complex is restricted to western North America and the *P. roveloi* and *P. endoi* complexes are known from both North America and Asia.

ROSS, JUNE PHILLIPS, Illinois State Geological Survey, Urbana, Illinois

Lower Permian Bryozoa, Carnarvon Basin, Western Australia

The early Permian (Asselian-Sakmarian) Lyons Group consisting of tillite, greywacke, sandstone, siltstone, and conglomerate rests unconformably on the Precambrian basement and is conformably overlain by the Permian (Artinskian) Callytharra Formation. Bryozoa occur in thin, local, calcareous lenses in the Lyons Group, 4,600 feet thick in its type section, whereas they form rich bryozoan calcarenites and bryozoan calcirudites in the overlying Callytharra Formation, 765 feet thick. The stenoporid species in the Lyons Group display similarities to certain Eastern Australian forms from the early Permian, and a well distributed fenestellid species of *Polypora* has close affinities with species from the Lower Permian in Eastern Australia and from the Bitauni Beds (equivalent to the Asselian Series of Russia) from Timor. These species of *Polypora* appear to be primitive members of a well-defined phylogenetic group of species including *P. tuberculifera*, *P. punctata*, *P. subovaticellata*, and *P. nadinae* from the upper part of the Sakmarian Series of the Ural Mountains. The geographic and stratigraphic distributions of such early Permian bryozoan lineages appear useful tools in the correlation of different stratigraphic units.

The generic and specific composition of the bryozoans in the overlying Callytharra Formation is vastly different and the bryozoan faunal break between these two stratigraphic units is very distinctive. Genera such as *Hexagonella*, *Evactinopora*, *Protoretepora*, *Ramipora*, *Streblotrypa*, *Rhombocladia*, and *Streblocladia* which are prominent in the Callytharra bryozoan faunas are not found in the Lyons Group.

RUMMERFIELD, BEN F., GeoData Corporation, Tulsa, Oklahoma
MORRISEY, NORMAN S., Consultant, Tulsa, Oklahoma

How to Evaluate Exploration Prospects

The problems of exploration evaluation are occupying an ever-increasing importance in the petroleum industry. Recent developments in exploration trends and in the field of data handling stress the need and desire to minimize risk in business decisions.

Geologic-geographic preference has long been an excellent criterion to determine where to concentrate exploration efforts. This becomes very obvious when the exploration efforts and results in areas such as the Gulf Coast and West Texas are carefully analyzed and compared with other areas. Exploring for oil in certain foreign countries, too, has paid off munificently, particularly when the oil finding costs are compared in dollars per barrel with similar costs in the United States.

All exploration programs have one common goal: To find and exploit oil and gas reserves at a profit. However, economic factors are playing an ever-increasingly important role. The problem of arriving at what appears to be the optimum route to follow in petroleum exploration can be facilitated by a statistical approach, particularly with the recent advent and utilization of data processing techniques. This approach is not a substitute for intelligence or judgment but it is a new advance in the solution of problems of all kinds. The theories of probability provide a method of measuring uncertainty that may lead to better exploration decisions.

Innumerable factors affect exploration decisions but these can be placed in four broad categories—geophysical, geological, economic and engineering aspects. Since the primary goal of any exploration problem is to find and exploit reserves efficiently, a realistic approach for exploration decisions is needed. The various factors must be considered and an attempt made to translate them into a desired return on investment. The resultant solution can be accepted or rejected, depending on good judgment and the particular company's criteria and policies.

Analytical evaluations bring oil exploration from the realm of educated guessing to a quantitative approach that fits into modern businesses' techniques. Management and explorationists can thus appraise the merits of a prospect or exploration program and expect to derive optimum results with minimum risk.

RUSNAK, GENE A., Institute of Marine Science, University of Miami, Florida
NESTEROFF, W. D., Laboratoire de Geologie Dynamique, Paris, France

Modern Turbidites: Terrigenous Abyssal Plain versus Bioclastic Basin*

Many of the fundamental characteristics of abyssal plain turbidites may be traced in the modern calcareous turbidites of the Tongue of the Ocean. However, less broad areas of coverage and greater diversity of the constituents are evident from the Tongue of the Ocean than would be expected in abyssal plain deposits. This difference reflects a narrower depositional basin and several localized sources, each with its own materials.

The abyssal plain deposits are laterally transported cyclic-graded beds of terrigenous sand, silt, and clay alternating with possibly minor layers of true pelagic sediment consisting of the vertically (particle by particle) settled clay components characteristic of red clays. The cyclic units are monotonously similar, with no outstanding distinctions between them except for thickness and maximum grain size, and are of broad areal extent.

The Tongue of the Ocean deposits are also cyclic, but the turbidites consist of bioclastics, pteropods, foraminiferal sands, and calcareous silts and clays; the pelagic beds between are homogeneous calcareous clayey silts (calcilutites) with varying amounts of Foraminifera and pteropods. The sediments are primarily calcareous silts in contrast to the terrigenous clays of the abyssal plain. Cyclic units vary in composition and are only locally distributed.

RYAN, ROBERT, Central Illinois Light Company, Peoria, Illinois
BUSCHBACH, T. C., Illinois State Geological Survey, Urbana, Illinois

Tectonic History of the Glasford Cryptoexplosion Structure

Exploration sponsored by the Central Illinois Light Company has delineated a structural high, 12 miles southwest of Peoria, near the village of Glasford, Illinois. The structure is nearly circular and consists of a normal sequence of Paleozoic strata down to the Ordovician Maquoketa Shale. The Maquoketa is abnormally thick over the dome, and the underlying 1,500 feet of rocks are faulted and severely brecciated. The structure appears

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* Contribution from the Marine Laboratory, University of Miami.

to be the result of a violent explosion caused by meteorite impact in very early Cincinnatian time.

Each recognizable stratigraphic interval thins over the brecciated core of the structure. Part of this thinning may be the result of differential compaction, comparable with that found over Silurian reefs. The possibility also exists that the brecciated core has been gradually and continuously uplifting, either by rebound after impact or by internal pressures locally exerting an upward movement through the area of disturbed rocks.

Isopach and structure maps indicate that the structural deformation continued into the Pennsylvanian Period and perhaps to the present time. Relative uplift of the dome has taken place at a gradually reducing rate, particularly after Devonian time.

SABINS, FLOYD F., JR., California Research Corporation, La Habra, California

SYMMETRY, STRATIGRAPHY, AND PETROGRAPHY OF CYCLIC CRETACEOUS DEPOSITS OF THE SAN JUAN BASIN

Late Cretaceous strata of the San Juan Basin consist cyclically interstratified non-marine, nearshore marine, and offshore marine clastic sediments which were deposited both during marine transgressions and regressions. Thickness of the transgressive and regressive parts of these cyclic sequences varies, permitting subdivision into two types of cycles: symmetrical and asymmetrical. In symmetrical cycles the thickness of transgressive and regressive parts are nearly equal; in asymmetrical cycles the transgressive sandstone is thin or absent.

The Hosta-Point Lookout wedge is an example of a symmetrical cycle. At its base the transgressive marine Hosta Sandstone overlies non-marine strata of the Crevasse Canyon Formation. The Hosta Sandstone grades upward into the offshore marine Satan Shale. The Satan Shale marks the mid-point of the cycle and the maximum marine inundation; it grades upward into the regressive marine Point Lookout Sandstone. The Point Lookout is overlain by the non-marine Menefee Formation. Southwestward, toward the former shoreline, the Satan Shale pinches out and the transgressive and regressive sandstones merge into a single massive sandstone, which is also called the Point Lookout Sandstone. Still farther southwestward this massive sandstone grades into non-marine strata of the Crevasse Canyon and Menefee formations.

The Mulatto-Dalton cycle is asymmetrical for it lacks a basal transgressive sandstone. Instead, the offshore Mulatto Shale directly overlies the non-marine Dilco Coal with only scattered marine sand lenses at the contact. The Mulatto Shale grades southwestward (toward the former shoreline) and upward into the regressive marine Dalton Sandstone which in turn grades southwestward into, and is overlain by, non-marine deposits of the Crevasse Canyon Formation.

Petrography is closely related to the sandstone depositional environments as follows.

Sandstone Type	*Petrography*
Regressive	Upward increase in maximum and median grain diameter; upward decrease in abundance of primary dolomite grains
Transgressive	Upward decrease in maximum and median grain diameter; upward increase in abundance of primary dolomite grains
Nonmarine	Wide range of grain sizes; primary dolomite grains absent; abundant carbonaceous material

These petrographic properties may be used to identify and correlate units in problem areas.

SANDERSON, G. A., Shell Oil Company, Midland, Texas
KING, W. E., Eastern New Mexico University, Portales, New Mexico

DIMPLE LIMESTONE MICROFOSSILS FROM THE MARATHON REGION OF TEXAS

Several exposures of the Dimple limestone in the western part of the Marathon region of Texas contain microfossils indicative of a shallow-water carbonate shelf biocoenose. Diagnostic microfossils include species of the fusulinid genera *Millerella*, *Staffella*, *Eochubertella*, *?Profusulinella* and *Fusulinella*, as well as algae and smaller Foraminifera. The fusulinids demonstrate that the Dimple Limestone is, at least in part, no older than Bendian (Atokan).

The limestone beds examined from the western and northwestern parts of the Marathon region consists, in part, of grainstones containing fossil fragments which indicate exposure to wave action. Graded bedding is generally absent, in contrast to the well graded turbidite beds (Thomasson and Thomson, 1963) on the east and southeast which contain redeposited, shallow-water benthonic fossils. Whether the western outcrops comprise redeposited material or *in situ* shelf sediments, the contained fossils establish at least a maximum age limit for the beds.

SCHAFER, SIDNEY, AND WEYAND, JACK C., Sidney Schafer and Company, Houston, Texas

ROLE OF GRAVITY DATA IN OFFSHORE EXPLORATION

Oil men, geophysicists, and geologists have been searching for years to find a direct method for locating oil and gas deposits. Strangely enough, an old method, gravity, comes very close to being such a method in certain areas such as the salt-dome province of South Louisiana. Most of the oil and gas fields of South Louisiana, both onshore and offshore, are associated with salt domes or salt masses. The gravity method is almost infallible in locating salt domes or salt masses.

The usual geophysical exploration procedure, a reconnaissance gravity survey followed by detailed seismic surveys of the gravity anomalies found, was not practical or feasible in the beginning of offshore exploration. Gravity exploration costs approximately ten times as much offshore as onshore and seismic exploration costs one third as much offshore as onshore. Except for a few instances, most companies completely dismissed gravity data in connection with their offshore prospecting. Improved underwater gravity meters and electronic surveying now make offshore gravity surveys practical and feasible but still rather costly. However, since the advent of joint participation by companies in extensive gravity programs, gravity data are now available at a nominal cost.

The next problem was to convince geophysicists, geologists, and management that they should obtain and use gravity data together with seismic data to evaluate offshore prospects. Many exploration people had been led to believe that the seismic method had rendered the gravity method obsolete and unnecessary.

There are numerous examples of failures on offshore seismic prospects which were selected and drilled without confirmation by gravity anomalies. In some areas seismic data are not at all conclusive, due to misleading multiple reflections, poor energy return and stray reflections, the sources of which can not be definitely determined. Since most oil fields in South Louisiana are