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STRATIFICATION, BED FORMS, AND FLOW PHENOMENA
(WITH AN EXAMPLE FROM THE RIO GRANDE)

Flow in alluvial channels is controlled by many variables, most of which are interdependent and adjust mutually. Bed form, for example, adjusts in response to changes in depth and slope, to changes in diameter, density, and shape of particles, and to changes in viscosity and density of the sediment-water mixture. Because stratification is the product of migrating bed forms, it too is complexly related to many variables. The concept of flow regime allows a grouping of the combined effects of these variables.

Five distinct stratification types were recognized in shallow trenches in the Rio Grande bed near El Paso, Texas. Four of these stratification types are products of specific bed forms observed in this section of the river during the preceding irrigation season, when discharge, velocity, depth, channel width, temperature, and sediment concentration had been measured and bed forms mapped at the trench areas. The five stratification types that can be related in a general way to flow phenomena follow. (1) Large-scale trough cross-stratification (sets 0.2-2 feet thick), volumetrically the most important sedimentary structure, forms by dune migration in the upper part of lower-flow regime where water depths exceed one foot. (2) Small-scale trough cross-stratification (sets 0.1 foot thick) commonly veneers the river bed and forms by ripple migration in the lower part of the lower-flow regime. (3) Tabular cross-stratification (sets 0.2-2 feet thick) forms by migration of bars or of terrace-like features in the lower-flow regime. (4) Horizontal stratification is the product of plane-bed transport achieved in the upper-flow regime, and is preserved in thin sheet-like sets on bar surfaces. (5) Parallel stratification, represented in a thin silt and clay layer mantling the forms on the emerged river bed, is deposited by settling of suspended material as flow slackens.

Stratification is potentially one of the most useful indicators of flow environment. However, stratification is the product of many complexly interrelated variables, some of which leave no discrete geologic record. Stratigraphers have traditionally interpreted stratification in terms of velocity depth, and (or) slope. Such interpretations are incomplete considerations of the problem and are commonly incorrect. It is more correct and useful to state environment simply in terms of flow regime, the integrated resultant of all variables.

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X-RAY SPECTROGRAPHIC ANALYSIS OF MINUTE MINERAL SAMPLES

X-ray spectrographic analysis is applied to the analysis of one milligram aliquots of mineral samples. Investigation of the sulpho-salt family of minerals indicated a need for non-destructive analysis of minute quantities of mineral samples usually available for study. Thus the X-ray spectrograph method offered a likely possibility.

The apparatus used in the spectrographic analysis consisted of a Norelco generator, a vacuum sample container (in which the sample is inverted), and circuit panel equipped with a scintillation counter and pulse height analyzer.

Standardization was achieved by analysis of 100 milli-

gram aliquots of selected mineral samples using the fusion technique. The samples were fused in 100:1 ratio of potassium pyrosulphate and the intensity ratios of the elements compared with those obtained from artificial standards to give the atomic ratios. Working curves were then prepared from finely ground 1 milligram aliquots of the analyzed minerals.

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EFFECT OF HURRICANES ON NEARSHORE SEDIMENTARY ENVIRONMENTS OF COASTAL BEND AREA OF SOUTH TEXAS

Tropical storms of hurricane strength (winds > 75 mph) cross the coastline between Tampico, Mexico, and Port Arthur, Texas, with a frequency of approximately one storm in two years. Greatest geological effects are produced by waves driven by winds that sometimes gust to 200 mph and by the tremendous elevations of water level that occur during storm tides (maximum of 22 ft. recorded at Port Lavaca, Texas, during Hurricane *Carla*, Sept., 1961). The comparison of a part of the nearshore environmental complex of the coastal bend area of south Texas before and after Hurricane *Carla* shows the effects of the storm.

The *inner continental shelf* bottom was both a contributor and a receiver of hurricane deposits. As the storm moved landward, it picked up mollusk shells indicative of depths up to 12 fathoms (for example, *Dinocardium*, *Semele*, *Strombus*, *Murex*, *Atrina*) and removed Pleistocene (?) rock fragments, coral blocks, and other materials from the sea floor, and deposited all these on the barrier island. After the storm passed inland, water rushed from the lagoon back to sea through numerous channels cut into the island by the storm. These currents deposited a thin layer (0.5-1.5 in.) of sand over what was previously sandy mud bottom to depths of about 60 ft. and a graded layer of fine sand, silt, and clay farther out on the shelf.

The seaward side of the barrier island (Padre Island) was severely altered. The storm removed a belt of fore-dunes 20-50 yards wide from the seaward side of the island and left a belt of larger dunes, partly stabilized by vegetation, with wave-cut cliffs up to 10 ft. high. Waves breaching inland deeply excavated many dunes along their flanks. The formation of a broad, flat "hurricane beach," consisting of poorly sorted sand and coarse shell, drastically altered the beach profile.

The landward side of the barrier island (*wind-tidal flats*) received much washover material containing placers of surf zone and beach mollusks (especially *Donax* sp.). The storm also submered high-level mud flats along the landward side of Laguna Madre and covered them with a fresh layer of mud.

A much milder storm (*Cindy*) passed through the area in September, 1963, and a small bar was deposited over the seaward edge of the pre-existing "hurricane beach."

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LATE TERTIARY AND QUATERNARY EVENTS AS INTERPRETED FROM RADIOLARIA IN ANTARCTIC SEDIMENTS

A study of the radiolaria from the tops of more than 80 cores spaced around the Antarctic continent between 35° and 77°S. has revealed two distinct faunas, the boundary between them corresponding closely with the position of the South Polar Front (Antarctic Con-

gence). An examination of samples taken at 40-cm. intervals down cores from both north and south of the Polar Front shows that several cores located north of the Polar Front contain alternating layers of the two faunas, whereas cores located at the south show no such faunal fluctuations. If the alternating faunal zones observed in the northern cores are caused by a shift in the position of the Polar Front, then the data collected so far suggest that the Polar Front today may be as far south as it has been during the time period represented by the cores sampled.

Other changes are exhibited by 10 cores from the area. In these cores there is an abrupt change from a fauna composed predominantly of recent species, the majority of which are not found living in Antarctic waters today. This change in the radiolarian assemblage is accompanied in 80 cores by a large decrease in other siliceous or calcareous organisms. In two cores the carbonate content drops from 40-60 per cent to zero. In one core the older assemblage is associated with abundant discoasters and on this basis is tentatively assigned a Late Tertiary age.

The cause of the change in planktonic assemblages from Late Tertiary to Quaternary is not known, but it is suggested that it may be due to a change from a relatively stable stratification of the Antarctic Ocean during Late Tertiary to a stronger degree of vertical convection in the Quaternary associated with the cooling of this part of the world during the growth of the Antarctic ice cap.

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LITHIUM METASOMATISM AROUND PEGMATITES

A widespread exogenetic effect accompanying the crystallization of lithium pegmatites is the introduction of small amounts of lithium into the wall rocks. Lithium is not found in altered wall rock around pegmatites that do not contain independent lithium minerals. This metasomatic lithium is housed in a number of different minerals, especially muscovite, biotite, tourmaline, and holmquistite. Lithium-bearing hedenbergite and hornblende each have been reported from a single deposit. Likewise, lepidolite and zinnwaldite have each been reported once, but proof of their identities has not been given. Thus it may be affirmed that the major pegmatic species (spodumene, lepidolite, petalite, amblygonite, Fe-Mn-Li phosphates) are not formed exogenetically.

Mineralogically, two types of lithium metasomatism are known. (1) The lithium is restricted to combinations of muscovite, biotite (usually also contains Li, Rb, Cs) and tourmaline. This type occurs typically in micaceous schists or gneisses around zoned or structurally complex pegmatites that contain lepidolite, amblygonite, Fe-Mn-Li phosphates \pm spodumene. (2) The lithium occurs chiefly in holmquistite (\pm a narrow Li-biotite zone closer to the pegmatite). This is developed invariably in hornblende wall rocks around unzoned, poorly zoned (Kings Mtn. type), or zoned pegmatites that contain early-crystallized spodumene, usually as the sole lithium species, or with petalite, rarely with lepidolite.

The number of holmquistite occurrences is now known to be ten, with a new discovery at Bernic Lake.

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PROPERTIES OF THE CRUST

Early refraction studies of the crust used widely spaced observing points. Consequently, secondary

arrivals, including possible reflections, could not be identified. This required the use of first arrivals, which limited the definition of the method.

Under the VELA UNIFORM project for the improvement of seismology, techniques and instrumentation have been developed closely paralleling those used in the study of sedimentary columns: continuous profiles, close spacing of observation points, high recording speed, use of magnetic tape recording, etc. These techniques have been applied widely in the United States, less widely in Canada; analogous techniques are well advanced in the Soviet Union.

The crust in continents varies from a thickness of about 20 km. in some coastal areas to as much as 50 km. in high plateau areas. Over most continental areas of moderate elevation the average thickness is 35 km. The number of layers in the crust is open to question. It is generally accepted that there are two layers, an upper granitic one and a lower basaltic one, but these are clearly defined only in some high plateau areas. In most regions a model involving a functional increase of velocity with depth fits the data as well as any system of discrete layers.

Most recent studies show no simple relationship between crustal thickness, surface elevation, and gravity values. Isostatic compensation may be accomplished through variation in the thickness, or the mean density of the crust, or by mass redistribution in the mantle.

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GENETIC AND GEOMETRIC RELATIONS BETWEEN STRUCTURES IN BASEMENT AND OVERLYING SEDIMENTARY ROCKS, WITH EXAMPLES FROM THE COLORADO PLATEAU AND WYOMING

Field studies of jointing, faulting, and folding in the San Juan-Grand Canyon region, Arizona, and the Bighorn-North Laramie region, Wyoming, show that tectonic movements are primarily vertical. Maximum deformation of the rocks occur along narrow, linear zones which appear to follow elements of a primordial fracture pattern in the Precambrian basement. Sedimentary rocks play a passive role in the formation of folds and structural lineaments.

Fold geometries are determined by the developing geometry of the basement surface. The basic causes and mechanisms of deformation are generated in basement rocks below the level of the sedimentary strata. Structures in the sedimentary strata are of secondary origin, generated as a result of folding following basement deformation.

Prominent fracture trends of Precambrian age in the basement rocks of the Grand Canyon region are present as major elements of the joint patterns in overlying sedimentary rocks.

Large-order structural lineaments in the Bighorn region are long, narrow zones of deformation in sedimentary rocks which reflect deformations in the underlying basement rocks. Areally, structural lineaments follow some element of the regional fracture pattern.

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NORMAL AND REVERSE PLEOCHROISM IN BIOTITE

Normal biotite has the absorption formula $Y > Z > X$ with Y reddish brown, Z greenish brown (thick sections only) and X pale brown. Rarely biotite is pleochroic with absorption $X > Y > Z$. Blue River, B. C., biotite is of the second ("reverse") type with the pleo-