number or locations of users.

The proposed system is being designed to be expandable and also to guarantee accuracy, reliability, ease of access and data security.

3.1.3 Financial and Economic Feasibility

The proposed system is operationally and technically feasible. Its financial and economic feasibility tests indicate that it would be good investment to any concerned oil company.

Tables 3.1 - 3.4 show the costs of the old and new (proposed) systems and their cost-benefit analysis. In conclusion, it is clear that the proposed project is very feasible and justifiable.

3.2 Facts Finding

3.2.1 The Objectives of Facts finding Stage

During the facts finding stage, attempt was made to discover information about the present system - the manual processing of the sequence stratigraphy of the Niger delta.

The major objectives are;

1. The objectives and scope of the system; To find out what the present system is attempting to accomplish.
2. The input to the system; To examine the form of the input when it enters the system, where it originates and what items are included in the input. In addition, we wish to determine volumes of input entering the system, the minimum, average and maximum volumes of input and the peak time of the input.
3. The file maintained by the present system are also of interest to the yield such details as the frequency of file updating and the nature of any coding systems which are used.
4. The nature and contents of the output from the system; the form of the output, how often it is produced and the purpose it is used for.
5. The processing carried out by the system; To check the input used to update the files and produce of the output, the equipment used if any, and how the accuracy checks are performed during processing; also to find out if there are any time constraints and what happens to exceptional items.
6. The organisational structure of the department(s) or section(s) presently carrying out the processing, and the personnel involved.

7. The problems and difficulties presently encountered as the system operates will need to be highlighted, with special reference to bottlenecks, duplication and weaknesses.

8. The costs of the present system will need to be estimated alongside with the type of information the management would like to receive from the system under ideal circumstances.

3.2.2 The Methods of Facts Finding

Facts about existing systems can be gathered by using one or more of the following techniques:

* reading records and documentation relating to the system;
* interviewing relevant members of staff;
* observation of the system in operation;
* sending questionnaire to persons involved with the present system.

In this project the above methods with the exception of the use of questionnaire is employed to glean details about the existing system.

3.2.2.1 Reading Around the System

The existing records and documents which relate to a system which is being investigated often prove to be a useful starting point in facts finding work. The following were consulted:

* organisation charts which depict the formal structure of the organisation's relevant parts;
* procedures manuals, job descriptions and job specifications which lay down how tasks should be carried out;

* the forms used within the system;

* the files which the system maintains;

* the output which the system produces;

* any other documentation which is generated by the system: reports, statistical summaries, memoranda, letters, handbooks and training aids, etc.

From such a study, the background knowledge of the system, the personnel involved with it, and the problems and difficulties encountered in its operation were obtained.

3.2.2.2Face-to-Face Interview

Because human systems are dynamic, written documentation becomes out-of-date over time, thus this second method was employed.

The interviews were designed to fit into the overall facts finding strategy bearing in mind the earlier listed objectives of the facts finding stage. The right people were interviewed in the right order to ensure that the correct questions were asked from each person. Prior to the interviews, the interviewees were aware of the purpose of the investigation. The presentations had the support of the management and staff.

3.2.2.3 Observation

Clearly, what actually happens may be quite different basically in practice. In view of this, and because, in certain situations, there is the possibility of a deliberate misrepresentation, observation is used as one of the facts finding methods. Via observation, the happenings in the selected department(s) and section(s) are seen and noted. The following are also considered:

* the frequency of interruption of staff in their work;

* the sort of pressures they are under;
* their relationships with colleagues;
* their attitudes to the work;
* the supervision and what the organisation is like, and
* how often and for how long they do tasks other than those they are supposed to.

The problems posed by observation as a fact finding technique are threefold:

First, observation takes a lot of time, thereby increasing the cost of the development of the proposed system.

Second, observation may antagonise staff who disliked being 'spied' upon.

Third, the behaviour of those being observed may, consciously or unconsciously, be modified.

In attempt to overcome these problems, several different approaches are applied such as activity sampling, integration into work activities, while remaining consciously alert to gleaning the needed data.

3.3 Fact Recording

3.3.1 The Need For Systematic Facts Recording

After a lengthy facts finding exercise, much information about the existing system will be accumulated. A good deal of that information, however, will be held in a rather haphazard form: notes taken during interviews, samples of forms used, and a varied collection of charts and manuals. After several weeks or months have elapsed, the significance of a scribbled note in the margin of a form, or on a chart, will be diminished or, worse still, lost.

The answer to the above mentioned problem is the systematic recording of all the facts found as the investigation is carried out. Facts finding and facts recording phases are thus carried out in parallel: as facts are uncovered, properly documented. Though many facts recording techniques are available, only those which are most appropriate were used. In all such cases, however, a formal system file, or project file, was maintained so that:

* individual facts could be retrieved when required,
* individual facts could be placed into the overall context of the total system,
* all recorded facts could be efficiently used in the subsequent stages of the system development.

3.3.2 Narrative

A narrative description is often a convenient method of recording facts. Narrative is used to describe the structure of the department(s) or section(s) carrying out a processing task to give a picture of the forms and records used and also to detail the processing steps carried out. The use of narrative, however, is time consuming and because of the inherent ambiguity of any natural language, formalised diagrams, tabulations and charts are used.

3.3.3 Recording Staff Details

An organisation chart is the commonest method of showing the staff involved in a particular data processing task, and their relationships.

An example of an organisation chart used is shown in Figure 3.1 This chart is supplemented by a staff deployment form, which gives a summary of the number of staff of different levels who are employed in the exploration department (see Table 3.5). Further detail is recorded on a job description form (see table 3.6). The time spent during the week by an employee on different tasks is recorded on a time utilisation form (Table 3.7).

3.3.4 The Form Description Document

After the recording of the facts about the operation of an existing data processing system, the forms which are used within the system were examined very closely and filed. To supplement sample forms, a form description document is used as field names and their sizes (see Tables 3.8 - 3.12).

3.3.5 The File Description Document

The file used within a system were also described. The document was used in conjunction with the record description document. Table 3.13 shows file description document.

3.3.6 The Record Description Document

For each record named on a file description document, a record description document is made. See Tables 3.8 - 3.12 for some examples.

3.3.7 The Clerical Procedures Flowchart

In recording the processing steps carried out within a system, many different methods such as the clerical procedures flowchart, the data flow diagram and the decision tables are used. Figures 3.2 - 3.6 are clerical procedures flowcharts which depicts the various routines and processes in the system.

3.3.8 Data Flow Diagram (DFD)

Data flow diagram (see Fig. 3.7) is used to indicate the flow of data through the system and the procedures which take place on it. The data flow diagram would be subsequently used in the analysis and design stages.

A source, e.g., Well, is the point at which data originated outside the processing area which was charted. A sink, e.g., Niger delta, is the destination for the information which leaves the system. A store is a point at which data is held. It thus receives a data flow and / or allows data to be accessed from it. Examples of the data stores are well_biofacies, biofacies_zonation, fauna_zonation, floral_zonation, well_logging, well_seismics and geodata.

A process carries out an activity which converts an incoming data flow into a (different) outgoing data flow. The following constitute the identified processes; check data , tabulate result, check type, search, and compare geodata.

The data flow is depicted by arrows which indicate how data flows around the system, perhaps from one process to another, or from a store to a process, or from a process to a sink. A boundary is drawn around the DFD to show the limits of the system which is charted.

3.3.9 Decision Tables

A decision table is similar to a flowchart in that it is an attempt to replace long-winded and, possibly, confusing narrative with a clear and structured definition of what happens under certain circumstances. A decision table usually contains the conditions and the necessary required actions for easy decision-making (see tables 3.14 - 3.17).

3.4 Analysis of Recorded Facts

At this stage, all the gathered facts were properly examined in order to make proper assessment of the existing system. Any untried idea was kept from the new system. The aim of this stage was to ensure that all feasible alternatives were considered. The existing system was criticised against the principle of procedure after which the strengths and weaknesses of the system became apparent:

3.4.1 Purpose

The job purposes were achieved by different sections of the organisation, but the processed data must be combined to yield better subsurface "picture". Thus there was need for an integrated system, which was a better feasible alternative.

3.4.2 Economical

The manual system is not economical. It is very expensive to produce the geodata, because lots of highly paid staff, procedural stages and physical transportation of information from one location to another are involved. The most economical alternative is an integrated electronic data processing and communications.

3.4.3 Work Flow

The work flow is fairly satisfactory. Nevertheless there is still room for improvement on the present work flow.

3.4.4 Specialisation / Simplification / Standardisation

The three S's underlined above are carefully practised and observed in the present system, thereby computer could be applied to do the jobs. In addition, most of the complex procedures could be simplified. Very strict industrial standards are observed.

3.4.5 Flexibility

The old system has some measure of flexibility. The increase or decrease in the volumes of processing of data has much effects on the system.

3.4.6 Exception Rule

The exception rule is observed to a certain extent. Factor requiring actions are usually highlighted and prevented from submerging in the mass of routine details.

3.4.7 Reliability

Though the procedure may be reliable, human factor could always introduce errors. Broken down machines are usually quickly replaced. Also, two or more staff handle a particular aspect of the system procedures. This policy is observed to take care of unforeseen emergency situations such as staff sickness, resignation from job or vacations.

3.4.8 Form

The information produced in the forms are suitable to the recipients. There is usually a high need for production of hard copies of such information.

3.4.9 Existing System

Because of the dynamic nature of the existing system, computerisation is highly needed and suitable.

3.4.10 Continuous Control

Errors usually associated with the old system include transcription, omissions, and transpose type. The errors control is tedious because the entire documents must be serially accessed for errors and their eventual correction or elimination. Other forms of control involve prevention of staff from taking out official documents pertaining to the new system and restriction of unauthorised persons to certain areas of the organisation.

3.4.11 Time

The existing system consumes lots of time to get jobs done.

TABLE 3.1 COSTS OF SYSTEM DEVELOPMENT & IMPLEMENTATION

S/N	ACTIVITY	MAN-HOURS	COST (₦000'000)
1.	Preliminary investigation	72	0.036
2.	Project Feasibility Studies	240	0.120
3.	Facts Finding	336	0.168
4.	Facts Recording	336	0.168
5.	System Analysis	720	0.360
6.	System Design	720	0.360
7.	Software Development	1440	0.720
8.	Staff Training	336	0.168
9.	Implementation	336	0.168
	Total	**4536**	**2.268**

TABLE 3.2 COST OF SYSTEM HARDWARE & SOFTWARE

S/N	ITEM DESCRIPTION	QTY	UNIT COST (₦000,000)	AMOUNT (₦000,000)
	Hardware			
1.	Compaq Computer with; - Pentium Micro-processor, - Windows 98 Opearating System, - EGA V.D.U., - Enhanced keyboard plus mouse, - Sound blaster	5	0.300	1.50
2.	Hewlett Packard Laserjet Printer	5	0.050	0.25
3.	HP Laserjet Toner Cartridge C3906A	12	0.012	0.144
4.	Epson LQ Printer	1	0.060	0.060
5.	Epson LQ Printer Ribbon	12	0.010	0.12
6.	SmartCell Battery	1	0.080	0.080
7.	APC Matrix UPS 3000	1	0.120	0.120
8.	Binatone Stabilizer 1000V	1	0.025	0.025
9.	VDU Screen Shade	5	0.005	0.025
10.	Computer Cover	5	0.0009	0.0045
11.	3½'' Floppy Maxell Diskette packet	12	0.0015	0.018
	Software			
12.	Visual or Borland C++ compiler for Windows	1	0.045	0.045
13.	Dr. Solomon Anti-Virus Utilities	1	0.035	0.035
14.	Other Productivity Software	1	0.050	0.050
			TOTAL	2.4765

TABLE 3.3 COST OF OLD SYSTEM

S/N	ACTIVITY	MAN-HOURS	COST (₦000,000)
1.	Seismic Exploration	6590	965.0
2.	Seismic Data Processing	5750	745.0
3.	Well Logging	4420	535.0
4.	Sedimentology	4650	585.0
5.	Biostratigraphy	5850	760.0
	Total	27,260	3590.0

TABLE 3.4 COST - BENEFIT ANALYSIS OF PROPOSED SYSTEM

S/N	ACTIVITY / REQUIREMENT	COST (N,000,000) OLD SYSTEM	NEW SYSTEM	BENEFITS OF NEW SYSTEM
1.	System Development	—	2.268	
	Equipment Cost			
2.	~ Computer Systems	—	1.50	
3.	~ Matrix UPS 3000 APC	—	0.12	
4.	~ Laserjet Printers	—	0.25	
5.	~ Epson LQ 2170 Printers	—	0.06	
6.	~ Diskette Storage Boxes	—	0.01	
7.	~ Computer Software	—	0.13	
8.	~ Air Conditioners	20.0	—	
9.	~ Storage Cabinets	0.10	—	
10.	~ Alarm Systems	0.20	—	
11.	~ Tables / Desks	2.50	1.20	
12.	~ Chairs	1.60	0.80	
13.	~ Soft Furniture	5.50	—	
14.	~ Calculators	0.10	—	
	Operating Cost			
15.	~ System running cost	10.0	2.50	
16.	~ CPU Time	—	0.15	
17.	~ 3.5'' Diskette Packs	—	0.03	
18.	~ Rims of Printer Papers	—	0.06	
19.	~ Disk Space	—	0.85	
20.	~ Salary & Wages	10.0	4.50	
21.	~ Hospital Bills	4.25	—	
22.	~ Maternity / Annual Leave	6.50	—	
23.	~ Writing Materials	3.50	—	
24.	~ Ribbons / Cartridge	—	0.45	
25.	~ Memory upgrade	—	0.25	
26.	~ Staff Training	—	—	
27.	~ Systems manual	13.50	—	
28.	~ Travelling / Tours	2.50	—	
29.	~ Postage / Telephones			
		89.75	15.128	

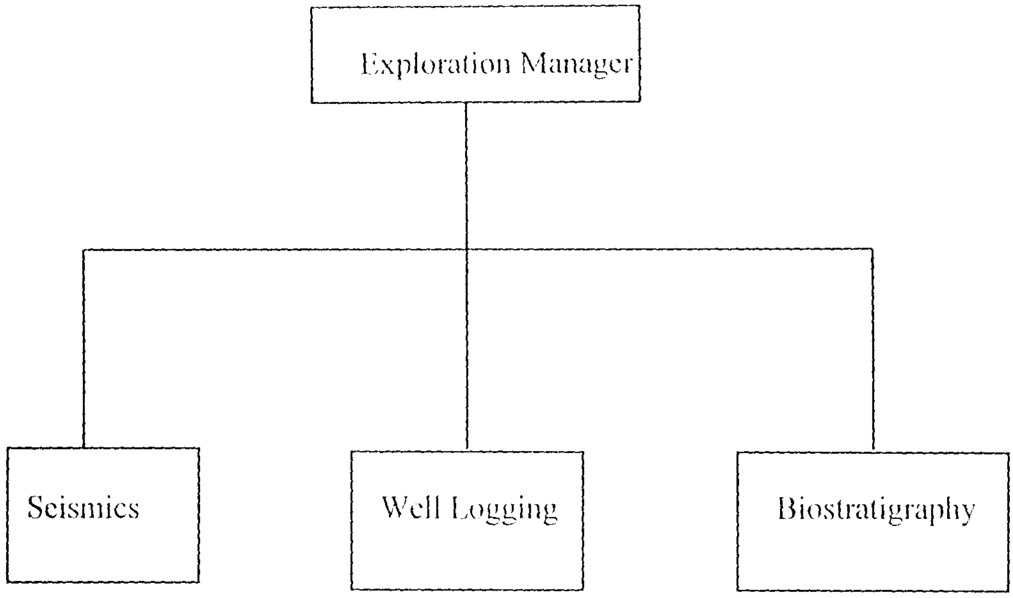


Figure 3.1 Part of an Organisation Chart

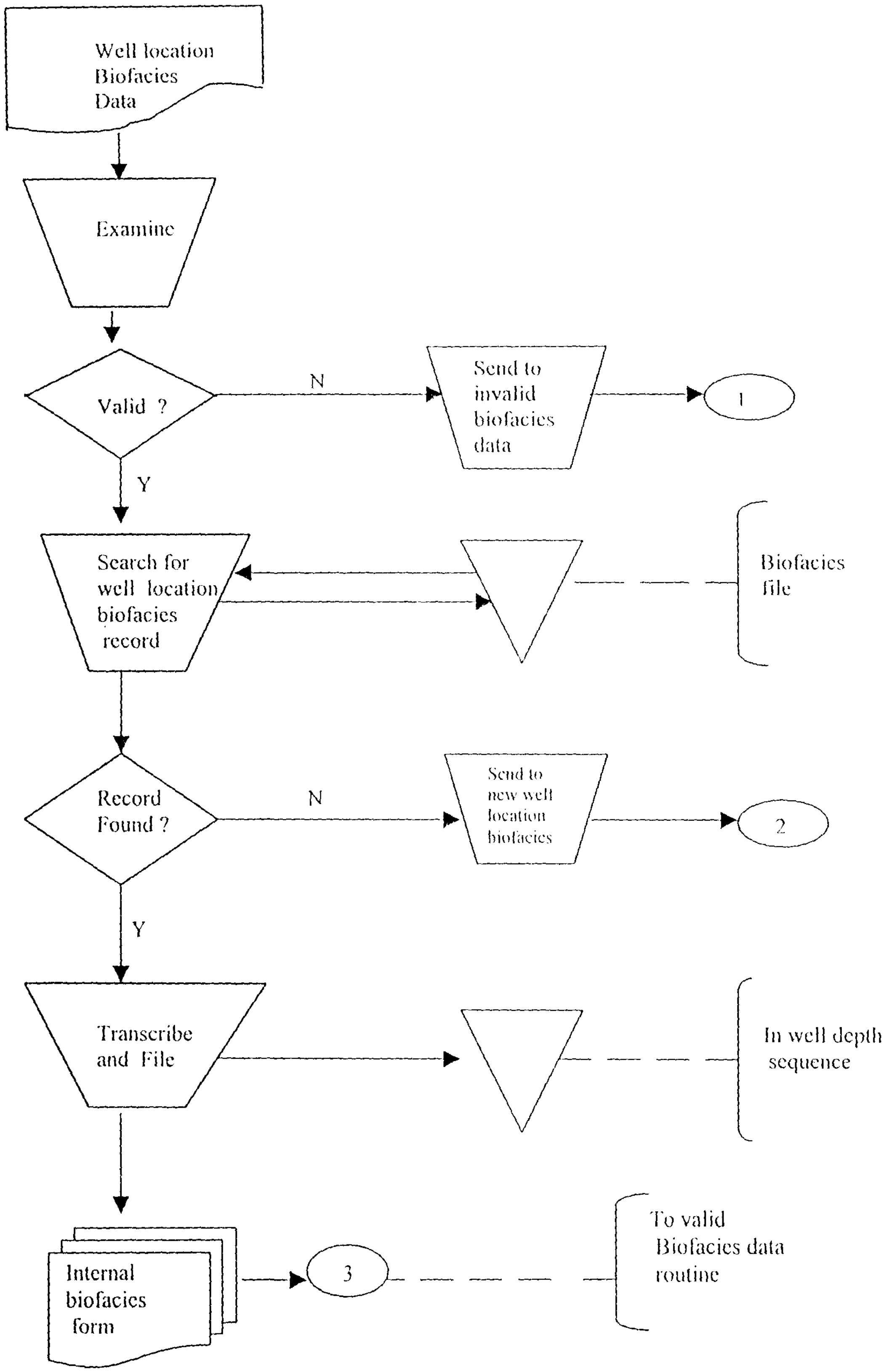


Fig. 3.2 Clerical Procedure Flowchart for Biofacies Data Routine

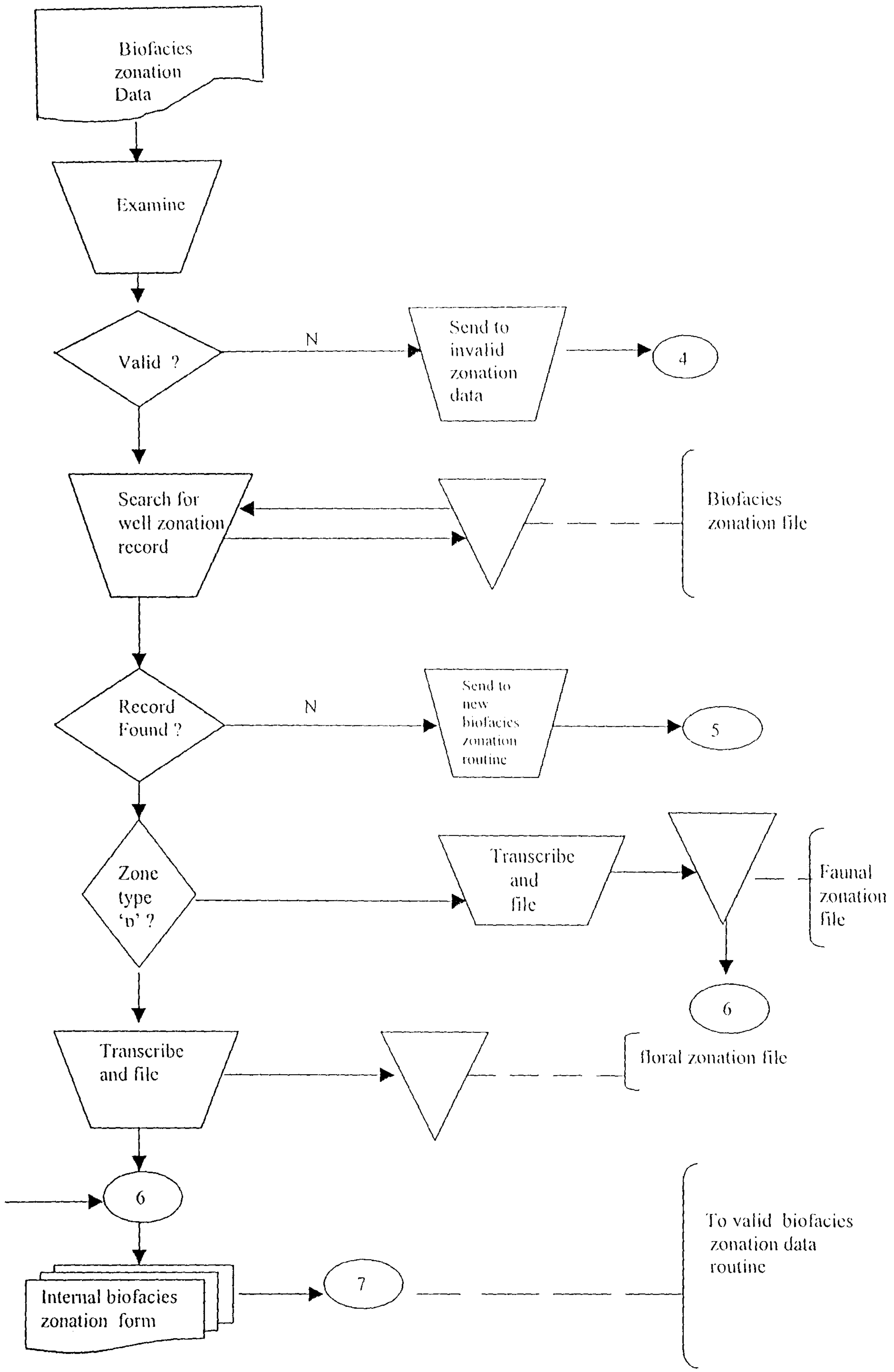


Fig. 3.3. Clerical procedure flowchart for biofacies zonation routine

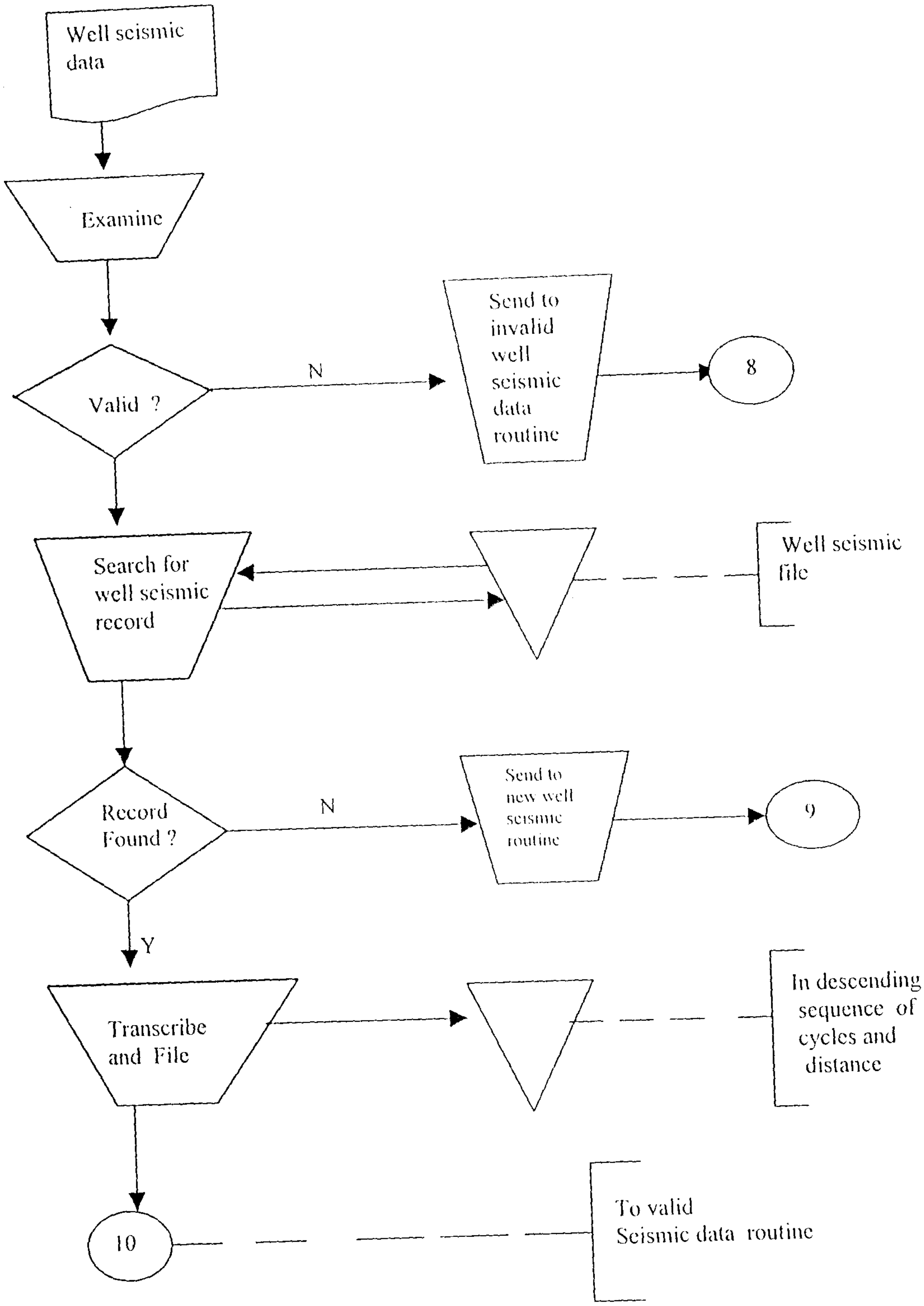


Fig. 3.4 Clerical procedure flowchart for seismic data routine

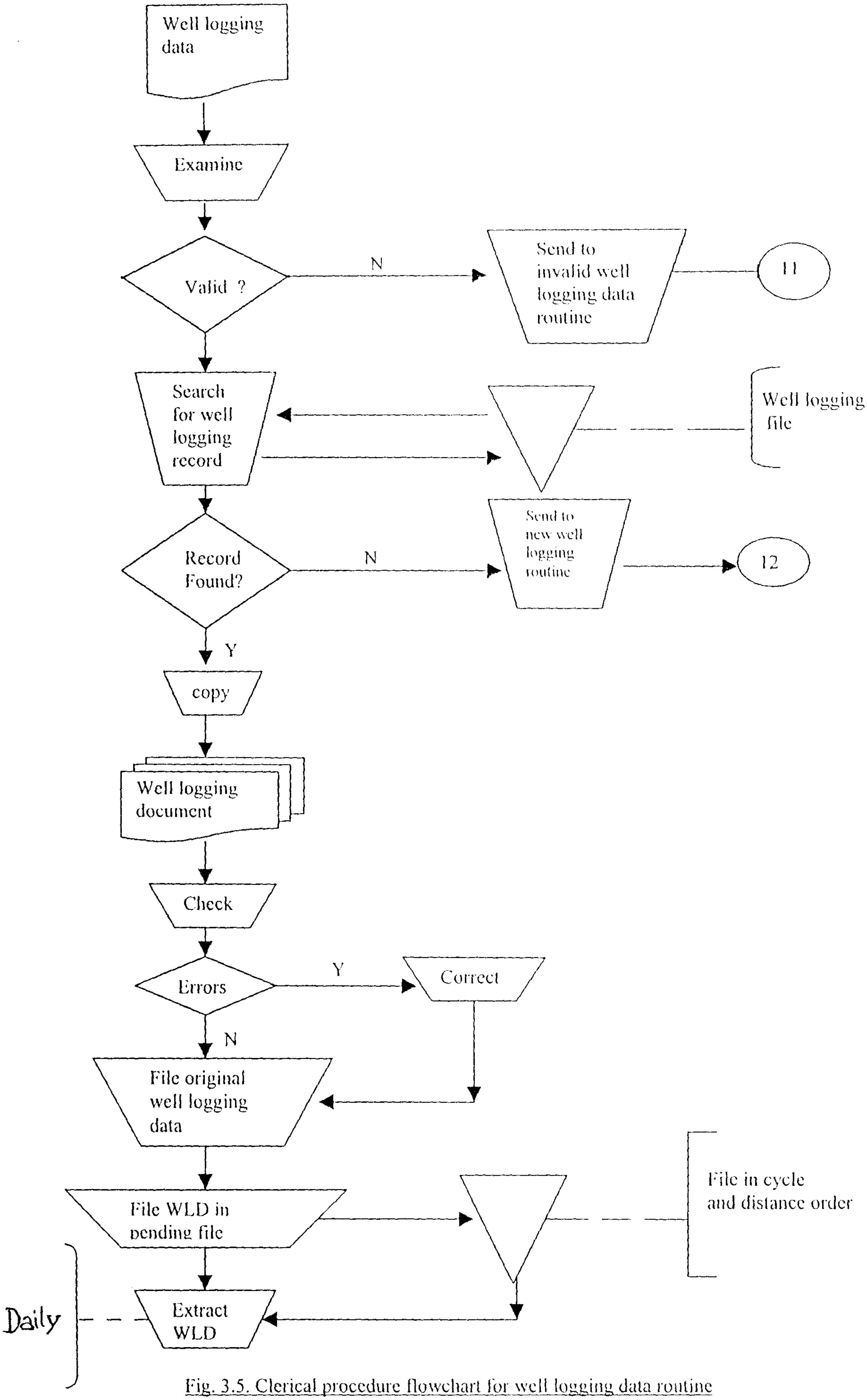
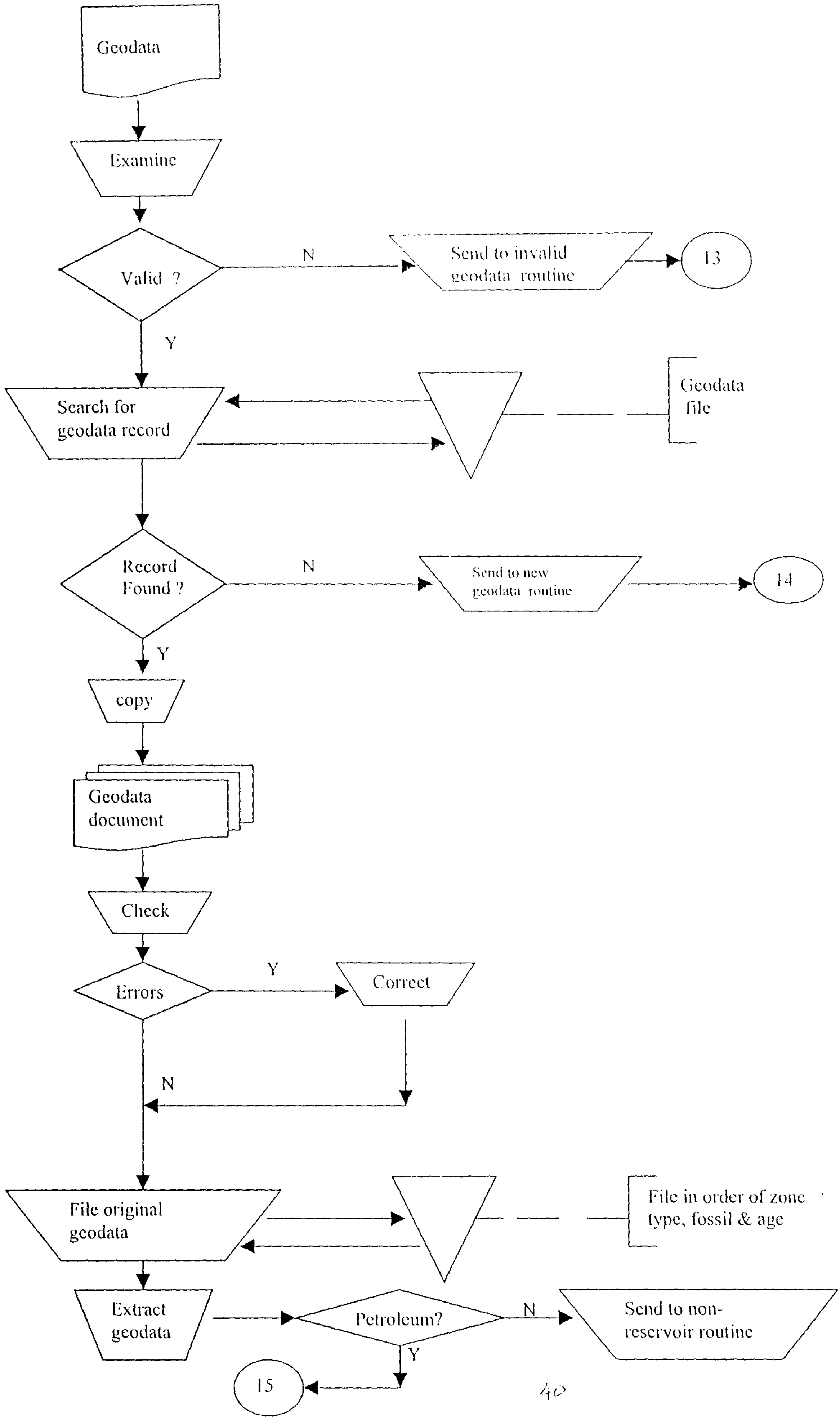


Fig. 3.5. Clerical procedure flowchart for well logging data routine



Geodata
Examine
Valid ?
N
Send to invalid geodata routine
13
Y
Search for geodata record
Geodata file
Record Found ?
N
Send to new geodata routine
14
Y
copy
Geodata document
Check
Errors
Y
Correct
N
File original geodata
File in order of zone type, fossil & age
Extract geodata
Petroleum?
N
Send to non-reservoir routine
Y
15

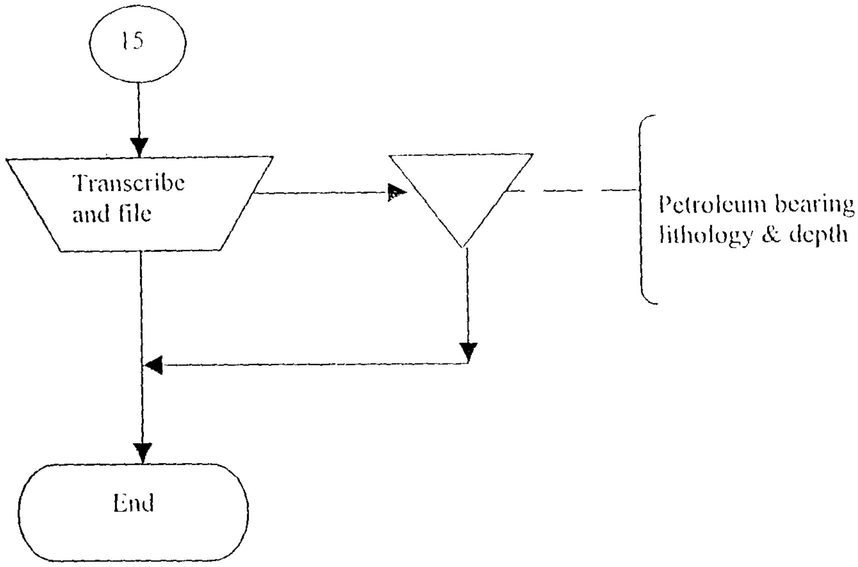


Fig. 3.6. Clerical procedure flowchart for geodata routine

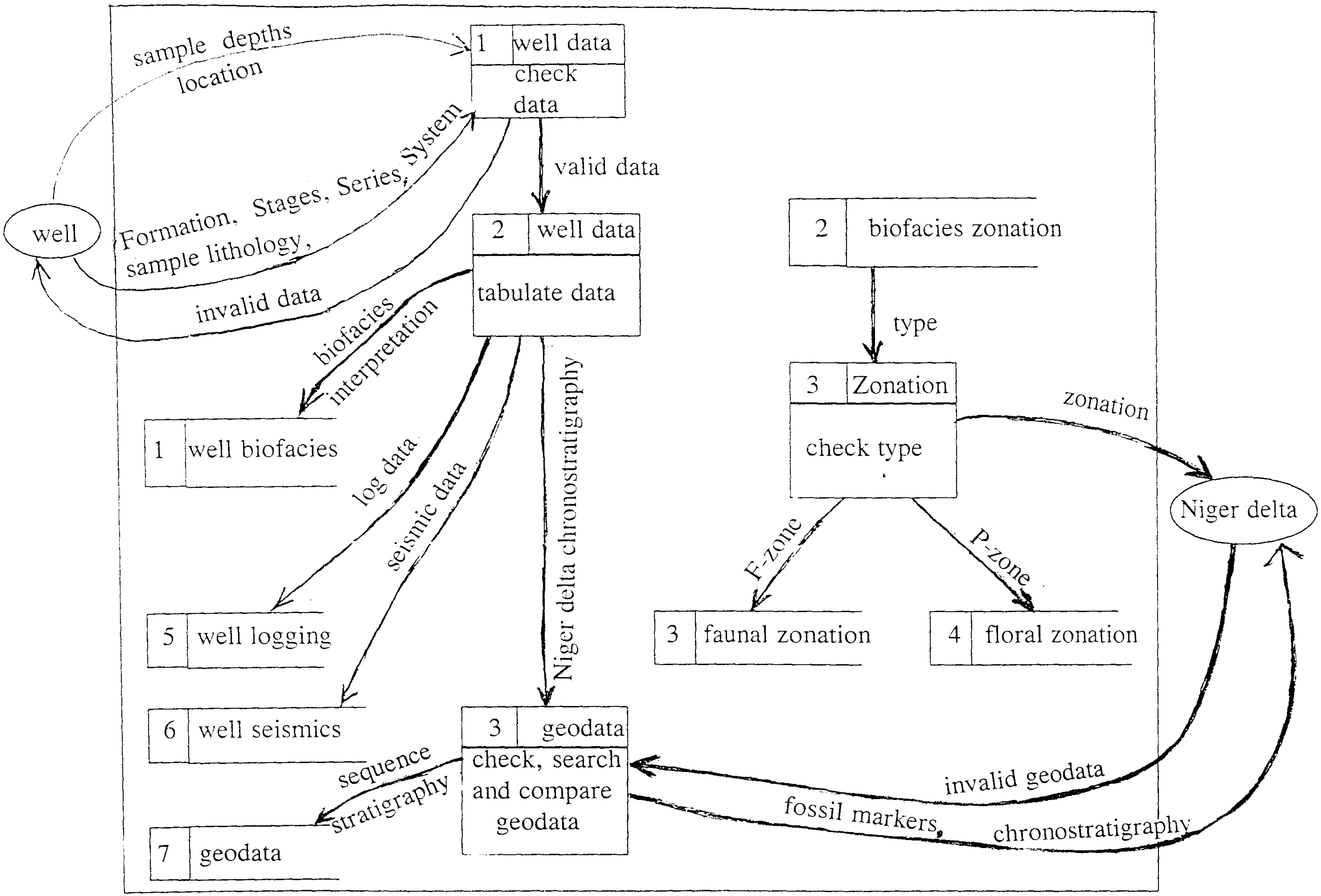


FIG. 3.7 DATA FLOW DIAGRAM OF GEODATA SYSTEM

TABLE 3.5 STAFF DEPLOYMENT FORM				
Project Name: An Automated Approach to the Sequence Stratigraphy of Niger Delta Analyst: S. O. Obaje Date: 250598				
Dept / Section	Manager	Supervision	Staff	Total
Exploration	1	10	250	261
Seismics	3	15	100	118
Well Logging	4	20	50	74
Biostratigraphy	5	18	80	104
Totals	13	63	480	547

TABLE 3.6 JOB DESRIPTION FORM FORMAT

Project Name: An Automated Approach to the Sequence Stratigraphy of Niger Delta

Analyst: S. O. Obaje

Date: 250598

Job Title	Reference	Responds To	Subordinate Staff	Responsibilities

TABLE 3.7 TIME UTILISATION FORM FORMAT	
Project Name: An Automated Approach to the Sequence Stratigraphy of Niger Delta Analyst: S. O. Obaje Date: 250598	
Task	Hours Spent
Total	

TABLE 3.8 BIOFACIES INPUT DESCRIPTION

S/N	FIELD NAME	FIELD TYPE	WIDTH	DEC	INDEX
1.	Compy	Character	15	-	Y
2.	Well_name	"	"	-	N
3.	Wellcode	Numeric	6	-	"
4.	Wellno	"	1	-	"
5.	Wlocat	Character	12	-	"
6.	Fieldcode	Numeric	3	-	"
7.	Oml	Character	4	-	"
8.	Day	Numeric	2	-	"
9.	Month	"	2	-	"
10.	Year	"	4	-	"
11.	Wdepth	"	8	2	"
12.	Environ	Character	6	-	"
13.	Fdiv	Numeric	3	-	"
14.	Fpop	"	3	-	"
15.	Pdiv	"	3	-	"
16.	Ppop	"	3	-	"
17.	Fossilmark	Character	20	-	"
18.	Bedmark	"	12	2	"
19.	Age	Numeric	10	-	"
20.	Epoch	Character	12	-	"
	Stage	"	"	-	

TABLE 3.9 MICROFLORAL ZONATION INPUT DESCRIPTION					
S/N	FIELD NAME	FIELD TYPE	WIDTH	DEC	INDEX
1.	Wellname	Character	15	-	
2.	Pzone	Character	5	-	
3.	Topdepth	Numeric	8	2	
4.	Botdepth	”	8	2	
5.	Relgrd	”	1	2	
6.	Remarks	Memo	20	-	
7.	Day	Numeric	2	-	
8.	Month	”	2	-	
9.	Year	”	4	-	

TABLE 3.10 MICROFAUNAL ZONATION INPUT DESCRIPTION					
S/N	FIELD NAME	FIELD TYPE	WIDTH	DEC	INDEX
1.	Wellname	Character	15	-	Y
2.	Fzone	Character	5	-	Y
3.	Topdepth	Numeric	8	2	-
4.	Botdepth	"	8	2	-
5.	Relgrd	"	1	2	-
6.	Remarks	Memo	20	-	-
7.	Day	Numeric	2	-	-
8.	Month	"	2	-	-
9.	Year	"	4	-	-

TABLE 3.11 SEISMICS INPUT DESCRIPTION					
S/N	FIELD NAME	FIELD TYPE	WIDTH	DEC	INDEX
1.	Oml	Character	4	-	Y
2.	Compy	"	15	-	-
3.	Geospt	Numeric	8	2	-
4.	Ttime	"	5	1	-
5.	Cycles	"	2	-	-
6.	Faultg	Character	1	-	Y
7.	Pincht	"	"	-	"
8.	Unconft	"	"	-	"
9.	Straps	"	"	-	"

TABLE 3.12 WELL LOGGING INPUT DESCRIPTION					
S/N	FIELD NAME	FIELD TYPE	WIDTH	DEC	INDEX
1.	Oml	Character	4	-	Y
2.	Wellname	"	15	-	-
3.	wdepth	Numeric	8	2	-
4.	Gml	"	6	1	-
5.	Ll9d	"	6	1	-
6.	Fed	"	6	1	-

TABLE 3.13 FILES DESCRIPTION DOCUMENT					
S/N	NAME OF FILE	PURPOSE	NO. OF RECORDS	MAINTENANCE	VOLUME & REMARKS
1.	BIOFACIES		21		
2.	FLORAL_ ZONZTION		9		
3.	FAUNAL_ZONATION		9		
4.	SEISMICS		9		
5.	WELL LOGGING		6		

TABLE 3.14 ZONATION DECISION TABLE

IF CONDITION					
Forams ?	Y	N	Y	Y	N
Pollen ?	Y	N	Y	N	Y
Fossil marker ?	Y	N	N	-	-
Marker bed ?	Y	N	-	-	-
THEN ACTIONS					
Petroleum bearing strata	X				
Petroleum barren strata		X			
No data			X		
F_Zone				X	
P_Zone					X

TABLE 3.15 WELL LOGGING DECISSION TABLE				
Gamma ray log ?	Y	N	N	Y
Resistivity log (LL9D) ?	Y	Y	N	-
Density log (FCD) ?	Y	N	N	-
THEN ACTIONS				
Petroleum reservoir with porosity and water/oil contact	X			
Paralic/transitional environments		X		
Marine			X	
Continental facies				X

TABLE 3.16 SEISMICS DECISION TABLE

IF CONDITION			
Fossil marker ?	Y	Y	N
Faulting ?	Y	Y	N
Pinchout ?	Y	Y	N
Unconformity ?	Y	N	N
Stratigraphic traps ?	Y	N	-
THEN ACTIONS			
Petroleum bearing reservoir	X		
Suitable depoevironments		X	
Petroleum barren strata			X

TABLE 3.17 FOSSIL MARKERS DECISION TABLE					
IF CONDITIONS					
Bolivina_46 ?	Y	N	N	N	N
Nonion_4 ?	N	Y	N	N	N
Uvigerina_8 ?	N	N	Y	Y	N
Cassidulina_7 ?	N	N	N	Y	Y
Chiloguembelina_3	N	N	N	Y	N
THEN ACTIONS					
Continental sands	X				
Transitional		X			
Sand_prone paralic			X		
Paralic				X	
Marine paralic					X

TABLE 3.18 Seismic cycles Decision Table

IF CONDITION							
Cycle 11	Y	N	Y	N	N	N	N
10	–	–	N	Y	–	–	N
9	Y	Y	N	N	N	Y	N
8	Y	Y	N	N	N	Y	Y
7	Y	–	N	N	Y	N	N
6	N	–	N	N	Y	N	N
THEN ACTIONS							
Bolivina _ 46			x				
Uvigerina _ 8				x			
Nonion _4							x
Cassidulina – 7	x						
Chiloguebelina_3					x		
Continental sands			x				
Sand-prone paralic						x	
Marine paralic	x						
Paralic		x					

Chapter Four

SYSTEM DESIGN

4.1 Output Specification

The system is designed to have the combined facility for real-time and batch processing. In real-time processing, much information would be produced on demand while the batch processing would require reports which are periodic in nature. In either case, the frequency of reporting and the timing of such reports are carefully put into consideration. The contents of each report are carefully determined by deciding on the fields of information that are really needed and also deciding upon the volume of output which each application warrants. In addition, the principle of exception reporting was employed. The sequence of items was built into the output design. The medium and device for the output are video display unit (VDU) and printer output on paper. Sample reports of intended output are included on special square papers known as print layout forms (see Figures 4.1 - 4.4).

4.2 File Design, Organisation and Access

4.2.1 Access Time

The file access time was designed to be optimum. Access time on disk is the time interval between the moment the command is given to transfer data from disk to main storage and the moment this transfer is completed. It is made up of three components, namely: seek time, rotational delay and data transfer time.

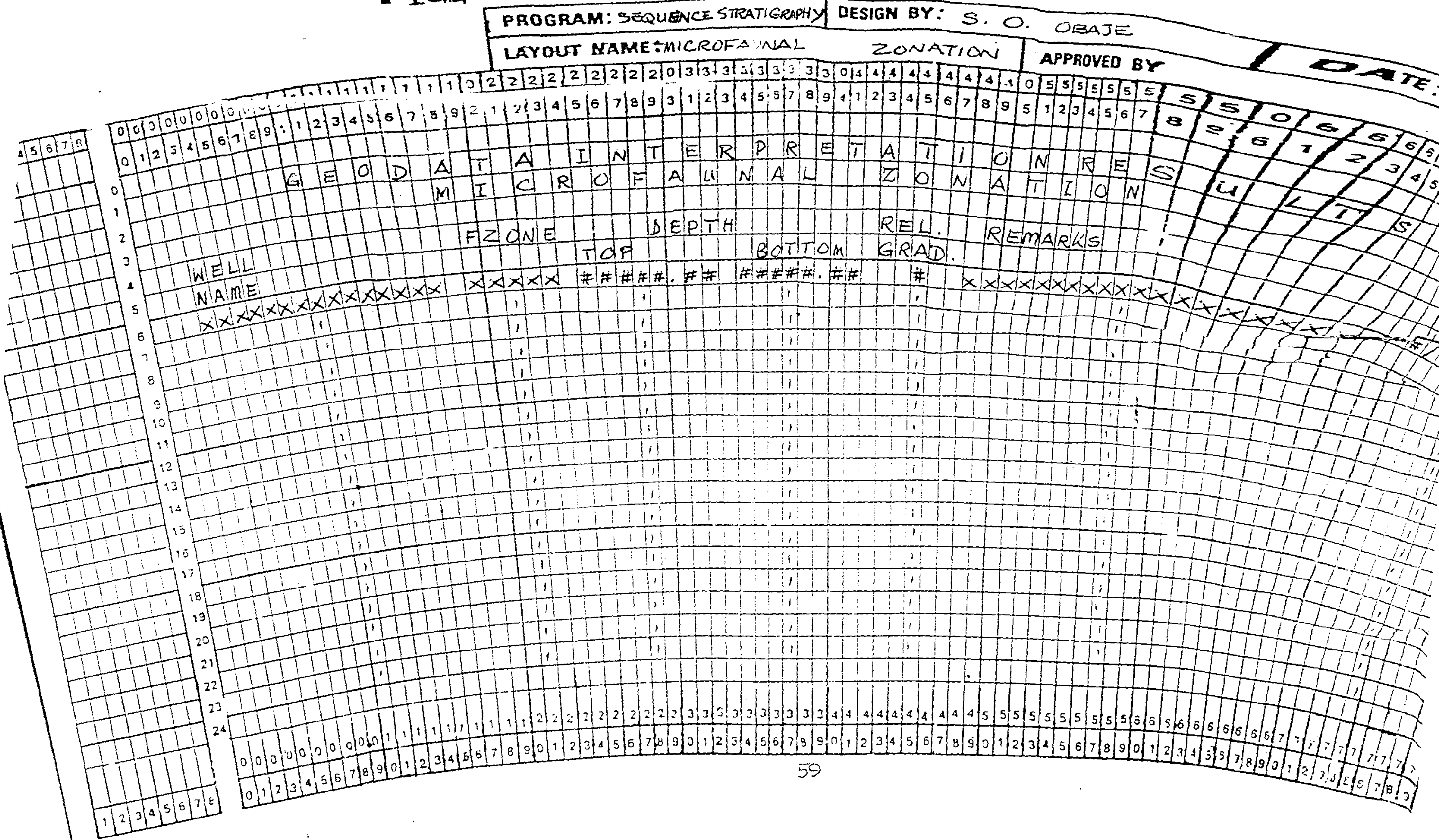
FIG.4.1 PROGRAM SCREEN DESIGN FORM

PROGRAM: SEQUENCE STRATIGRAPHY	DESIGN BY: S. O. OBAJE	DATE: AUGUST 1998
LAYOUT NAME: GEODATA INTERPRETATION RESULTS	APPROVED BY	

```
        G E O D A T A   I N T E R P R E T A T I O N   R E S U L T S
        ===========================================================

             COMPANY   :XXXXXXXXXXXXXX        WELL CODE  :######
             WELL NAME :XXXXXXXXXXXXXX        FIELD CODE :
             WELL NO.  :#                     UML        :XXXX
             LOCATION  :XXXXXXXXXXXXXX        DATE       :##/##/####
             RESERVOIR
             CHARACTERISTICS: XXXXXXXXXXXXXXXXXXXXXXXXXXXX
             ENVIRON  OF
             DEPOSITION      : XXXXXXXXXXXXXXXXXXXXXXXXXXXX
             BEDMARK:XXXXXXXXXXXXXXXXXXX
  DEPTH    F.POPLN.   F.DIV.   P.POPLN.  P.DIV.  FOSSIL MARKER          STAGE
  ####.##  ###        ###      ###       ###     XXXXXXXXXXXXXXXXXXXX   XXXXXXXXXXXXXXX
```

FIG.4.2. PROGRAM SCREEN DESIGN FORM



PROGRAM: SEQUENCE STRATIGRAPHY | DESIGN BY: S. O. OBAJE

LAYOUT NAME: MICROFAUNAL ZONATION | APPROVED BY | DATE:

GEODATA INTERPRETATION RESULTS

MICROFAUNAL ZONATION

FZONE DEPTH REL. REMARKS

TOP BOTTOM GRAD.

WELL

NAME XXXXXXXXXXXXXXX XXXXX ####.## ####.## # XXXXXXXXXXXXXXXXXXXX

XXXXXXXXXXXXXXX

FIG.4.3 PROGRAM SCREEN DESIGN FORM

PROGRAM: SEQUENCE STRATIGRAPHY	DESIGN BY: S. O. OBAJE	DATE: AUGUST 1998
LAYOUT NAME: MICROFLORAL ZONATION	APPROVED BY	

```
0
1                G E O D A T A   I N T E R P R E T A T I O N   R E S U L T S
2                        M I C R O F L O R A L   Z O N A T I O N
3
4   WELL              PZONE        DEPTH                REL.  R E M A R K S          D A T E
5   NAME                       TOP         BOTTOM       GRAD.
6   XXXXXXXXXXXXXXX   XXXXX    ####.##     ####.##      #     XXXXXXXXXXXXXXXXXXXX   ##/##/####
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
```

FIG. 4.4. PROGRAM SCREEN DESIGN FORM

PROGRAM: SEQUENCE STRATIGRAPHY	DESIGN BY: S. O. OBAJE	DATE: AUGUST 1998
LAYOUT NAME: SEISMICS & WELL LOGGING DATA	APPROVED BY	

```
GEODATA INTERPRETATION RESULTS
SEISMIC AND WELL LOGGING DATA

GEOPHONE  TIME   SEISMIC  GAMMA   RESISTIVITY  DENSITY
SHOT PT.         CYCLES   RAY
#####.##  ##.##  ###      ###.#   ####.#       ####.#
```

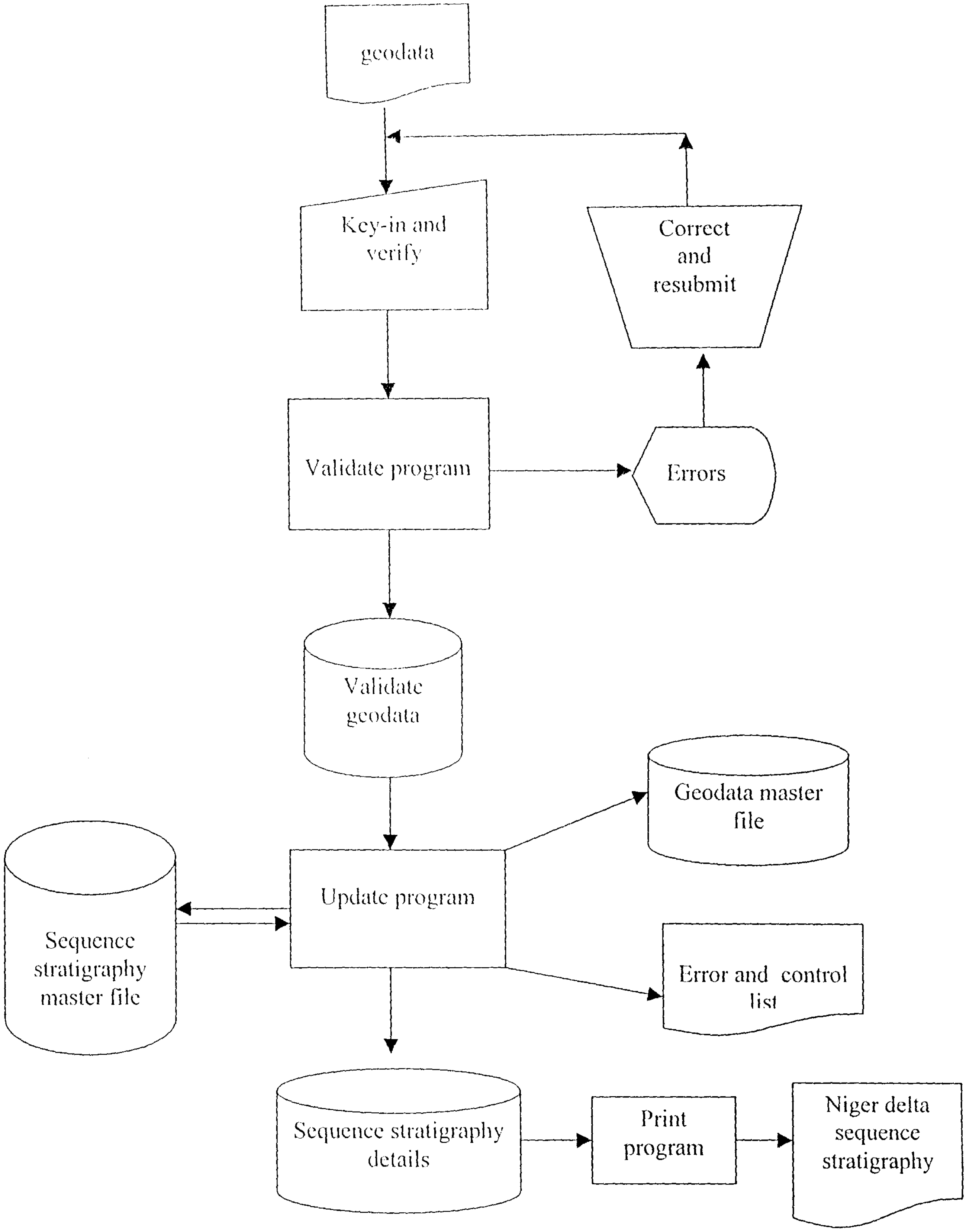


Fig. 4.5 System Flowchart of the Niger Delta Sequence Stratigraphy

4.2.1.1 Seek Time

This is the time it takes the access mechanism to position itself at the appropriate cylinder.

4.2.1.2 Rotational Delay

This is the time taken for the bucket to come round and position itself under the read-write head. On average this will be the time taken for half a revolution of the disk pack. This average is called the latency of the disk.

4.2.1.3 Data Transfer

This is the total time taken to read the contents of the bucket into main storage.

4.2.2 File Organisation and Access

There are four basic methods of organising files on disk, namely: serial, sequential, indexed sequential and random. The method of access is similar to the method of file organisation.

4.2.2.1 Serial

Records are placed onto the disk one after the other with no regard for sequence.

4.2.2.2 Sequential

Records are written onto the disk but in a defined sequence according to the record keys.

4.2.2.3 Indexed Sequential

Records are stored in sequence but with an index which provides easy access to individual records. Though the records may not be sequentially stored, the index could always enable the sequence to be determined.

4.2.2.4 Random

Records are actually placed onto the disk at random. A mathematical formula is derived which, when applied to each record key, generate an answer, that is a bucket address. The record is then placed onto the disk at this address.

4.3 Input Specification

Having established the output required from the system and the files which are needed to help in the production of the output, the input design becomes very necessary. The following areas are considered for the input design:

* Data collection methods and validation
* Types of input media available
* Volumes of input document
* Design of input layouts

4.3.1 Data Collection Methods and Validation

Data are collected from the petroleum drilling sites and from related fieldworks. Most data are first manually validated and sorted before the actual processing commences. Validation module would also be necessary for the data entry routines.

4.3.2 Types of Input Media Available

Data capture devices such as scanners, OCR, could be used. The input medium used is key-to-diskette.

4.3.3 Volume of Input Document

The volume of input document is quite large. In addition, the input of raw data will be frequent and it may always take some time to complete a given routine data entry into the system.

4.3.4 Design of Input Layouts

Special square paper called input layout was used to code the input into the system. The input layout enhance the design of the data entry forms.

See Figures 4.1 - 4.4 for sample input layout designs.

4.4 Procedure Specification

Procedures are the steps that unify the whole process. In other words, procedures link everything together to produce the desired output. These will involve both computer and the clerical procedures. These usually start with the origination of the source document and end with the output document being distributed (Figure 4.5).

4.5 Forms Design

The design of forms and the design of procedures are very much linked. The completion of a form may be the first operation of a procedure, a by-product of an operation within a procedure, the end of a procedure, or the form may be completed at various stages within a procedure.

4.5.1 Features of Forms Design

The features of design constitute the following:
sizes, types of paper, identification, common information, vertical spacing, columns, pre-printing, clarity and multi-part sets.

4.5.1.1 Sizes

Standard-size forms are used because they are more economical and handling, filing and copying are simplified using them.

4.5.1.2 Type of Paper

80 gramme papers were used because this particular specification meets the requirements of frequent handling, storage needs, conditions under which the forms would be completed and prestige.

4.5.1.3 Identification

Each form has a brief, self-explanatory title and copies could be identified by bold symbols. Serial numbering is used for each form for internal check purposes.

4.5.1.4 Common Information

Where two forms are used in conjunction with each other, the common information is usually kept in the same sequence and position.

4.5.1.5 Vertical Spacing

Adequate space is provided for each item of entry.

4.5.1.6 Columns

The length of column headings are tailored to the width required by the information to be entered in the column.

4.5.7 Pre-printing

Using laserjet printer, each common detail is pre-printed to leave space for entry of variable data.

4.5.1.8 Clarity

The instructions on the forms are well simplified. Materials of a similar nature are grouped together , and any ambiguous wording is removed. The size of the print is made suitable for ease of reading.

4.5.1.9 Multi-part Sets

Provision is made for raising of more than one document using carbon or no-carbon-required paper, carbon patches, etc.

4.6 Control Aspects of System Design

When a data processing task is undertaken manually, the human beings carrying out the job will naturally use their common sense; for example, they would automatically reject input which states that an employee has worked 120 hours in a week and they would query output which quoted a payment of minus ₦50 on an invoice.

When a task is computerised, however, the picture changes somewhat. The computer will do exactly what it has been instructed. In other words, raw data is input to a system, it is processed according to the rules laid down in the programs which handle it, and information is the result. Unless the computer is specifically instructed to report on items such as the absurd ones detailed above, the computer will readily accept them!

It is against this background that control measures are built into the system being designed as internal accuracy checks to prevent 'garbage in, garbage out' phenomenon. The controls built into the system design include:

* character checks,
* field checks and
* record checks.

Chapter Five

PROGRAMMING, IMPLEMENTATION AND MAINTAINING THE SYSTEM

5.1 Programming

5.1.1 Choice of Programming Language

A popular programming language called C++ is chosen for the program implementation. The minor advantages of this language include the following:

* It is an object-oriented programming language;
* There is a rise in productivity and reliability because of the re-usability of code;
* The program components are self-contained;
* Objects may be easy to identify in real-life problems than procedures or functions.

In object-oriented programming (OOP), the design concentrates upon objects which are the things upon which functions or procedures might be performed rather than upon the functions and procedures. For example, the object "*well_biofacies*" might be identified as one on which operations might be performed. The operations to be performed on *well_biofacies* might include "*create*", "*remove*", "*get_fossil_name*", "*get_marker_bed*", "*get_formation*", "*get_environment*" and "*get_age*". This suggests that at the heart of any object are data representing its current state. The Operations belong to the object whereas in a process-oriented program, the data may be thought as belonging to the procedures or functions. Individual objects are created and combined into a complete program (see Appendix A for the program listing and output).

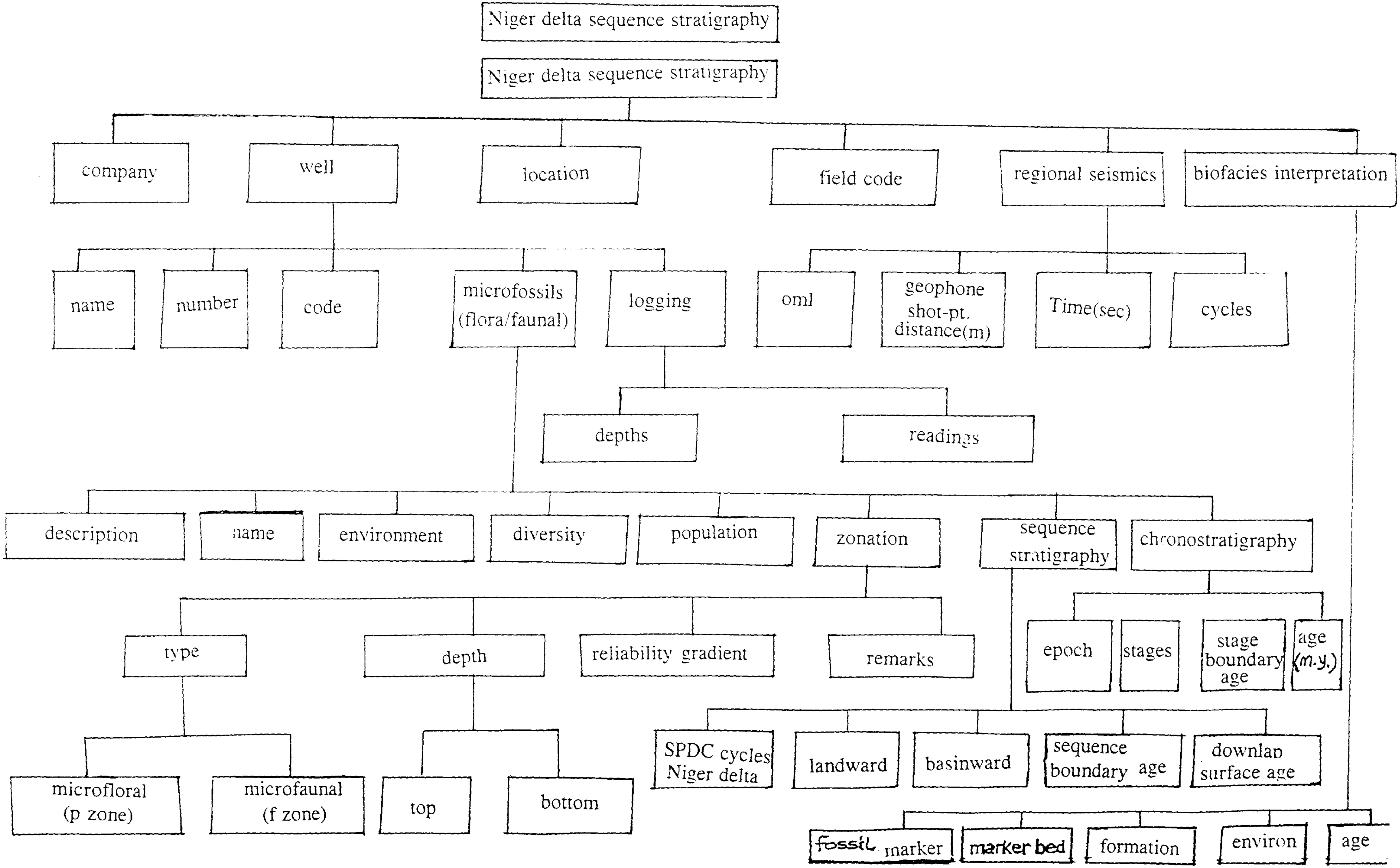
5.1.2 Program Design

5.1.2.1 Top Down Method

In object-oriented programming attention is directed toward identifying objects such as data structures and the operations performed upon them. Top down method starts with what is required and then breaking the whole into component parts, and then tackling the component parts in the same manner. The interrelationships between components are decided upon before the components are created so that the final integration of the parts into the whole will be direct. Figure 5.1 indicates a stepwise refinement of the sequence stratigraphy of the Niger delta. Figure 5.1 is a top down design chart that displays the idea of hierarchical decomposition and extends it. It is used in order to arrive at a functional decomposition of the program. Functional decomposition is a form of modular decomposition which is applied to object-oriented programming. The objective of modular decomposition is the development of a program in which the program components are functions, which themselves may be composed of other functions, etc., right down to the lowest level of program design.

5.1.2.2 Program Algorithms

A set of instructions that described the steps to be followed in order to carry out an activity is called an algorithm. If the algorithm is written in the computer's language then the set of instructions is called a program. The task of producing a computer program involves going through several stages, not all of which involve writing in the computer's own language. The complete task is called programming. Program consists of sequences of instructions specifying controlled and ordered operations on data that are to be performed by a computer.


Niger delta sequence stratigraphy
Niger delta sequence stratigraphy
company
well
location
field code
regional seismics
biofacies interpretation
name
number
code
microfossils (flora/faunal)
logging
oml
geophone shot-pt. distance(m)
Time(sec)
cycles
depths
readings
description
name
environment
diversity
population
zonation
sequence stratigraphy
chronostratigraphy
type
depth
reliability gradient
remarks
epoch
stages
stage boundary age
age (m.y.)
microfloral (p zone)
microfaunal (f zone)
top
bottom
SPDC cycles Niger delta
landward
basinward
sequence boundary age
downlap surface age
fossil marker
marker bed
formation
environ
age

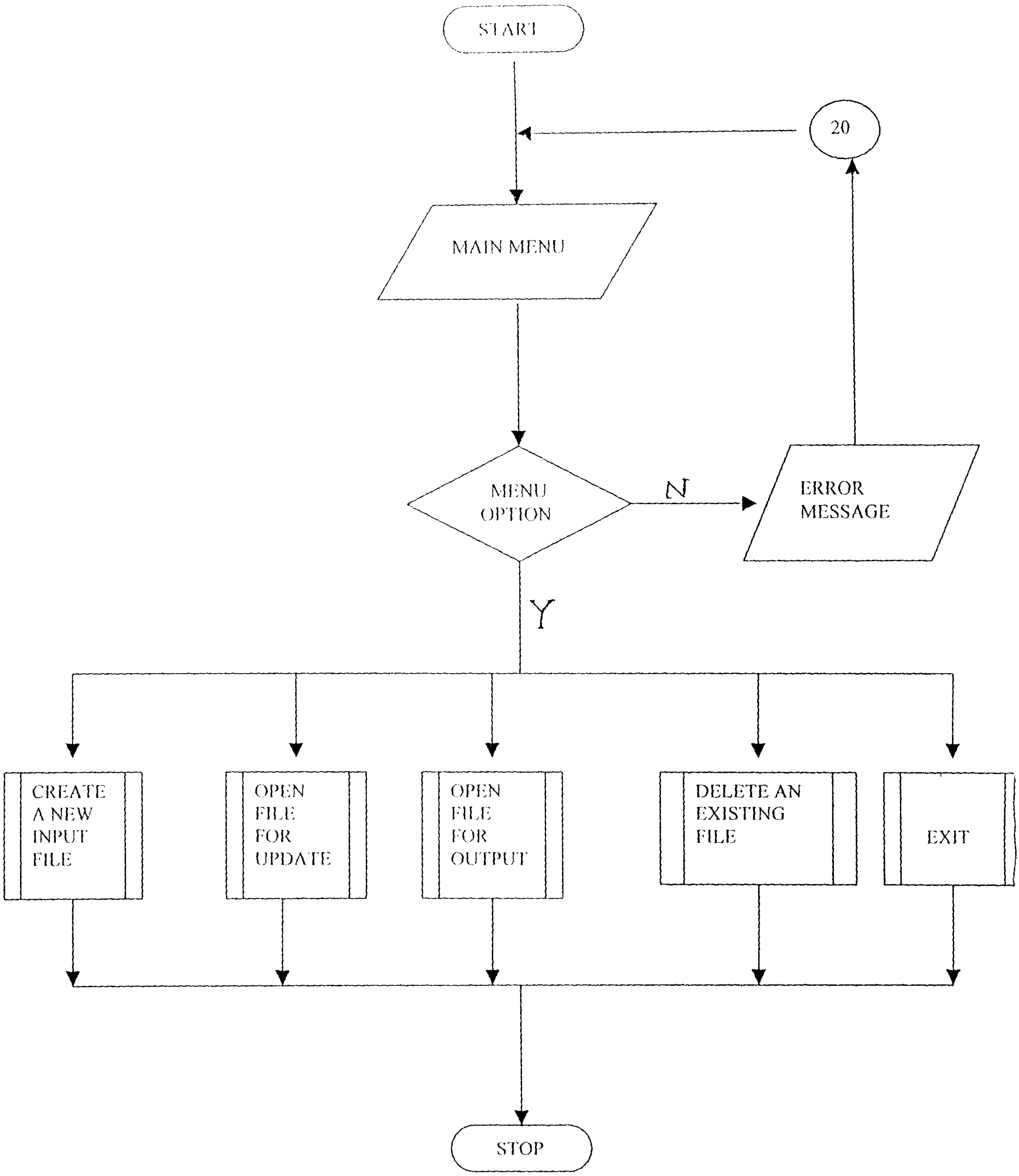


FIG. 5.2 FLOWCHART OF MAIN MENU

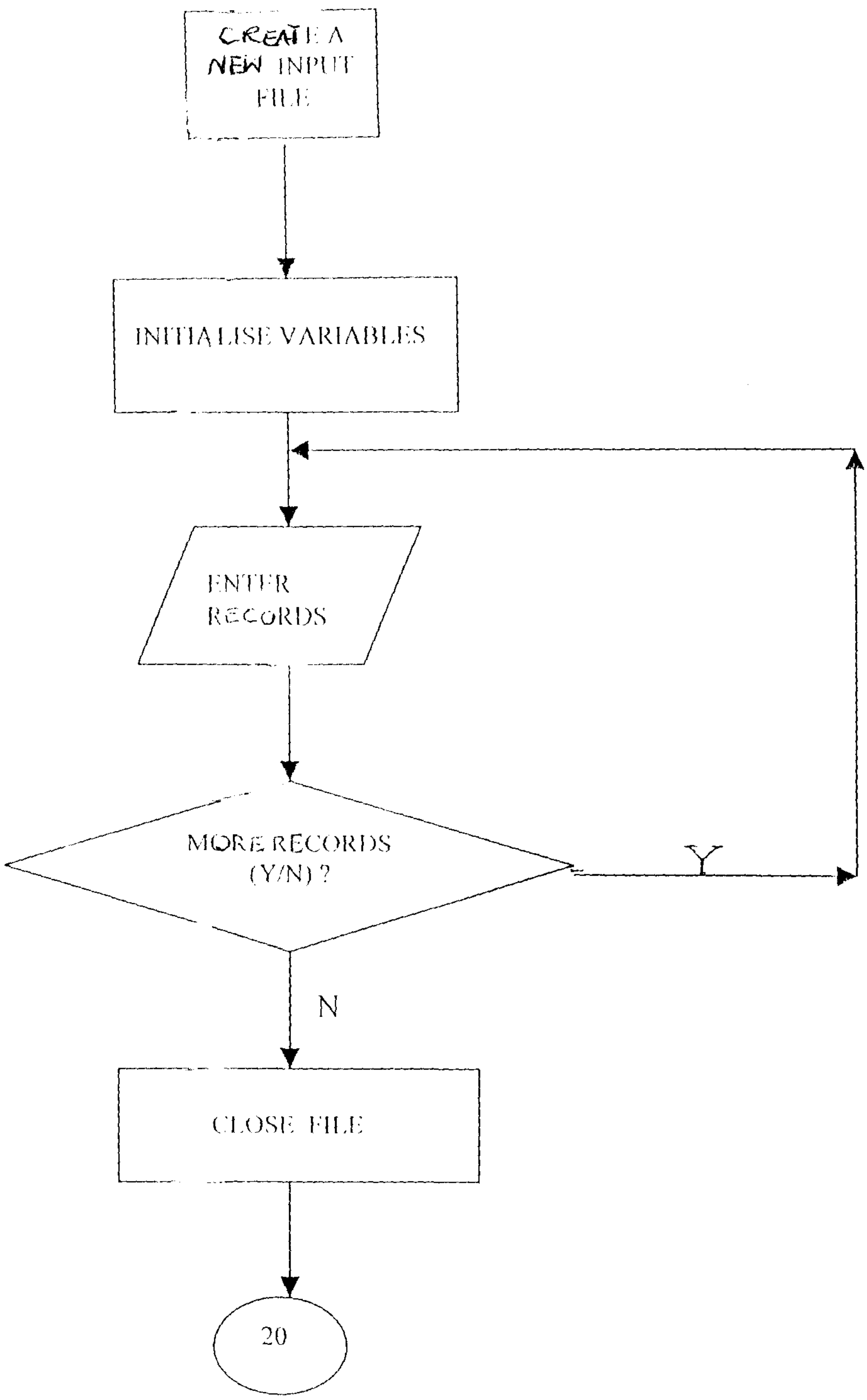


FIG. 5.3 FLOWCHART FOR CREATING A NEW INPUT FILE

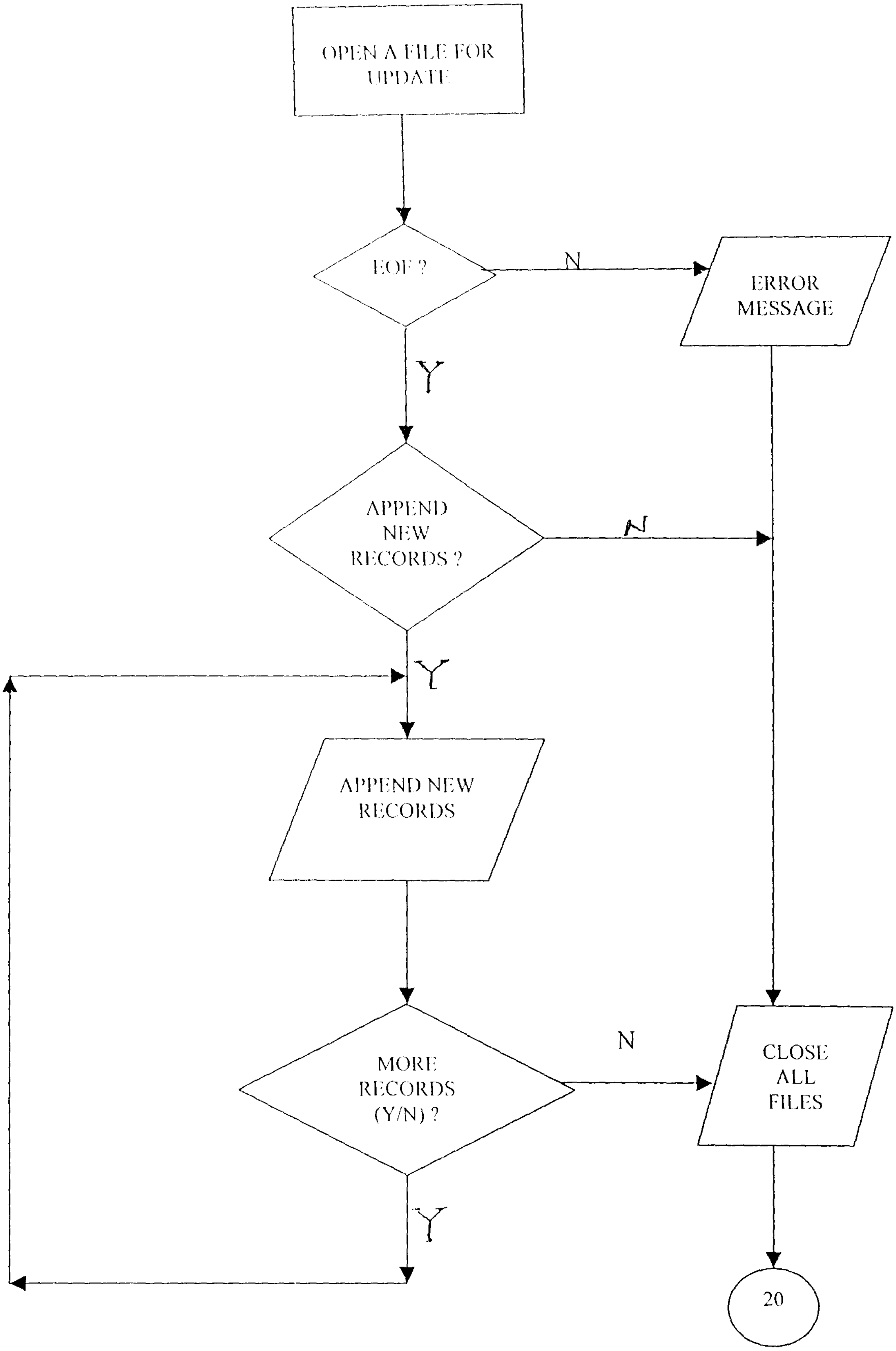


FIG. 5.4 FLOWCHART TO OPEN A FILE FOR UPDATE

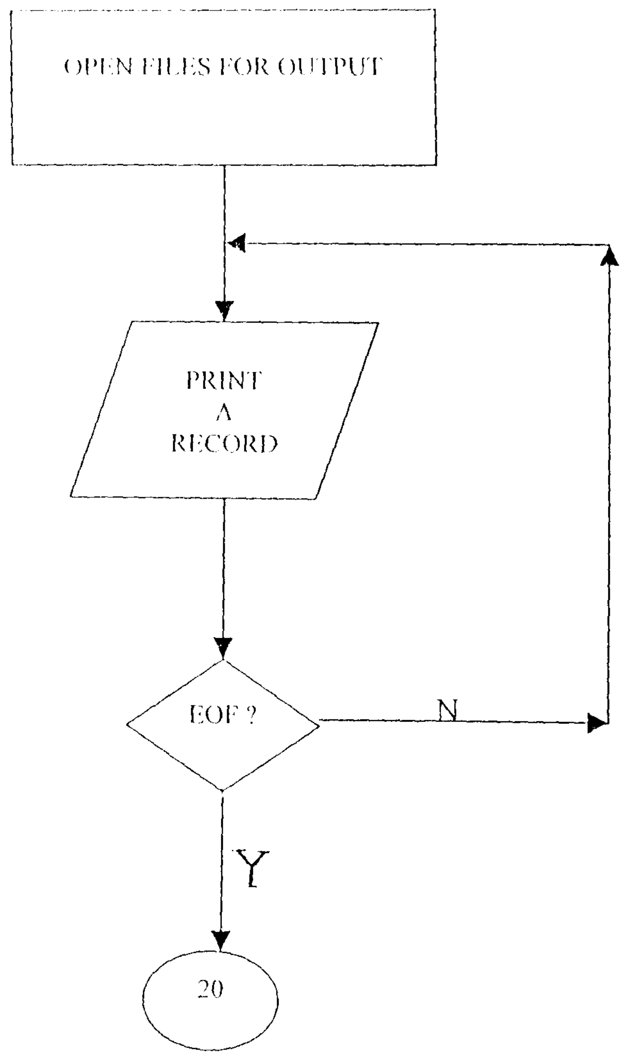


FIG. 5.5 FLOWCHART TO OPEN FILE FOR OUTPUT

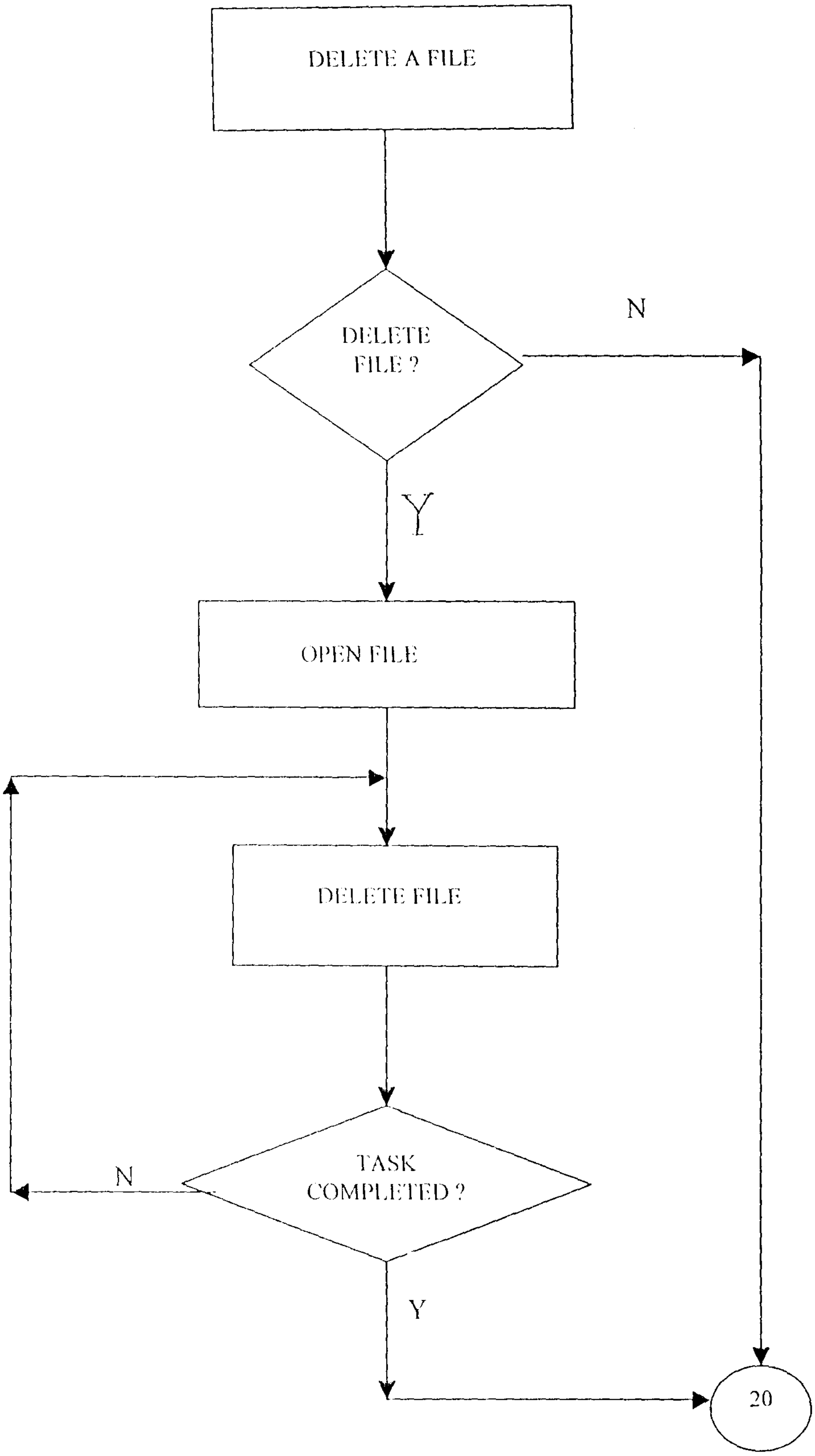


FIG. 5.6 FLOWCHART TO DELETE A FILE

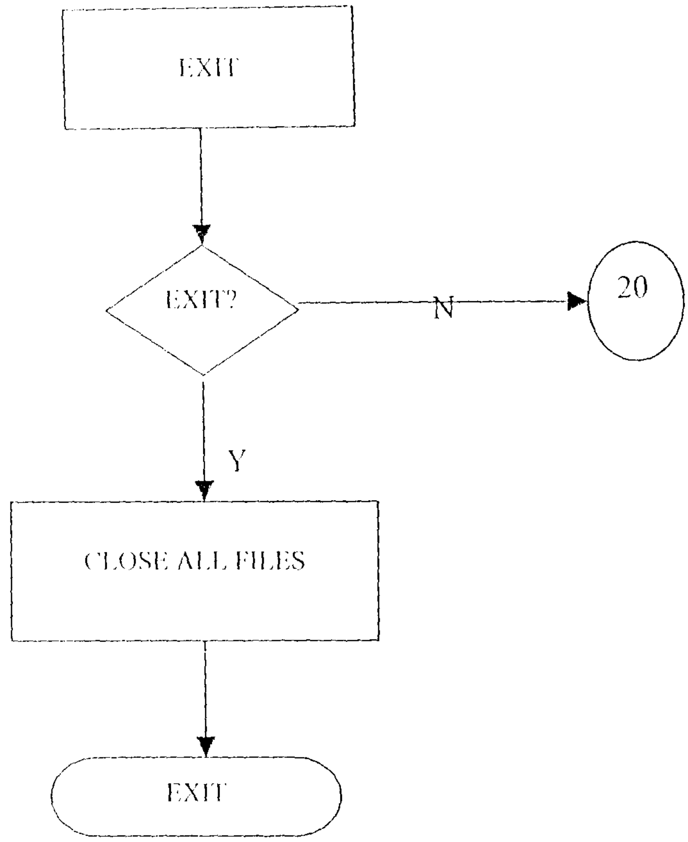


FIG. 5.7 FLOWCHART TO EXIT PROGRAM

5.1.2.2.1 Pseudocodes

A pseudocode is a simple language with a few basic grammatical constructions which avoids the ambiguities and complexities of English, but which can easily be converted into a programming language. A pseudocode is an algorithm.

The program pseudocodes used are given hereunder:

```
1. START
        20:   Display "MAIN MENU"
              Display the 5 menu options
              Display "Enter Menu Options"
              SELECT CASE
                          Menu_Option
                    CASE Menu_Option = 1
                          Create a new input file
                    CASE  Menu_Option = 2
                          Open a file for update
                    CASE Menu_Option = 3
                          Open a file for output
                    CASE Menu_Option = 4
                          Delete an existing file
                    CASE Menu_Option = 5
                          Exit
              ENDSELECTCASE
   STOP
```

2. (*Create New File Routine*)

New File:

Initialise variables

```
REPEAT

        Input records

UNTIL No_More_Records = "N" .OR. "n"

        Close File

        Go to 20
```

3. (* Open file for update*)

```
                    Open File

                    Check EOF ?

        If EOF = "false" THEN

                    Display "Error"

              ELSE

                    Continue

        END IF

        Check "Append New Records Y/N ?"

        IF Append_New = "N" THEN

                    Go to f_Close_File

              ELSE

                    Append new records

        END IF

        Check "More Records Y/N ?"
```

IF More_Records = "N" THEN

Go to F_Close_File

ELSE

Continue

F_Close_File:

Close all files

Go to 20

4. (*Delete a file*)

Display "Want to delete file y/n ?"

IF del_File = "N" .OR. "n" THEN

Go to 20

ELSE

REPEAT

delete file

UNTIL Task_Completed = "Y"

Go to 20

5. (*Exit Routine*)

Display "Want to EXIT Y/N ?"

IF Want_Exit = "N" THEN

Go to 20

ELSE

Close all files

Exit

5.1.2.2.2. Program Flowcharts

As a program becomes more complex, a flowchart is most useful in planning, designing and structuring. A flowchart is a graphical representation of an algorithm, that is, it is a visual picture which gives the steps of an algorithm and also the flow of control between the various steps. Figures 5.2 - 5.6 show the various program flowcharts used in the program planning and development.

5.2 System Testing

5.2.1 The Role of System Testing

It is most important that computer system does not contain errors. The system testing phase is carried out in order that any errors remaining after programs have been individually tested can be detected and rectified.

System testing therefore:

* further test the robustness of each program in the system;
* test that all programs in a system are compatible, one with another, so that a file output by an update program can be read by a print program, for example;
* test that the computerised elements of the system interface successfully with the system's clerically operated aspects.

5.2.2. The Nature of System Testing

To test a newly-written system, dummy data which contained correct and invalid items are used, and the expected result are determined. The test data were carefully devised so as to check the accuracy of each program. During testing of the system, the following items are examined:

* details of all input files, both transaction and master files;
* details of all output files;
* printed reports from all stages of the processing;
* screen displays.

All output were meticulously checked against anticipated results to ensure that the system is behaving exactly as specified. Discrepancies are examined and the causes are determined. Where necessary, amendments are made to the program and, in consequence, the documentation is altered so that it reflects the changes.

5.2.3 The System Test

The test data used for system testing cover conditions such as the following:

i. range errors, for example in ages;

ii. format errors, a digit in a Well_Name, for example;

iii. zero or negative values where only positive values are allowed, for example Well_Depth;

iv. non-integers in such fields as Cycles;

v. a transaction record which is not matched by a corresponding master record;

vi. a master record which is not matched by more than one transaction;

vii. invalid combinations of data.

In addition, controls are vigorously tested and corrections made, then erroneous data are re-submitted to the system to test for its effectiveness.

5.3 Documenting the System

The system is documented via statement of the problem (system specification), pseudocodes, flowcharts, coding sheets, test data and results (output). The system is carefully documented to aid the maintenance of the program during its lifetime and also to serve for staff training in the use of the program.

5.4 Staff Training

Staff training thus has several functions:

(i) to convince the user-department's staff that the new system is an effective and efficient one;

(ii) to enable the staff to carry out the tasks required of them in support of the system;

(iii) to overcome their fear of change, and any feeling that they may not be able to cope with the demands of the new system.

Basically, however, all staff who will come into contact with the system will need some training. These will include:

i. the management and staff of the departments whose work is being computerised;

ii. the staff of any other department which is affected by the new system;

iii. the organisation's management;

iv. staff in the electronic data processing (EDP) department such as operators and data preparation staff;

v. the auditors.

The following methods of staff training could be used to achieve the best results:

* lectures;
* films;
* group discussions;
* case studies;
* role playing;
* literature.

5.5 The Changeover

The implementation of the new system involves two major aspects, namely:

i. the changeover from the old system to the new one; and

ii. the creation of a new file, either from the scratch or by converting an existing file.

5.5.1 Direct or Straight Changeover

Where a system is a small, relatively simple one, or where no other method appears viable, direct or straight changeover may be opted for. In such a case the old system ceases to run one day, and the new system commences to run on the next. Such an approach presumes that a system has been completely tested and that the user department's staff have confidence in it. Clearly, the cost of a direct changeover will be low, but the risks involved, if something should go wrong, are considerable.

A straight changeover can be used in conjunction with one or other of the following methods of file creation: straight file creation and/or dummy file creation.

5.5.2 Parallel Running

Where a computer system produces fairly similar output to that produced by the system which it is replacing, parallel running may be used. This implies that, when the operation of the new begins, the old system is left running.

Parallel running is thus, in effect, an extension of system testing. The cost of using this approach is very high, as staff are asked to run two systems at once, but the method gives a good back-up because the manual system is continued for a time. It may well increase staff confidence in the new system, too, as clerical staff can see for themselves that the new system works.

Of course, direct or dummy file creation methods could be used in conjunction with parallel running.

5.5.3 Pilot Running

Where the volume of data involved in a system is too great to be coped with by a straight changeover, or where the establishments being dealt with are geographically scattered, a pilot scheme may be opted for. Pilot running involves the gradual take-on of parts of a system one-at-a-time.

Pilot running lends itself to phased file creation, where parts of the master file can be dealt with using straight or dummy creation methods, as appropriate.

Pilot running will only be suitable in the right circumstances but, where it can be used, it spreads the workload and reduces the risk of a disastrous failure at take -on time. Pilot running is highly recommended for the changeover to the new system due to economic and organisational reasons.

5.5.4 Staged Changeover

This involves a series of limited size direct changeovers, the new system being introduced piece-by-piece. A complete part, or logical section, is committed to the new system while the remaining parts or sections are processed by the old system. Only when the selected part is operating satisfactorily is the remainder transferred. This method reduces the risks inherent in a direct changeover of the whole system.

The disadvantages of staged changeover are twofold, namely:

* it creates problems of controlling the selected parts of the old and new system;
* it tends to prolong the implementation.

5.5.5 Handover

Once the system has been working for an agreed period of time, the systems analyst will wish to withdraw. Prolonged involvement of the systems analyst with the working system should be avoided. The system becomes the responsibility of a maintenance group with the electronic data processing (EDP) department instead of the development's staff. This handover point should be established as part of the implementation plan.

The users must be satisfied that the system works properly and meets all their requirements by the time handover takes place. It is essential, therefore, that the handover takes place formally, with a clear understanding on all sides that the systems analyst's involvement has come to an end.

5.6 The Post-implementation Review

To ensure that no major factors have been overlooked, and to determine how closely the user's requirements have been met, a post-implementation review is usually carried out.

The electronic data processing team, the users and the auditors should meet after the system has been running operationally for a short time, and they should review the system in an attempt to ascertain how close its performance is to that which was predicted at the design stage. The findings are usually summarised in a post-implementation review report.

5.7 Maintenance

A system has to be maintained throughout its life to ensure that it can continue to operate effectively and efficiently over time. Whatever cause gives rise to the need for changing an existing computer system, maintenance will have to be carried out. This will involve re-specifying parts of the affected program(s) and re-writing, and re-testing them. The cost of maintenance depends on the quality of the documentation which accompanied the system.

Two distinct types of maintenance can be identified, namely:

emergency maintenance;

modifications and development.

5.7.1 Emergency Maintenance

Program testing and system testing, however diligently they are carried out, can never guarantee the absence of bugs in a system. Clearly, in the first few cycles of operation, such bugs are likely to emerge and cause programs either to come to a sudden unexpected end, or to produce non-sensible results - garbage. Even after a program has been running for several months or years, it is possible that a unique combination of data will enter the system and cause a hitherto undetected bug to come to light.

Whenever such problems arise in the running of operational programs, they must be investigated and corrected immediately, so that the system involved can go back 'on stream' in order to produce the required information.

5.7.2 Modification and Development

Systems analysts try hard to design flexibility into computer systems. But, however well they manage to do this, a system will need to be modified or developed at some stage of its operational life. Changes may be required for one or more of the following reasons:

(i) After a system has been running for a certain length of time, it may become clear to the electronic data processing staff that its efficiency could be improved by carrying out certain tasks in a different way.

(ii) The user may require changes to the system, having had a chance to see how it actually works in practice. A change of personnel in the user department may lead to such a request.

(iii) Changes may be required because the circumstances surrounding the system have altered:

company policy may have changed, the organisation's structure or the products it produces may have been modified, the volume of transactions may have grown, or other systems which impinge on the system in question may have been computerised.

(iv) New hardware or software may come onto the market which makes the 'old' way of doing things obsolete, and relatively costly.

(v) Bodies or events external to the organisation may cause changes to be required.

The government, with legislation on such matters as taxation and increased rate on operating mining licence (OML), etc.

5.8 SUMMARY/CONCLUSION AND RECOMMENTATIONS

5.8.1 SUMMARY/CONCLUSION

The major objective of the project was to design an information system that will meet the operating requirements of petroleum exploration managers. The proposed system was designed to be dependable and also to guarantee accuracy, reliability, efficiency, ease of data access and security. From the details on the cost-benefit analysis of the old and new system, the new (proposed) system is an economical alternative, feasible and justifiable.

In recording the processing steps carried out within the system, many different methods such as the clerical procedures flowchart, the data flow diagram and the decision tables were used to describe the various routines and processes in the system. Data were collected from the petroleum drilling sites and from related field -works in the Niger delta. The data were first manually validated and sorted before they were entered into the system for processing.

The input medium is key-to-diskette. The volume of input document is quite large and the input of raw data is frequent the file organisation and access are random and indexed sequential. The system is designed to have the combined facility for real-time and batch processing. The medium and device for the output are video display unit (VDU) and printer output on paper. The volume of output is large.

Three major control measures are built into the system as internal accuracy checks to prevent 'garbage in, garbage out' phenomenon. These control measures are character, field and record

5.8.2 Recommendations

The following recommendations are proffered:

Pilot running is highly recommended for the changeover to the new system due to economic and organisational reasons:

* System handover should be included in the implementation plan.
* Post-implementation review of the system should be carried out after the system has been running operationally for a short time to determine how closely the users' requirements have been met.
* The cost of maintenance should be built into the running cost of the system.
* The user department should employ systems analysts/programmers for-the-spot maintenance of the system and for system modification and development in order to accommodate the changes resulting from hardware/software technology, company and government policies, etc.
* The company management should ensure effective and close monitoring of the new system and the staff involved to enhance control and accountability.

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APPENDIX A: PROGRAM LISTING & OUTPUT

```
/*	PROJECT:	An automated approach to the sequence stratigraphy of the
Niger delta.
Author:		S. O. Obaje.
Date:		August 1998.
*/
//	MAIN PROGRAM MENU

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <math.h>
#include <ctype.h>
#include <time.h>

main ()
{	char option1;
20:printf("MAIN MENU\n");
	printf("==========\n\n");
	printf("1.	Create a (N)ew file for input \n");
	printf("2.	Open a file for (U)pdate \n");
	printf("3.	Open a file for (O)utput \n:");
	printf("4.	(D)elete an existing file \n");
	printf("5.	(E)xit \n\n");

printf("Enter Menu Option (1...5) \n");
printf("(or enter upper case letters: N, U, O, or E) \n");

switch(option1)
	{	case '1': case 'N': goto 100; break;
		case '2': case 'U': goto 150; break;
		case '3': case 'O': goto 200; break;
		case '4': case 'D': goto 250; break;
		case '5': case 'E': goto 300; break;
		default: printf("Wrong entry, retry ...\n");
			goto 20;
	}

100: {FILE *fp;
//	initialise variables
int wellcode, wellno, fieldcode, fdiv, fpop, pdiv, ppop, day, month, year, relgrd,cycles,
faultg, pincht, unconft, straps, num1, filelength;
char	copmy, wellname, wlocat, oml,  environ, fossilmark, bedmark, epoch, fzone,
stage, pzone, remarks, fossil, reserv, answer, filename, option;
float wdepth, age, topdepth, botdepth, geospt, ttime,  gml, ll9d, fcd;
```

```
//      Geodata (biofacies, zonation, seismics, & well logging) input data

struct rec
{ int wellcode[6], wellno[1], fieldcode[3], fdiv[3], fpop[3], pdiv[3], ppop[3], day[2],
month[2], year[4], relgrd, cycles[3], faultg, pincht, unconft, straps, num1[200],
filelength[100];
 char  compy[15], wellname[15], wlocat[12], oml[4], environ[30], fossilmark[20],
bedmark[20], epoch[10], stage[12], pzone[5], fzone[5], remarks[20], fossil[1],
reserv[30], answer, filename[10], option[1];
float  wdepth[8], age[12], topdepth[8], botdepth[8], geospt[8], ttime[5], gml[6],
ll9d[6], fcd[6];
}r, p, f, s, w;

fp = fopen("project1.cpp", "w+b");                  // create a new file for input/update
// you can also write your data to it and read from it later.
for ( ; ; )
{ printf("\n well depth or (STOP): ");
if (scan("%d", &r.wdepth) < 1 || &r.wdepth < 0 ) break;
// the symbol "||" is used for "OR".
printf("Enter well code: ");
scanf("%6d", &r.wellcode);
printf("Company: \n");
scanf("%15s", r.compy);
printf("well name: \n");
scanf("%15s", r.wellname);
printf("Location: \n");
scanf("%12s", r.wlocat);
printf("OML: \n");
scanf("%4s", r.oml);
printf("Fossil Marker: \n");
scanf("%20s", r.fossilmark);
printf("Bed Marker: \n"); scanf("%20s", r.bedmark);
printf("Epoch: \n"); scanf("%10s", r.epoch);
printf("Stage: \n"); scanf("%12s", r.stage);
print("Age: \n"); scanf("%9.2f", r.age);
printf("depth: \n"); scanf("%5.2f", r.wdepth);
printf("Well Number: \n"); scanf("%hd", &r.wellno);
printf("Field Code: \n"); scanf("%hd", &r.fieldcode);

printf("Enter DATE (e.g. 30\12\1990): \n");
scanf("%d\%d\%d", &r.day, &r.month, &r.year);
printf("Enter fossil type: \n"); scanf("%c", fossil);
        if (fossil == 'f')
                {       printf("faunal population: \n"); scanf("%hd", &f.fpop);
                        printf("faunal diversity: \n"); scanf("%hd", &f.fdiv);
                        printf("top depth: \n"); scanf("%5.2f", f.wdepth);
                        print("bottom depth: \n "); scanf("%5.2f", f.botdepth);
                        printf("relative gradient: \n"); scanf("%hd", f.relgrd);
                        printf("remarks:  \n"); scanf("%20s", f.remarks);
                }
```

```
        else
                {
                        printf("floral population: \n"); scanf("%hd", &p.ppop);
                        printf("floral diversity: \n"); scanf("%hd", &p.pdiv);
                        prinf("top depth: \n"); scanf("%5.2f", p.topdepth);
                        prinf("bottom depth: \n"); scanf("5.2f", p.botdepth);
                        printf("relative gradient: \n"); scanf("%hd", p.relgrd);
                        printf("remarks: \n"); scanf("%20s", p.remarks);
                }
printf("Enter geophone shot point: \n"); scanf("%5.2f", s.geospt);
printf("Enter seismic time \n"); scanf("%2.2f", s.ttime);
printf("Enter seismic cycle: \n"); scanf("%hd", s.cycles);
printf("Any faulting present (Y/N)?: \n"); scanf("%c", answer);
                answer == toupper(answer);   // convert content to upper case letter.
        if (answer == 'Y')
                s.faultg == 1;
        else
                s.faultg == 0;
printf("Any pinchout (Y/N)?: \n"); scanf(("%c", answer);
                answer == toupper(answer);
        if (answer == 'Y')
                s.pincht == 1;
        else
                s.pincht == 0;
printf("Any unconformity (Y/N)?: \n"); scanf("%c", answer);
                answer == toupper(answer)
        if (answer == 'Y')

                s.unconft == 1;
        else
                s.unconft == 0;
printf("Any stratigraphic trap (Y/N)?: \n"); scanf("%c", answer);
                answer == toupper(answer);
        if (answer == 'Y')
                s.straps == 1;
        else
                s.straps == 0;

90: printf("enter gamma ray readings: \n"); scanf("%4.1f", w.gml);
         printf("enter resistivity readings: \n"); scanf("4.1f", w.ll9d);
         printf("enter density log readings: \n"); scanf("%4.1f", w.fcd);
                r.wellname == p.wellname == f.wellname == w.wellname;
                r.oml == s.oml == w.oml;
                r.compy == s.compy;
                r.wdepth == w.wdepth;
                r.day == p.day == f.day;
                r.month == p.month == f.month;
                r.year == p.year == f.year;
```

```
if ((fossil == 'f') || (fossil == 'p' || (r.fossilmark != NULL) && (r.bedmark != NULL)
                r.reserv == "petroleum bearing strata";
    else
                r.reserv == "petroleum barren strata";
     if ((r.fossilmark != NULL) && (s.faultg == 1) && (s.pincht > 0) &&
    (s.unconft > 0) && (s.straps == 1)
                r.reserv == "petroleum bearing strata"
    else
                r.reserv == "petroleum barren strata";
        if ((r.fossilmark == "bolivina_46") && (r.fossilmark == "nonion_4") &&
         (r.fossilmark == "uvigerina_8") && (r.fossilmark ==
           "cassidulina_7") && (r.fossilmark == "chiloguembelina_3"))
                r.environ == "continental sands";
    else
        if ((r.fossilmark != "bolivina_46") || (r.fossilmark != "uvigerina_8")
              ||(r.fossilmark != "cassidulina_7") || (r.fossilmark !=
              "chiloguembelina_3") || (r.fossilmark == "nonion_4")
                r.environ == "transitional";
    else
       if ((r.fossilmark != "bolivina_46") || (r.fossilmark != "nonion_4") ||
            (r.fossilmark != "cassidulina_7") || (r.fossilmark !=
            "chiloguembelina_3") || (r.fossilmark == "uvigerina_8"))
                r.environ == "sand-prone paralic";
    else
        if ((r.fossilmark == "uvigerina_8") && (r.fossilmark =="cassidulina_7")
          && (r.fossilmark == "chiloguembelina_3") || (r.fossilmark !=
          "boliva_46") && (r.fossilmark == "nonion_4"))
                 r.environ == "paralic";
         else
          if ((r.fossilmark != "bolivina_46") || (r.fossilmark != "nonion_4") ||
                (r.fossilmark != "uvigerina_8") || (r.fossilmark !=
                "chiloguembelina_3") && (r.fossilmark == "cassidulina_7")
                 r.environ == "marine paralic";
     if ((w.gml > 75) && (w.ll9d < 50) && (w.fcd > 2.15))
         {
                {       r.reserv == "petroleum bearing strata";
                        r.environ == "sand-prone paralic";
                }
         else
         if ((w.gml > 75) && (w.ll9d < 50) || (w.fcd < 2.15))
                        { r.reserv == "petroleum bearing strata";
                          r.environ == "marine continental facies";
                        }
         } else
                          r.environ == "paralic / transitional";
     printf("more records (Y/N)?: \n"); scanf("%c", &answer);
                        answer == toupper(answer);// to upper case letter.
     if (answer == 'Y')
                { fwrite(&r, &p, &f, &s, &w, sizeof(rec), 1, fp);
                        continue;
```

```
                }
        else
                        break;
    }
    fclose(fp);     // close open file.
    goto 20;                // return control to the program's main menu.
}

150: void file_error(void)
printf("There is a problem with the file 'project.cpp' \n");
                exit(1);
{FILE *fp;
    int nr, code;
    long pos, filelength, i;
    char answer;
    fp == fopen("project.cpp", "a+b");
            // open file 'project.cpp' for records update.
    if (fp == NULL)file_error();

    for ( ;  ;  )
        {       printf("\n well depth or (STOP): ");
        if scanf("%d", &nr) < 1 || nr < 0) break;
            pos == (long)nr *sizeof(rec);
        if (fseek (fp, 0l, SEEK_END)) file_error();
            filelength == ftell(fp);
        for (i = filelength; i < pos + sizeof(rec); i++)
            code == putc('\0', fp);    // compute position
        if (code == EOF) file_error();
                {
                        fseek(fp, pos, SEEK_SET);  // set file position.
                        fread(&r, &p, &f, &s, &w, sizeof(rec), 1, fp);
                                // read records.
                }
    if (r.wellname[0] == '\0') answer == 'Y';
      else
            {
    printf("Company:     %15s  Well Code:    %d \n", r.compy,
      r.wellcode);
    printf("Well Name:  %15s  Field Code:   %d \n",
     r.wellname, r.fieldcode);                  printf("Well No.:      %d
    OML:  %d \n", r.wellno, r.oml);
    printf("Location:      %15s  Date:  %d\%d\%d \n", r.wlocat, &r.day,
     &r.month, &r.year);

    printf(r.wellname, "Biofacies Interpretation Results \n\n");
    printf("%5.2f %30s", r.wdepth, r.environ);
    printf("%hd   %hd", &f.fdiv, &f.fpop);
    printf("%hd   %hd", &p.pdiv, &P.ppop);
    printf("%20s  %20s  %9.2f", r.fossilmark, r.bedmark, r.age);
    printf("%10s  %12s", r.epoch, r.stage);
```

```
        printf("%30s", r.reserv);
        printf("update records (Y/N)?: ");   // request for records update.
        scanf("%c", &answer);         // store request to buffer.
                answer == toupper(answer); //to upper case.
         }  printf("enter number of record"); scanf("%hd", num1);
if (answer == 'Y')
for (i=1; i < num1; i++)
    printf("Company: Well Code:    Field Code: \n");
    scanf(("%15s       %d      %d", r.compy, &r.wellcode, &r.fieldcode);
    printf("Well Name:        Well No.:      Location: OML: \n");
    scanf("%15s        %d      %15s  %d", r.wellname, r.wellno, r.wlocat, r.oml);
    printf("Date: \n"); scan("%d\%d\%d", &r.day, &r.month, &r.year);
    printf("Fossil Marker: \n"); scanf("%20s", r.fossilmark);
    printf("Bed Marker: \n"); scanf("%20s", r.bedmark);
    printf("Epoch: \n"(; scanf("%10s", r.epoch);
    printf("Stage: \n"); scanf("%12s", r.stage);
    printf("Age: \n"); scanf("%9.2f", r.age);
    printf("Depth: \n"); scanf("%5.2f", r.wdepth);
    printf("Well Number: \n"); scanf("%hd", &r.wellno);
    printf("Field Code: \n"); scanf("%hd", &r.fieldcode);
    printf("Enter date (e.g. 30\12\1990): \n"); scanf("%d\%d\%d", &r.day,
    &r.month, &r.year);
    printf("Enter fossil type: \n"); scanf("%c", fossil);
if (fossil == 'f')
        {
        printf("faunal population: \n"); scanf("%hd", &f.fpop);
        printf("faunal diversity: \n"); scanf("%hd", &f.fdiv);
        printf("top depth: \n"); scanf("%5.2f", f.topdepth);
        printf("bottom depth: \n"); scanf("%5.2f", f.botdepth);
        printf("relative gradient: \n"); scanf("%hd", f.relgrd);
        prntf("remarks: \n"); scanf("%20s", f.remarks);
        }
       else
        {
        printf("floral population: \n"); scanf("%hd", &p.ppop);
        printf("floral diversity: \n"); scanf("%hd", &p.pdiv);
        printf("top depth: \n"); scanf("%5.2f", p.topdepth);
        printf("bottom depth  \n"); scanf("%5.2f", p.botdepth);
        printf("relative gradient: \n"); scanf("%hd", p.relgrd);
        printf("remarks:  \n"); scanf"%20s", p.remarks);
        }
        printf("enter geophone shot point: \n"); scanf("%5.2f", s.geospt);
        printf("enter seismic time:  \n"); scanf("%2.2f", s.ttime);
        printf("enter seismic cycle:  \n"); scanf("%hd", s.cycles);
        printf("any faulting present (Y/N)?:  \n"); scanf("%c", &answer);
                answer == toupper(answer);
        if (answer == 'Y')
                s.faultg == 1;
        else
                s.faultg == 0;
```

```
            printf("any pinchout (Y/N)?: \n"); scanf("%c", answer);
                    answer == toupper(answer);
        if (answer == 'Y')
                    s.pincht == 1;
        else
                    s.pincht == 0;
                printf("any unconformity (Y/N)?:  \n"); scanf("%c", answer);
                    answer == toupper(answer);
        if (answer == 'Y')
                    s.unconft == 1;
        else

                    s.unconft == 0;
            printf("any stratigraphic trap (Y/N)?:  \n"); scanf("%c", &answer);
                    answer == toupper(answer);
        if  (answer == 'Y')
                    s.straps == 1;
          else
                    s.straps == 0;
                        goto 90;
                }
200: {FILE *fp;
        fp == fopen("project.cpp", "r+b");                //open file for output.
        if (fp != NULL)               //check if file is not empty.
                {       fseek(fp, 0l, SEEK_END);
                        fread(&r, &p, &f, &s, &w, sizeof(rec), 1, fp);  // read records.
                        printf("GEODATA INTERPRETATION RESULTS \n");
                        print("================================== \n\n"
                        printf("COMPANY:  %15s   WELL CODE:%hd  \n");
                        printf("WELL NAME:         %15s   FIELD CODE:%hd  \n");
                        printf("WELL NO.:   %d      OML:  %4s \n");
                        printf("LOCATION:  %15s  DATE:%d\%d\%d  \n");
                        printf("RESERVOIR  \n");
                        printf("CHARACTERISTICS:        %30s  \n");
                        printf("ENVIRONMENT OF \n");
                        printf("DEPOSITION:         %20s  \n");
                        printf("DEPTH         F.POPLN       F.DIV.FOSSIL
                            MARKER STAGE \n");
        for (i == 1; i <= num1; i++)
                printf("%5.2f %hd    %hd    %hd    %hd    %20s   %15s \n");
                fclose(fp);
                }
}
                goto 20;
```

```
250:    /* Delete a named file */
{
        printf("\n do you to delete a file (Y/N)?: ");          // display prompt.
        scanf("%c", &answer);       // accept input and store in answer.
                answer == toupper(answer);        // to uppper case
if (answer == 'Y')
        {
        printf("enter file name:         ");              // display  prompt for filename.
        scanf("%10s", filename);          // accept input from keyboard.
        int remove(const char *filename);    // deletes a file with the given name.
          //  If this is indeed possible, remove returns 0, if not,
            //   it returns a    nonzero value.

        printf(filename "has been deleted \n");
        }
     else
        { printf("The deleting operation on" filename "is aborted \n");
          printf("You will now be returned to the MAIN MENU, please");
        }
                goto 20;
}

300:    //EXIT module.
{       printf("\n want to exit (Y/N)?: "); scanf("%c", answer);
                        answer = toupper(answer); //  convertto upper case.
if (answer == 'N') goto 400;
   else
        void exit(int status);
          // This command line causes a normal program
        // termination and all open files are closed, as if the program
        // terminated normally without calling exit.
        // The use of the argument
        // status is system dependent.

400: goto 20;
void return(0);          //exit program.
}
```

GEODATA INTERPRETATION RESULTS

COMPANY	: SPDC	WELL CODE	:	401001
WELL NAME	: OSUOPELE-1	FIELD CODE	:	401
WELL NO.	: 1	OML	:	M31
LOCATION	: SWAMP	DATE	:	03/10/1994

RESERVOIR
CHARACTERISTICS : petroleum bearing strata
ENVIRON OF
DEPOSTION : marine continental facies
BEDMARK : sandy shale

DEPTH	F.POLN.	F.DIV.	P.POLN.	P.DIV.	FOSSIL MARKER	STAGE
3870	0	0	0	0	NONE	MESSINIAN-TURONIAN
4050	717	38	57	12	HAPLOPHRAGMOIDES-24	TURONIAN
4230	15	4	0	0	HAPLOPHRAGMOIDES-24	TURONIAN
4620	0	0	0	0	NO DATA	TURONIAN
4890	0	0	0	0	NO DATA	TURONIAN
5130	0	0	0	0	NO DATA	TURONIAN
5430	0	0	0	0	NO DATA	TURONIAN
5760	0	0	0	0	NO DATA	TURONIAN
5790	1	1	0	0	UVIGERINA-8	TURONIAN
5910	23	5	1	1	UVIGERINA-8	TURONIAN
6030	474	8	6	1	NONION-4	TURONIAN

GEODATA INTERPRETATION RESULTS

COMPANY	: SPDC	WELL CODE	: 401001
WELL NAME	: OSUOPELE-1	FIELD CODE	: 401
WELL NO.	: 1	OML	: M31
LOCATION	: SWAMP	DATE	: 03/10/1994

RESERVOIR
CHARACTERISTICS : petroleum bearing strata
ENVIRON OF
DEPOSTION : marine continental facies
BEDMARK : sandy shale

DEPTH	F.POLN.	F.DIV.	P.POLN.	P.DIV.	FOSSIL MARKER	STAGE
6061	12	2	0	0	NONION-4	TURONIAN
6073	0	0	0	0	NONE	TURONIAN
6120	1089	26	70	7	NONION-4	TURONIAN
6180	669	19	32	5	NONION-4	TURONIAN
6240	944	21	68	4	NONION-4	TURONIAN
6390	573	22	24	6	NONION-4	TURONIAN
6510	67	15	2	2	UVIGERINA-8	TURONIAN
6720	50	14	3	4	CASSIDULINA-7	TURONIAN

GEODATA INTERPRETATION RESULTS
MICROFAUNAL ZONATION

WELL NAME	FZONE	DEPTH TOP	DEPTH BOTTOM	REL. GRAD.	REMARKS	DATE
EGUNABO-1	F0001	0	4100		NO DATA	29/08/1997
EGUNABO-1	F0002	4120	4454		BARREN	29/08/1997
EGUNABO-1	F9697	5420	5520		HAPLOPHRAMOIDES-24	
EGUNABO-1	F9600	5630	11930		NONION-4	29/08/1997
EGUNABO-1	F9596	11940	12802		UVIGERINELLA-8	

GEODATA INTERPRETATION RESULTS
MICROFLORAL ZONATION

WELL NAME	FZONE	DEPTH TOP	DEPTH BOTTOM	REL. GRAD.	REMARKS	DATE
AGAYA-1	P800	5550	6090		UVIGERINELLA-8	31/03/1997
AGAYA-1	P820	6270	7890		UVIGERINELLA-8	31/03/1997
AGAYA-1	P780	8100	11900		NONION-4	31/03/1997
AGAYA-1	P770	11970	12980		CASSIDULIA-7	31/03/1997

GEODATA INTERPRETATION RESULTS

MICROFLORAL ZONATION

WELL NAME	FZONE	DEPTH TOP	DEPTH BOTTOM	REL. GRAD.	REMARKS	DATE
OGBOTOBO-1	P820	4270	5590	2	UVIGERINELLA-8	29/08/1997
OGBOTOBO-1	P788	5800	6275	4	UVIGERINELLA-8	29/08/1997
OGOBTOBO-1	P784	6365	9950	4	NONION-4	29/08/1997
OGBOTOBO-1	P770	10050	11950	2	CASSIDULIA-7	29/08/1997

GEODATA INTERPRETATION RESULTS
SEISMIC AND WELL LOGGING DATA

GEOPHONE SHOT PT.	TIME	SEISMIC CYCLES	GAMMA RAY	RESISTIVITY	DENSITY
240		10	100.2	58.6	42.1
300		10	150.5	62.4	48.8
360		9	111.3	100.8	101.4
480		9	58.9	59.1	78.6
540		9	65.5	80.2	90.8
600		8	120.6	100.8	120.0
660		11	124.7	120.3	111.1
720		11	148.8	156.2	130.2
780		8	118.6	149.5	150.6