of asymmetric, upward-coarsening, depositional sequences referred to here as "cycles." Four major cycles called sandstone "zones" by others, have been studied in exposures and mapped in the subsurface in a preliminary manner. Thinner, less conspicuous cycles occur within each major cycle.

Where typically developed, a cycle begins with relatively non-sandy gray shale at the base and becomes progressively more sandy upward, terminating where the cycle is thickest with a conspicuous body of fine- to medium-grained, submature to mature, chert-rich orthoquartzite having a relatively sharp upper boundary. Chert-rich pebble conglomerate of uncertain origin occurs in places within the sandier parts of the cycles.

Detailed correlations of bentonitic layers reveal that the major cycles pinch and swell laterally in a complex but generally systematic manner, displaying two- to four-fold thickness variations. The relatively thick parts of each major cycle generally lie on flanks of the underlying cycle. Proceeding upward through the sequence, axes of maximum sandstone development are offset progressively eastward away from the central Casper arch. The uppermost cycle also is relatively thick and sandy on the arch.

Upward coarsening within the cycles and the complex, but orderly, shifting pattern of the depositional axes of the major cycles suggest that the rate of sediment influx exceeded the rate of subsidence in the area during deposition of the Frontier. The thickness variations are *not* most plausibly explained by differential compaction or by differential subsidence, at least in the lower three major cycles. Thickness trends suggest that the major source of sand was north and northwest of the Casper arch area.

Although the cycles appear to be essentially regressive in nature, sand deposition under transgressive conditions is suggested in places by more glauconitic and (or) calcareous upper parts of the sandstone bodies. West of the Casper arch, coaly beds and channel-like conglomerate lenses directly overlie sandstone bodies in cycles that otherwise are similar. Definite evidence of non-marine deposition has not been observed in the Casper arch study area and general observations suggest that the sequence is essentially marine. As reasoned from stratigraphic observations, the general slope at the top of the lowermost major cycle did not exceed ½° and the maximum depth of water in the area was about 100 ft.

Although understanding of the depositional agents must await additional studies specifically aimed at this objective, some analogies are drawn between gross characteristics of the cycles and typical features of deltaic deposits along modern shorelines.

More realistic concepts of the internal geometry and genesis of sandstone and shale complexes could be of considerable aid to the petroleum geologist in explaining and predicting oil and gas occurrences.

24. EDWIN D. MCKEE, U. S. Geological Survey, Denver, Colorado

Study of Sedimentary Structures

Primary structures in sedimentary rocks are significant in the interpretation of ancient environments. They furnish data on the processes involved and on the general geologic setting inasmuch as most are formed at the time of deposition. Because numerous sedimentary structures are poorly understood, much information still is needed both from observation of modern sediments and from controlled experiments before general conclusions can be reached concerning the genesis of many rock types.

Principal varieties of stratification and cross-stratification are described with reference to environments in which they are known to have been formed. Some of these structures are typical of more than one environment; most environments are characterized by two or more varieties of structures. Knowledge concerning natural combinations or associations of structures, therefore, is especially useful in interpreting conditions of deposition.

25. DARYL B. SIMONS, Colorado State University, Fort Collins, Colorado

Interpretations of Sedimentary Structures by Flume Experiments

The various types of bed roughness that are formed by the interaction between the flowing water and a sand bed form distinctive but complex sedimentary structures. The resultant forms of bed roughness and sedimentary structures are related to many variables such as regime of flow, channel geometry, velocity, and the characteristics of the sediment. By studying the characteristics of the sedimentary structures, it is possible to determine quantitatively the magnitude of many of these variables. The characteristics of the sediment can be determined by analyzing samples from the sedimentary structures. The regimes of flow and forms of bed roughness can be identified from the cross-bedding of the sedimentary structures. The spacing and amplitude of these structures indicate velocity and depth of flow at the time of deposition. From relations describing channel geometry and with preceding information, channel width can be determined approximately. Last, knowing channel geometry, type of bed roughness, and the characteristics of the sediment, various sediment transport relations can be used to estimate the total bed-material discharge.

In summary, utilizing knowledge of the relations between bed forms, bars, sedimentary structures, hydraulic variables, sediment variables, sediment discharge, and channel geometry, it is possible to determine quantitatively many of the hydraulic and hydrologic characteristics of the depositional environment that formed the sedimentary structures.

26. CHARLES D. MASTERS, Pan American Petroleum Corporation, Denver, Colorado

Stratigraphic Analysis Through Determination of Depositional Environments

The Mesaverde Formation of the Western Interior Cretaceous seaway includes rock units representative of off-beach, beach, lagoon, swamp, and floodplain environments of deposition. Because of migration of the shoreline by transgression and regression, the sedimentary products of various environments are arranged vertically in the geologic record in the same succession as they occurred laterally at the time of deposition. The detailed distribution of the potential reservoir beach sandstone bodies in a regressive sequence follows different patterns, depending on variations in the relative rate of submergence during progradation. These variations are reflected in the character of the back-beach environment. A mainland beach-floodplain progradation, reflecting a low rate of submergence, results in a tabular sheet of beach sandstone which intertongues only slightly with the overlying flood-