diameter per 100 square microns surface. *Globigerina bulloides* is roughly finished, and possesses only large conical pores spaced widely apart over the surface.

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Interpretation of Some Pennsylvanian Cyclothems through Environmental Mapping

Regional mapping of the sedimentary environments of the different stages within the Liverpool, Summum, St. David, Brereton, Sparland, Gimlet, Exline, Trivoli, and Carlinville cyclothems of Illinois has been completed, or is in progress, for western Kentucky, western Indiana, Illinois, Missouri, Iowa, eastern Kansas, and northeastern Oklahoma. These cyclothems cover the upper half of the Des Moinesian Series and the basal part of the Missourian Series of the Mid-Continent region. The maps are based on approximately 1,100 control points which, where possible, have a preferred geographic spacing of one point per township. Lithofacies maps were prepared for each depositional stage by placing, at each control point, the lithology, thickness, and other characteristic features such as fossils—plant and animal, color, and sedimentary structures. After the lithofacies maps were completed, the sedimentary environments were inferred.

A sequential viewing of the environmental maps gives an idea of the dynamic changes that occurred within the area and illustrates the alternate predominance of the opposing forces of marine transgressions and deltaic growth. The maps show that the western part of the region experienced predominantly marine conditions while the eastern part was subjected to predominantly non-marine conditions. The non-marine sands and shales of the delta and fluviatile environments followed the north, northeast, and east paleoslope in the region and formed platforms on which coal swamps could develop later. The marine water transgressed from the Mid-Continent, north of the Ozarks, into the Illinois basin, depositing marine limestones and shales.

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Cyclic Lacustrine Sediments in (Upper Triassic) Lockatong Formation, Central New Jersey and Adjacent Pennsylvania

Two kinds of cycles: "detrital" and "chemical" can be recognized in the Lockatong Formation, a lacustrine deposit of Late Triassic age in central New Jersey and adjacent Pennsylvania.

"Detrital" short cycles, averaging 17–22 feet thick, comprise several feet of black shale succeeded by platy carbonate-rich mudstone in the lower part and gray massive calcareous silty argillite in the upper. The argillite has a small-scale crenulate fabric produced by crumpled casts of shrinkage cracks and burrows. Thicker, coarser-grained "detrital" cycles contain 3–5-foot layers of thin-bedded, commonly cross-stratified, fine-grained sandstone. Some sandstone has small-scale convolute bedding.

More common "chemical" short cycles average 7–14 feet thick. Lower beds are alternating platy carbonate-rich mudstone and marlstone $\frac{1}{2}$–3 inches thick, extensively broken by crumpled shrinkage cracks. Locally, initial deposits are crystalline pyrite or dolomite (rarely calcite) as much as an inch thick. In the middle, several feet of dark gray mudstone encloses 1–3-inch layers of disrupted gray marlstone fragmented by syneresis. The upper part is massive gray analcime- and carbonate-rich argillite containing as much as 7 per cent soda, as little as 47 per cent silica, and a maximum of 35–40 per cent analcime. The argillite is brecciated on a microscopic scale, probably the product of syneresis. Much of the argillite is also disrupted by crumpled shrinkage cracks irregularly filled with crystalline dolomite and analcime.

Some thinner "chemical" cycles are reddish brown, especially in the uppermost part of the formation. These contain thin greenish gray beds of mosaic intraformational breccia produced by mud-cracking, and small lozenge-shape pseudomorphs of dolomite and analcime after glauberite(?).

Varve-counts in black mudstone suggest that short cycles resulted from 21,000-year precession cycles.

Groups of "detrital" and "chemical" short cycles in couples 325–350 feet thick apparently resulted from alternating wetter and drier phases of a long climate cycle, producing through-flowing drainage and a group of "detrital" short cycles or a closed basin and a group of "chemical" short cycles.

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Extending Photogeologic Horizons

Interpretation of aerial images, produced on photographic emulsions by radiation in the visible portion of the electromagnetic spectrum, is a well known and important tool of the exploration geologist. Visible light, however, comprises an extremely small portion of the electromagnetic spectrum. Airborne systems have been developed that are capable of recording images produced by radiation in the infrared, radar, and other spectral regions. Most infrared systems, as well as those employed in conventional aerial photography, are passive. In this case, radiation emitted by the material itself and reflected or reradiated energy, originating in some natural source such as the sun, are recorded. Radar, on the other hand, is an active system, i.e., energy of known characteristics is artificially propagated and the reflected or reradiated energy recorded.

Photographic emulsions are only sensitive to radiation having wavelengths of less than 1.35 microns (near infrared). The majority of infrared and radar systems, therefore, utilize various types of scanning devices which translate fluctuations in received energy into fluctuations in electrical currents. These electrical currents may be recorded directly or converted to light energy to produce images on photographic emulsions. Such images thus present the infrared or radar energy intensities of the viewed materials and differ from conventional visible-light aerial photographs. As in photogeology, identification of specific geologic conditions from infrared and radar images should be possible by analysis of such factors as image tone, texture, and pattern. Interpretation of infrared and radar strip maps holds great promise for complementing photogeologic investigations and increasing the amount of geologic data obtainable by airborne methods.

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Geophysical Research and Progress in Exploration

This is the fifth of a series of review papers on the subject of research and progress in geophysical exploration.

In the three years since the last presentation of this nature the most salient trend in geophysical exploration has been one toward full utilization of the available data. Modern data processing equipment and techniques of analysis are being introduced while theoretical studies attack seismic stumbling blocks like multiple reflections, ghosts, diffractions, and scattering.

The vistas of innovation opened by digital recording and processing spurred several operators to intensive study of the possibilities and the cost picture of digital methods. The use of seismic energy sources other than conventional dynamite explosions is increasing, as are special shooting techniques aimed at ghost elimination. Synthetic seismograms from continuous velocity logs are being brought to bear increasingly on stratigraphic problems; inverse convolution techniques seek to reconstruct the CVL from better quality seismograms while research on synthetic seismograms continues at a high level.

Applications of the rubidium vapor magnetometer have been reported both in exploration for minerals and for oil. The accuracy of the airborne gravimeter has been improved, but is still insufficient for exploration purposes. The shipborne companion instrument is in use as an exploration tool.

Existing well logging methods have undergone further development with modern methods of electronic data processing being applied increasingly. A new logging technique, nuclear magnetism logging, promises to give an indication of porosity above a certain pore size. The attenuation of the signal in acoustic well logging is being used to locate fractures and to evaluate cement bondings.

There is a new interest in natural electromagnetic fields and the degree of coherence between electric and magnetic field components.

Several of the projects sponsored by Vela Uniform, the U. S. Government Project created to achieve adequate detection of underground nuclear blasts by the U. S. Atomic Energy Commission and other agencies, have exploration potential (e.g., long seismic and electrical profiles, theoretical studies, certain instrumental developments).

Academic research in all branches of geophysics is active, with major benefits deriving from modern data handling techniques, and the new defense interest in the earth sciences providing many opportunities.

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Use of the Vertical Profile in Environmental Reconstruction

The relation of the vertical stratigraphic succession to areal depositional patterns was first observed by Johannes Walther and is known as Walther's Law of Facies. Each depositional unit in a vertical stratigraphic succession is the result of a particular sedimentary environment. When these units are compiled vertically, they represent a sequence of environments characteristic of a specific over-all sedimentary process such as regression or transgression. These environmental successions are definite and recognizable and may be used to define over-all sedimentary processes in ancient rocks. Therefore, environmental sequences provide a reference framework for interpreting the sedimentary history of any stratigraphic section.

Only a limited number of specific vertical sequences has been found in a comparative study of Recent and ancient sediments. The following sequences have been developed into models of sedimentation.

Regressive Marine

c. Marine shale or lagoonal deposits
b. Thin-bedded sand/silt and shale
a. Poorly bedded shale

Lowermost units are deposited below wave base; higher units close to sea-level.

Fluvial (channel or valley-fill sequence)

d. Ripple cross-laminated zone
c. Laminated, even-bedded sand/silt zone
b. Festoon cross-bedded zone
a. Basal conglomeratic bedload zone

Deltaic Sequences

Regressive marine sequences overlain by nearshore fluvial, bay, and marsh deposits; characterized by extensive marine deposits and variable non-marine sediment distribution patterns.

Transgressive Marine

b. Marine shales or fragmental limestones
a. Sand or silt

Widespread distribution and thinness are diagnostic; basal unit abruptly overlies shale in many instances; gradation upward into marine shale is rapid.

Bathyal-Abyssal Sediments

Widely distributed, thin-bedded; fauna and sedimentary structures characteristic of deeper water.

Lacustrine Sediments

Resembles regressive marine sequences, but is developed on a smaller scale and lacks marine fauna.

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General Tectonics and Paleozoic Stratigraphy of the Delaware Basin of West Texas

The pre-Morrow sediments of the Delaware basin were deposited uniformly over a cratonic shelf in a marine environment. During early Morrow time an orogenic movement began which reached its zenith during post-Morrow time. The area was severely eroded and peneplaned. During Strawn and later time, the area began to subside with definite depositional troughs forming. Generally, four facies were deposited simultaneously—the arkose and conglomerate facies on the flanks of the highlands, the lagoonal facies of light-colored limestones and shales in the marginal areas, local reef type or carbonate buildup facies, and the dark-colored basinal facies of limestones, shales, and sands. In some locales, the carbonate buildup facies tended to separate the lagoonal from the basinal facies. These conditions persisted until late Wolfcampian-early Leonardian time.

At this time, the area experienced a broad epeirogenic movement. This movement resulted in a change of regional strike and in many areas resulted in a change in the nature of the sediments being deposited. The sea, during Leonardian time, reached its maximum extent, and for the first time since pre-Morrow time, completely inundated the area. A well defined, barrier type reef developed which separated the light-colored lagoonal facies from the dark-colored basinal facies.

The sea began to recede by late Leonardian or early Guadalupian time. Reef growth continued until Ochoan time when an evaporitic basin was forming due to further restriction of the sea. The basin continued to subside as the continent emerged, resulting in a thick evaporite sequence. The end of the Permian was marked by the advent of the Triassic redbeds filling in the basin. This was followed by the complete uplift of the area during late Triassic and Jurassic time.