Grand Saline salt dome, Texas, and Winnfield salt dome, Louisiana, have well-developed cap rock on top of them and topographic lows at the surface. In contrast to this, the Five Islands domes of South Louisiana form topographic highs at the surface and give evidence of recent and perhaps fairly rapid movement. Differences in types of fold structure observed in these domes also suggest more recent and rapid movement of the South Louisiana domes. Salt petrofabric patterns indicate that there is a more distinct preferred orientation of salt crystals in the central parts of domes than in their periphery. The relatively stable domes have a more distinct orientation than those that have been subject to Recent differential movement.

The best preferred orientation patterns of salt from Grand Saline are derived from samples taken farthest from the dome margin, and can be related to dodecahedral or cubic gliding of halite if the axial planes of the folds are considered to be the planes of motion. Samples from Winnfield dome show less distinct preferred orientation patterns than those from Grand Saline, but are interpreted as combinations of cubic and dodecahedral gliding or superimposed patterns resulting from successive movements of the salt in different directions. Recent surveying of a water-etch line formed about 27 years ago inside the Winnfield dome when the mine was temporarily flooded show irregularities that may indicate slight differential movement during that interval. Irregular uplift probably tends to blur or destroy the patterns of preferred orientation that formed during slow unidirectional movement, and distinct petrofabric patterns therefore probably indicate a condition of relative stability.

MURRAY, GROVER E., Department of Geology, Louisiana State University, Baton Rouge, Louisiana

GEOLOGY OF GULF COAST SALT DOMES

More than 300 diapiric structures formed by the intrusion of relatively pure salt are known in Alabama, Mississippi, Louisiana, Arkansas, and Texas. In form, they are rod-like, domal, anticlinal, and ridge-like; they rise vertically or nearly so; and they expand or contract with depth. Some reflect growth by a succession of differently positioned, local uplifts, as well as shifts in the locus of principal growth. Many are capped by residual masses of anhydrite, altered in varying degrees to gypsum, sulphur, and calcite.

Modern theory postulates growth resulting from density differences between the salt and surrounding sediments through (1) upthrusting (upward movement of salt through sediments in response to gravitational inequilibrium), or (2) downbuilding (maintenance of an essentially static level by the salt while the surrounding sediments subside). Model studies suggest that variations in overburden and faulting are primary motivators of growth.

The "parent" bed from which the salt came exists at depths which range from less than 10,000 to approximately 30,000 feet and is judged to have been as much as 5,000 feet thick. It may have covered as much as 150,000–200,000 square miles and may have had a volume of 50,000–100,000 cubic miles. The presence of large amounts of calcium sulphates peripheral to the Gulf of Mexico basin suggests that the salt is a precipitate from brines concentrated in the Gulf basin or in partially restricted marginal basins.

Surrounding sediments are arched adjacent to or over the salt masses. They may thin against or over the salt to more than half their normal thickness. Normal faults frequently disrupt them; reverse faults are extremely rare. Grabens, occasional horsts, multiple offsets in single or different directions, and radial, tangential, or peripheral faults often combine to form complex patterns.

MUSGRAVE, A. W., Mobil Oil Company, Dallas, Texas, and HICKS, W. G.[1]

OUTLINING OF SHALE MASSES BY GEOPHYSICAL METHODS

Shale masses are here defined as large bodies of shale at least several hundred feet in thickness. These may be formed either as diapiric masses (as described by Atwater and others) or as depositional masses. The shale masses exhibit the following properties by comparison to the normal section: (1) low velocities, in the range of 6,500′/sec to 8,500′/sec, with very little increase of velocity with depth, (2) low densities—in the range 2.1 to 2.3, (3) low resistivities—approximately 0.5 ohm-meters, and (4) high pressures—about 0.9 overburden pressure. These properties all seem to be caused by the high porosity and low permeability of these large shale masses.

Maps and cross-sections of Ship Shoal Block 113 field, offshore Louisiana, illustrate how a shale mass is outlined by geophysical means. Low velocities were measured by acoustic logs and verified by refraction shooting. Low densities were deduced from gravity maps. Low resistivities were observed on the electric logs and high pressure was deduced from drilling difficulties with heaving shales.

The shale mass, like the salt mass (commonly combined to form the domal mass), may form the updip seal for stratigraphic accumulation of oil.

MYERS, DONALD A., U. S. Geological Survey, Denver, Colorado

RHYTHMIC SEDIMENTATION IN UPPER PART OF MADERA LIMESTONE, NORTHERN MANZANO MOUNTAINS, NEW MEXICO

The Manzano Mountains, on the east edge of the Rio Grande Valley south of Albuquerque, are fault-block mountains tilted to the east. Precambrian rocks that make up the main mass of the mountains are overlain by about 180 feet of clastic rocks assigned to the Sandia Formation of Middle Pennsylvanian age, which in turn is conformably overlain by the Madera Limestone of Middle and Late Pennsylvanian age. Fusulinid faunas indicate that the lower part of the Madera Limestone, about 600 feet thick, was deposited during Des Moines time, and the upper part of the Madera Limestone, about 780 feet thick, during Missouri and Virgil time.

As exposed near Tajique, the upper part of the Madera Limestone consists of three similar sequences of limestone and clastic rocks, designated units B, C, and D, of Missouri, early and middle Virgil, and later Virgil ages, respectively.

Unit C, the best exposed and most typical, consists of a basal channel-like deposit of arkose and siltstone as much as 90 feet thick which, to the east, may be truncated by reef-like masses of limestone. It grades upward into siltstone followed by gray shale that contains local red beds and becomes calcareous toward the top. A limestone unit as much as 140 feet thick conformably overlies the shale. The basal part of the limestone is commonly yellowish gray, poorly bedded calcilutite that contains many algal (?) bodies. The calcilutite grades upward into light olive-gray, well-bedded, bioclastic calcarenite composed in large part of comminuted shell

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[1] Deceased. Formerly with Mid-Tex Oil & Gas Co., Midland, Texas.

debris. In turn, this bioclastic member grades upward into calcarenite composed of particles of limestone. Basal arkose of unit D overlies the calcarenite.

Unit B, insofar as exposed, and unit D show this same sequence of rocks, although there are differences in the proportion of red beds.

NAGATA, TAKESI, Department of Earth and Planetary Sciences, University of Pittsburgh, Pittsburgh, Pennsylvania

Magnetism of the Earth's Crust and the Earth's Interior

Power spectrum analyses of the geomagnetic field over the earth's surface show that the field fluctuations of wave lengths shorter than about a thousand kilometers are connected mostly with the geological structure of the earth's crust. Possible interpretations of the relation between geological structure and the surface geomagnetic anomalies are demonstrated by referring to fairly detailed maps of geology, geomagnetic anomaly, and Bouger anomaly of the gravity field over Japan Islands as well as magnetic properties of various rocks. Special attention is drawn to the absolute importance of natural remanent magnetization of rocks for this kind of interpretation.

It seems likely that geomagnetic anomalies of wave lengths from several hundred kilometers to several thousand kilometers are related to the distribution of continents, to the variation of thickness of the earth's crust, and to the undulation of isothermal surfaces in the earth's upper mantle. Geomagnetic field fluctuations of larger scale seem to be attributable to the electric eddy currents just beneath the surface of the earth's core.

NAIDU, A. S., and RAO, C. BORRESWARA, Department of Geology, Andhra University, Waltair, India

Some Aspects of Lower Godavari River and Delta Sediments, India

To study the progressive changes along a river and to delineate sedimentary environments based on variations in the litho- and chemo-facies, 400 recent sediments from the fluvio-marine environment of the Godavari were collected in the pre- and post-flood seasons.

The present river morphology is a manifestation of the bed load material. Higher silt-clay ratios increase the degree of sinuosity and decrease the width/depth ratios of the channels. Decrease in the sinuosity of the river course in the last one hundred years is probably a result of the coarsening in the bed load.

Mean size decreases and coefficient of sorting increases progressively along the river course; skewness changes from positive to negative while kurtosis remains constant. These changes are probably attributable to the decrease in the energy levels downstream.

Heavy mineral percentages are directly proportional to the mean size of the sediments. Heavy minerals indicate a predominantly igneous (acidic) and high-grade metamorphic (khondalite, calc-granulite, and amphibolite) provenance. Few authigenic and rounded zircons are considered secondary. Downstream increase of pyroboles and sillimanite, and decrease of opaques and garnets, is apparently due to sorting based on shape and density.

Delineation of sedimentary environments based on conventional size measures has been partially successful. Similarity in the backwater and marine shoal sediments north of the river confluence indicates that the former was a part of the open sea.

Phosphate, uranium, and iron concentrations were determined in the clay fractions. Phosphate and iron are highest in the marshes. Iron concentration decreases in the backwater and is least in the river channels. Preliminary data show higher uranium content in the upper river.

X-ray analyses show illite, chlorite, and Na-montmorillonite increasing and Ca-Na montmorillonite and kaolinite decreasing from the fluvial to the marine environment. Na-montmorillonite is more predominant in the swamps and illite in the backwater.

The hydrographic data collected are being processed to understand the physico-chemical conditions of deposition.

OAKESHOTT, G. B., California Division of Mines, San Francisco, California

Diapiric Structures in the Diablo Range, California

The Diablo Range is one of the northwest-trending central Coast Ranges of California. It is a complexly-faulted, asymmetrical anticlinorium structurally bounded on the west by the San Andreas fault and on the east by the San Joaquin Valley. Its core consists of the Late Jurassic Franciscan Formation and intruding serpentine. These rocks were formed in an extremely deep and narrow eugeosynclinal trough directly on a simatic base. Younger, flanking rocks, locally overturned, are of Early Cretaceous to late Pliocene age. Core rocks crop out (1) as faulted slivers in the San Andreas fault zone and (2) as piercements along the crest of the principal anticlinal axis.

A major diastrophic episode closed the Jurassic period, broad folding took place late in the Cretaceous, and local uplift occurred in late Miocene time. The piercements transected rocks of the anticlinal crest in late Pliocene and early Pleistocene time.

The diapiric structures are the result of intense compression of a thick sedimentary wedge, accompanied by great vertical movements in a series of intermittent orogenies. Sheared serpentine played an important part in final emplacement. In the broad view, these structures are but detail in the great fault features of western California which developed at the continental margin while faulting, folding, and intrusion took place during thrusting of the simatic sea-floor materials under the sialic edge of the continent.

ODÉ, H., Shell Development Company, Houston, Texas

Viscous Properties and Creep of Salt

Experiments by Nettleton and others to simulate salt dome formation by means of superposed viscous liquids have clearly demonstrated that gravitational instability provides a physically sufficient explanation of the origin of these structures. In the hydrodynamic theory of stability of a layered sequence, exceedingly high viscous parameters must be used. Very few reliable direct measurements of the viscosity of rocks, obtained in the laboratory under realistic conditions of strain rate, pressure, and temperature, are available. The reason is that creep is a complex phenomenon, part of which is of a transient nature. Most creep rates measured for rocks and cited in the literature refer to transient creep and are probably of little value with regard to a determination of rock viscosity. Only the steady-state creep be-