nifer zones of Bolli (1965), Bermúdez (1966), Banner and Blow (1965), and radiometric dating of terrestrial mammalian remains (Evernden *et al.*, 1964). "Warm" and "cold" are used to denote *complex climatic events* in which temperature is one of many factors influencing the biostratigraphic record.

An Oligo-Miocene plankton correlation model (Rothwell, ms., Geneva, 1967) shows great mobility of benthonic lineages synchronous with poleward extension of planktonic zones of Blow *et al.* (1965) during warm transgressive cycles. Conversely, there are trends toward restricted mobility of both fossil plankton and benthos during major cold climatic changes at approximately 17, 24, 30, and 37 m.y.B.P.

Radiometric dating within representative sequences of mammalian provincial ages and superposition of Pacific marine and nonmarine strata have established a nearly complete North American Cenozoic biostratigraphic history. No stage name has been accepted yet in Europe for an approximate 7-m.y. interval of the "upper Oligocene/lower Miocene" which is well represented by Pacific and Gulf Coast faunas and in the world tropical planktonic foraminifer zonation approximately in N1 to within N4 of Banner and Blow (1965).

An Upper Cambrian correlation model, using the trilobite data and biomere concept of A. R. Palmer (1965), illustrates mirror-image biostratigraphic relations of benthonic and "planktonic" trilobites of Pacific and Atlantic sources, suggesting three major climatic cycles in the Upper Cambrian correlated with Palmer's biomere boundaries.

Both the Cenozoic and Cambrian studies illustrate mirror-image biostratigraphic trends between widely separated geographic regions, suggesting major irregular synchronous climatic cycles of 3–8 m.y. duration. Uniformitarian physical (Nairn, 1965) and biologic principles can explain the analogies between the Cambrian and Oligocene-Miocene fossil occurrences which are modified by complex climatic causes resulting in unique physical and evolutionary histories.

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SEDIMENTOLOGIC ANALYSIS OF TONGUE RIVER AND SENTINEL BUTTE FORMATIONS (PALEOCENE), WESTERN NORTH DAKOTA

The contact between the Tongue River and Sentinel Butte sequences of western North Dakota has been regarded by many workers as a vague color boundary within a relatively homogeneous sequence of continental Paleocene strata. Recognition of distinctive stratigraphic relations at the Tongue River—Sentinel Butte contact, and documentation of their regional persistence, demonstrate that the Sentinel Butte interval is a mappable lithostratigraphic unit which merits formational rank. Granulometric analysis of approximately 500 sediment samples from 11 stratigraphic sections amplify textural differences of the units; Tongue River sediments are finer grained and less well sorted than the Sentinel Butte Formation and median diameter and skewness are environmentally sensitive particle-size statistics.

CM patterns illustrate the fluvial origin of these Paleocene deposits and are used to differentiate sediment-transport types and depositional environment; channel, floodplain, and backswamp facies are recognized. Significant differences in the regimes of fluvial systems which existed during middle and late Paleocene times are suggested by differences in the relative abundance of facies types.

Sedimentation models have been formulated for each sequence. Tongue River strata were dispersed eastward across the North Dakota part of the Williston basin by slow-moving streams which drained a low-lying source area on the west. Paleoslope gradient was low and sediments were transported primarily in suspension. The fluvial system was stable and protected backswamps developed. Basinal subsidence was uniform and controlled the rate of sedimentation during most of the episode; western North Dakota was near base level during the time of Tongue River deposition. Near the close of the episode, the elevation of the source area was reduced, basinal subsidence exceeded sedimentation, and swamp conditions prevailed through much of western North Dakota.

Sentinel Butte deposition was begun by an influx of coarse sediment dispersed eastward and southeastward, in deltaic fashion, across the last Tongue River swamps. Streams had slightly greater velocities than those of the previous episode, but sediment transport was still primarily by suspension. The paleoslope appears to have been variable, both in magnitude and direction, and reflects mid-Paleocene tectonism on the west and northwest. The elevation of western North Dakota above base level increased during the time of Sentinel Butte deposition, probably due to vertical accretion and eastward overstepping of the Sentinel Butte sequence.

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MORPHOLOGIC VARIABILITY OF GENUS *Schwagerina* IN PERMIAN WREFORD LIMESTONE OF KANSAS

Fusulinids referable to the genus *Schwagerina* occur in the basal part of the Threemile Limestone Member of the Permian Wreford Formation in Chase County, Kansas. Three hundred specimens from six collecting localities in four townships in Chase County were used in this study. The restricted stratigraphic range and limited geographic distribution of the fusulinid fauna within the intracratonic, cyclical succession tend to minimize the effects of diachronism, and it is presumed that the collections approximately are contemporaneous.

Considerable morphologic variability is evident within the Threemile fusulinid fauna, and affinities with several previously described species of *Schwagerina* can be demonstrated. Studies of measurable morphologic parameters suggest that all the Wreford schwagerinids sampled are referable to a single population, and thus the validity of several established taxa is open to challenge.

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ANALYTICAL APPROACH TO NIAGARAN STRATIGRAPHY, MICHIGAN BASIN

Analytical techniques utilizing very small samples make it possible to work with drill cuttings as well as cores and surface samples and obtain quantitative chemical analyses of the hydrochloric acid soluble

parts of carbonate rocks. Reasonably small samples also can be used to obtain semiquantitative insoluble residue data. The combined procedures yield accurate classifications and descriptions of carbonate sediments. The data are plotted as varying ratios in obtaining curves which are susceptible to visual correlation. These procedures yield common denominators which are applicable equally to surface rocks. They also equate with electric logs so that detailed analysis of all sections is unnecessary.

Reliable correlations generally place considerable dependence on a genetic interpretation of the sediments involved. The data permit some generalizations regarding the origin of carbonate rocks, particularly dolomite, as well as forming a basis for the interpretation of the carbonates in the northern part of the Michigan basin.

A continuous core for beginning the study was available from Grand Traverse County and surface exposures also occur in the northern part of the basin. The core from Carter Oil Company No. 1 Lemcool included all but the top 17 ft of the Niagaran and extended into the Alexandrian. Some rotary samples and surface collections also are being analyzed. In all, approximately 475 analyses are available at the writing of this abstract.

On the basis of the analytical data, subdivision of the subsurface sections into stratigraphic units is possible although this becomes difficult if formations are dolomitized extensively. The process of dolomitization appears to result in unconformity of some of the parameters and implies chemical equilibrium within these rocks so that correlation is more dependent on the residues.

Although the subsurface stratigraphic units appear to correlate with surface stratigraphy, these are not necessarily time correlations in a strict sense. Layers with arenaceous foraminifers do not appear to have equivalence. The petrogenesis of the rocks can be interpreted and facies relations determined but the correlation of time-stratigraphic units, at least in this area, may be an ephemeral concept.

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SARIR, LIBYA: DESERT SURPRISE

The Bunker Hunt-British Petroleum's Sarir oil field of Libya appears to be truly one of the 10 or 12 supergiants of the world. Credited with approximately 12 to 15 billion bbl of in-place oil, it is a water-drive field that could and probably will eventually recover nearly 50 percent of the total oil present. There is a maximum 300-ft oil column and an area of surface closure of 155 sq mi. The field was discovered in November 1961 on a seismograph-defined structure. Development drilling was steady throughout the next 4 yr, and culminated with pipeline, loading terminal, and first actual production in late 1966. The oil reservoir is a Cretaceous sandstone on basement, the oil source being the several hundred feet of overlying marine Cretaceous shale. Structurally, the field is a combination anticline and high fault-block complex within a broad structural low.

There appears to be a good fluid communication throughout the reservoir. Average porosity values are about 18–19 percent and permeability values average several hundred millidarcys, with some 2–3 d streaks. All production is water-free. It is a sweet, sulfur-free oil, though of high paraffin content.

More than 100 wells have been drilled. About 70 are on production; 12 to 14 are waiting on gathering lines; and most of the remainder are observation wells for pressure or fluid control. There has been some decline of reservoir pressure during the first year of production; however, in most of the field a sustained water drive is developing. Individual well-producing capacities range from a few thousand barrels daily up to estimates of 28,000 to 30,000 bbl daily in the best wells. The field went on production at 100,000 bbls daily. This figure rose to 300,000 bbls within the first year. Additional field facilities will permit even greater increases in the future.

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EVAPORITE DEPOSITION IN DEEP WATER

Reasoning by analogy with modern salinas, most geologists believe that ancient marine evaporite deposits were formed in shallow, slowly subsiding basins in regions of arid or semiarid climate. When this "Salina" model is applied to several well-studied ancient salt deposits, however, inconsistencies arise which suggest the need for an alternative hypothesis.

Sedimentation rates inferred for the Zechstein salts of Germany and the Salina of Michigan appear compatible with temperate rather than arid climates. More significantly, the thickness of evaporite salts in each of these localities requires either extremely rapid subsidence of the evaporite basin or salt deposition during a period of time substantially greater than that permitted by existing stratigraphic control. In addition, the petrography and bromine content of the halite in both basins may be reconciled with the "Salina" model only with great difficulty.

Most of the inconsistencies observed may be overcome by postulating salt deposition in a basin several hundred to several thousand feet deep. A "deep basin" model of evaporite deposition is developed in detail. The model is shown to be both geologically and oceanographically reasonable, and to be consistent with at least part of the depositional history of both Zechstein and Michigan evaporite basins. Direct stratigraphic evidence of deep-water evaporite deposition in the Midland basin is cited in further support of the model.

The Elk Point evaporites of Alberta are examined in the light of the deep basin model, and certain implications of the model for the exploration geologist in this region are developed.

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SIMULTANEOUS EVAPORITE–CARBONATE DEPOSITION?

It is widely accepted that carbonates, especially where these give evidence of origin as banks or reefs, and the primary evaporites with which they are associated closely, represent two distinct successive phases of deposition: (1) a stage of carbonate bank or reef deposition under conditions of normal marine circulation, followed by, (2) a time of sulfate and chloride accumulation under conditions of restricted circulation. Examples of the application of this concept are found in the literature and in current discussions of