of the cycle was initiated by decrease in stream competence and continued basin subsidence. Changes in sea-level and stream competence depended on climatic variation.

TANNER, W. F., Department of Geology, Florida State University, Tallahassee, Florida

SCALED-UP MODEL IN STUDIES OF SEDIMENT TRANSPORT

The study of sediment transport has been handicapped greatly because most of the pertinent processes are too small and too fast to be observed, controlled, and measured. This is the reverse of the problem which confronts the student of tectonics: the processes which he wishes to clarify are too large and too slow to be observed, controlled, and measured. He attempts to solve this problem by scaling *down* the phenomena involved, building scaled models in which the model ratio of length is commonly on the order of 10-4 to 10-8, and other model ratios are set accordingly. The sedimentologist who would like a closer look at sediment transport can apply the same general methodology.

Scaled models have been employed, in the general field of hydrodynamics, for many years. The usual practice, however, is to select a reach of a river, or a stretch of beach, or a complete estuary, or perhaps even a complete ocean, and scale this study area *down*. In order to examine, in detail, sediment transport, the geologist must be prepared to design, build, and operate devices in which the model ratio of length is about 10^2: that is, he must scale *up*.

Consider a grain 0.4 mm in diameter. With a ratio of length $= 10^2$, one can design a grain which should behave as the tiny prototype does. The model grain will have a diameter of 4 cm. The shape and surface markings ideally should duplicate the original, and the density can be adjusted if necessary. The remaining criterion which must be satisfied is the Reynolds number, which involves fluid viscosity.

Once a few trials have been made, the experimenter can alter his variables so that more favorable velocities and viscosities are used. This alteration can be pushed until a change in behavior sets a limit; thereafter, all runs must be made on the correct side of the limiting value, but without necessarily matching the precise requirements of the model ratios. This permits considerable freedom in design and operation of the models.

Models of this kind show that turbulent regime holds, for settling grains, for Reynolds numbers of about 10, and more. The triple vortex trial which developes behind (above) the grain imparts both a spin and a spiral motion to the grain. Similar models can be operated and evaluated for grain pick-up.

THOMASSON, M. RAY, AND THOMSON, ALAN, Shell Oil Company, Midland, Texas

DIMPLE LIMESTONE—A TURBIDITE SEQUENCE

Recent work on the Dimple Limestone (Atokan) of the Marathon tectonic belt of West Texas indicates that it is predominantly a turbidite sequence deposited in relatively deep water below normal wave base. A narrow upperslope facies of nongraded, festoon cross-stratified grainstone, packstone, and chert conglomerate beds deposited in relatively shallow water occurs in the northwest part of the area. Wherever exposed, the formation is part of an overthrust complex which moved northwestward a distance of several miles or more.

The basin facies to the southeast consists of inter-bedded pelagic and turbidite beds. The pelagic beds are dark gray to black terrigenous shale, calcilutite, and chert containing a sparse fauna of radiolaria and sponge spicules. The turbidite beds are graded lithoclastic fossiliferous limestones ranging in thickness from less than an inch to more than 9 feet. Lithoclasts are mostly angular fragments of Devonian and Ordovician cherts. The fauna is characteristic of shallow shelf and slightly deeper slope environments, and indicates redeposition by turbidity currents. Small quantities of ooliths, pellets, glauconite, and quartz sand grains occur commonly in the turbidite beds.

The turbidite beds contain current direction features including aligned fossil fragments (particularly sponge spicules and brachiopod spines), cross laminae, ripple marks, and flame structures; and slope indicators such as convolutions and medium-scale slump structures. Sole markings are not evident. Delicate laminae in upper parts of graded beds commonly consist of siliceous sponge spicules aligned parallel with the current direction.

Numerous measured sections of the basin facies indicate a record of continuous deposition from the flysch-like Tesnus Formation, through the Dimple Limestone, and into the overlying flysch-like Haymond Formation. Submarine slides containing large blocks of white Devonian chert locally produced erosional surfaces. A comparison of the Tesnus Formation, Dimple Limestone, and Haymond Formation with the Scaglia-Brecciola-Macigno sequence of the northern Apennines shows striking similarities.

Current direction indicators, bed thickness, grain size, facies, and over-all formation thickness indicate that the Dimple Limestone was transported down a slope from the northwest. During early Atokan time, a carbonate shelf in the vicinity of the Glass Mountains provided shallow-water fossils and other carbonate debris for later redeposition in a relatively deep basin on the southeast.

TOWE, KENNETH M., HAY, WILLIAM W., AND WRIGHT, RAMIL C., Electron Microscope Laboratory and Department of Geology, University of Illinois, Urbana, Illinois

EXAMINATION OF THE ULTRASTRUCTURE OF SOME FORAMINIFERAL TESTS

Foraminiferal tests have been studied in the electron-microscope using carbon replicas. Thin sections of the tests have been studied in transmitted and polarized light and phase microscopy. Miliolids show two intergrading kinds of surficial ultrastructure; some areas are made of numerous oriented rhombs of calcite, presenting a pattern resembling a tile roof; other areas show randomly distributed rods of calcite. In phase microscopy, sections of the miliolid test present a furry appearance. *Peneroplis planatus* shows a more massive surficial ultrastructure, and presents a different appearance in polarized light, certain layers having oriented calcite crystals. *Nodosaria affinis* and *Robulus midwayensis* have perforate areas with about 50 pores per 100 square microns surface area, each pore being about ½ micron in diameter. Imperforate areas of these tests are made of relatively large crystals of calcite, up to 2 microns in diameter. Sieve plates have been found covering the ends of pore canals in *R. midwayensis*. *Sphaeroidina bulloides* and *Bulimina marginata* are strikingly similar in their ultrastructure. They have about 40 pores per 100 square microns surface area. The pores average ½ micron in diameter. *Discorbis vesicularis* has a rough surface, and only about 4 pores 2 microns in diameter per 100 square microns surface area. *Elphidium macellum* has a finely finished surface and 120 pores ½ micron in diameter per 100 square microns surface. *Globigerina bulloides* is roughly finished, and possesses only large conical pores spaced widely apart over the surface.

TUBB, J. B., JR., GEDNETZ, D. R., GLOVER, A. D., MANOS, C. T., ORLOPP, D. E., ROSEMAN, C., AND WEINER, J. L., University of Illinois, Urbana, Illinois

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.

VAN HOUTEN, F. B., Princeton, New Jersey

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.

VAN LOPIK, JACK R., AND FEDER, ALLEN M., Geoscience Department, Texas Instruments Incorporated, Dallas, Texas

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.

VAN MELLE, F. A., FAASS, D. L., KAUFMAN, S., POSTMA, G. W., AND SERIFF, A. J., Shell Development Company, Houston, Texas

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