photographs taken from orbital altitudes. Sufficient relatively high-quality space photography is available to permit evaluation of selected areas offering a broad spectrum of structural complexities, rock types, and geographic locations. An important aspect of hyperaltitude photography is the synoptic overview of large areas without regard to natural and artificial boundaries. This type of view will prove quite valuable in regional geologic studies and the planning of exploratory programs. Many difficult geologic problems in one area may easily be solved by comparison with another area where the critical relations are exposed. Certain electronic image enhancement techniques may prove to be a valuable aid in the interpretation process, especially for the ERTS imagery. The ERTS program scheduled for 1972 will furnish imagery with a ground resolution of 400–600 ft. The Skylab program in 1973 will provide the geologist with excellent color photography with 30–60-ft resolution of large areas between the 50th parallels. Space photography should yield important data which will result in a much better understanding of such things as major tectonism, continental drift, nearshore deposition, and comparative geology on a global scale.

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TRANSPORT OF OCEAN SEDIMENTS BY DEBRIS FLOW

Debris flow, a gravity-transport mechanism commonly observed on land, may be a significant agent of high-density mass transport of sediment in the oceans. Debris flow is distinguished from other mass-transport agents by the mechanism of support of granular solids in the flow. Support is provided mainly by the strength of the debris, but also by buoyant forces. Strength is derived from the fluid phase of the debris (clay minerals plus water), which acts as a plastico-viscous material. Suspension of granular solids by this mechanism does not depend on flow conditions and occurs if the debris is moving very slowly or even not at all. Movement of a debris flow depends on a critical thickness of the debris as well as the internal-friction angle. The slope angle required for debris flow typically is less than the 18–37° required for normal grain flows or avalanching. Thus, debris flow may carry large amounts of sediment in suspension while moving sluggishly down a gentle slope. The amount of clay, relative to granular solids, necessary completely to support sand-size material is on the order of 10% or less. Thus, sandy debris-flow deposits may be texturally similar to current-deposited sands.

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SIGNIFICANCE OF THIN CARBONATES IN INTERPRETING DEPOSITIONAL ENVIRONMENTS OF THICK CLASTIC SEQUENCES

When interpreting depositional environments of dominantly clastic sequences, thin carbonates, if present, often are overlooked or given short shrift. Detailed study of the carbonates, however, can be instrumental in environmental interpretations of enclosing clastics. This is particularly true if the clastic units lack fossils or environmentally significant sedimentary structures. This hypothesis is supported by 2 examples from Pennsylvanian and Permian strata of southeastern Wyoming.

The Permian Goose Egg Formation consists of thick, red siltstone and mudstone with interbedded thin, widespread carbonates. The clastic units have been interpreted by various workers as deep-water marine, shallow marine, deltaic, specialized marine, or continental deposits. Petrographic examination of the carbonates suggests that they were deposited in shallow subtidal, intertidal, and supratidal environments. The facies mosaic exhibited by the carbonates suggests that enclosing siltstone and mudstone were deposited in nonmarine environments.

Festoon cross-stratified sandstone which characterizes the Casper Formation (Pennsylvanian-Permian) in the extreme southern Laramie basin has been interpreted as marine, subaerial, or fluvial in origin. Carbonate beds in the Casper Formation are thin, lenticular lithosomes of limited geographic extent. Petrologic studies of these limestones suggest that they were deposited in small lakes or ponds which periodically were emergent. The inferred environment of carbonate deposition supports a subaerial dune environment for the festoon cross-stratified clastics.

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EXPLORATION AND DEVELOPMENT OF NATURAL GAS, 1970–1975

The energy crisis in the United States has been making headlines for more than 2 years. Most energy materials are expected to be in short supply, but the shortage of natural gas is recognized as being most critical. Liquefied natural gas and coal gas will supply a part of the demand but most of the new gas required must result from domestic drilling. An all out effort must be made to discover and develop the 1,178 trillion cu ft of gas estimated by the Potential Gas Committee to remain undiscovered in the United States. Cost of finding and developing this new gas might well be in the same range as the estimated cost of LNG and coal gas.

Compensation for today's higher risks and higher costs must be provided by incentives in the form of tax credits and higher wellhead prices. A graduated wildcat-well tax credit, similar to the now repealed investment tax credit, may be the way to encourage the drilling of the higher risk new-field wildcats required to discover the gas that the country will require during the next 2 decades.

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COPRECIPITATION OF STRONTIUM AND MAGNESIUM WITH HOLOCENE CAVE CALCITES, BARBADOS, WEST INDIES

Within stalactites from Barbados caves, progressively younger calcite conical growth layers and central canal void-filling calcites contain smaller amounts of Sr and Mg. The observed distribution of Sr and Mg in the stalactites is in agreement with a solution-reprecipitation model in which calcite-to-calcite transitions within a low-Mg calcite vadose zone yield amounts of Sr and Mg decreasing with time to vadose water seeping into ventilated cavern macropores. Within the overall trend of decreasing Sr and Mg content, vadose seepage and speleothem calcites may become locally enriched in Sr and Mg when (1) the groundwater temperature decreases, thus affecting the temperature dependence of the calcite-water distribution coefficients for Sr (0.14 ± 0.02 at 25°C) and Mg (0.062 ± 0.015 at 27°C), or (2) meteoric waters bypass the upper vadose zone to dissolve low-Mg calcites of higher Sr and Mg content in the

deeper parts of the vadose environment. As determined from radiocarbon dating, the stalactites have vertical growth rates of from 0.013 to 0.22 mm/yr and an average rate of lateral conical growth layer accretion of 0.006 mm/yr.

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SOME FACTORS CONTROLLING EVOLUTION OF NEAR-SURFACE DIAGENETIC FABRICS IN PLEISTOCENE CARBONATES OF BARBADOS

On the uplifted Pleistocene reef tracts of Barbados the nature and distribution of subaerial diagenetic fabrics reflect changes in 3 primary controlling factors: climate, soil, and substrate facies. These factors influence the amount and rate at which meteoric water is introduced into and held within the immediate subsurface.

Annual rainfall varies areally by a factor of 2, and evaporation, locally potentially greater than precipitation, is generally at a maximum in areas coincident with minimum rainfall. Soils grade from montmorillonitic, with an exceedingly slow rate of internal drainage, to kaolinitic, where drainage is as much as an order of magnitude faster. Substrate facies plays a subordinate but definite role in that sediments with a very open framework are incapable of retaining the pore water necessary for upward capillary transfer back to the evaporative sediment-air interface.

Subaerial fabrics are best developed in areas of low rainfall, high evaporation, and montmorillonitic soil cover. These conditions favor a local solution-reprecipitation process at or near the rock-soil-air interface. Where water is introduced into the subsurface in greater quantity or more quickly (because of higher rainfall and/or more kaolinitic soils) intense dissolution predominates, commonly with the attendant destruction of earlier formed subaerial fabrics.

Subaerial diagenesis appears to be a geologically rapid process bearing a nonlinear relation to length of exposure. Fabrics are equally well developed on successive reef tracts spanning approximately 300,000 years of exposure, and are present on subsurface discontinuities which represent breaks of only a few thousand years.

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PERMIAN PALYNOFLORAS AND THEIR BEARING ON CONTINENTAL DRIFT

By use of standardized taxonomic groups, Permian miospore assemblages were subjected to areal and temporal analysis on a global scale. The distribution patterns confirm the existence of botanic provinces and subprovinces during the Permian Period. Each botanic province has different characteristics and their geographic distribution is related to Permian latitudinal belts and sea-floor spreading.

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EXPLORATORY SUCCESS IS PREDICTABLE—EXAMPLE FROM DENVER BASIN

Analyses of Denver basin Cretaceous "D" and "J" sandstone fields reveal trends in field size and areal extent that should be helpful in predicting results of new exploration in areas with similar stratigraphy and geologic history. Within the 11-county "fairway" (excluding Arapahoe and Elbert Counties, Colorado), during the 1949–1969 period, there were 9,512 exploratory wells (11% oil, 2% gas) and 8,650 development wells (52% oil, 2% gas).

A log-log plot showing areal extent (in acres) versus ultimate oil recovery of 557 fields (218 abandoned, 339 extrapolated from production-decline curves) is a straight line and may be used in estimating the ultimate recovery of fields that have areal definition but insufficient history for extrapolatable decline curves. As an example, the 4,640-acre Peoria field (limit of present development) should have an ultimate production of 25 million bbl, if it is an average Denver basin field.

"D" and "J" production to January 1, 1970, was 560 million bbl (Colorado, 304 million bbl; Nebraska, 256 million bbl). Estimated reserves are 75 million bbl (Colorado, 37 million bbl; Nebraska, 38 million bbl). The area analyzed contains approximately 17,000 sq mi; 1,700 sq mi (10%) has oil or gas production (more than 400,000 bbl/productive sq mi). Approximately 200 of the 1,700 sq mi has gas production, but during 1971 an additional 1,000 sq mi has been added in the spaced area of Wattenberg gas field.

Oil fields were divided into 16 size classes (ultimate production), each class twice the size of the next smaller class, and the number of fields was plotted versus the size on semi-log paper. The resulting plots show a log-normal size distribution for both Colorado and Nebraska. It would have been possible, given a projected number of wildcat wells, to predict the approximate number and sizes of fields found in Nebraska from Colorado data, or vice versa.

Extension of the "fairway" into Arapahoe County and the northern townships of Elbert County should result in a predictable number of fields, and their size distribution should follow the pattern developed by past exploration. At least 60 million bbls should be added to the basin oil reserves (including Peoria), if there is sufficient exploratory drilling. Eleven percent of the wildcats should be oil discoveries and 2% of the wildcats should discover fields of one million bbls or more.

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IMPLICATIONS OF PROBABILISTIC STRATIGRAPHY

If stratigraphic correlation expresses the probability that samples from 2 different sections represent the same level in a known sequence of events, it can be considered to be the product of the probabilities that (a) the events defining the stratigraphic increment have been detected, (b) the true sequence of events is known, and (c) the events have been correctly identified. If the probability of correlation is to be greater than 0.90, each of the 3 factors must have a probability greater than 0.96. From this several important implications can be drawn.

1. If fossils are used to determine stratigraphic events, samples must generally have populations of hundreds of specimens.

2. The probability that a sequence of genetically unrelated events is correctly known reaches the required level only if sequence pairs are known from 6 sections and never occur in reverse order, or are known from 9 sections with 1 reversed occurrence, or from 12 sections with 2 reversed occurrences, or from 15 sections with 3 reversed occurrences, *etc.*

3. After 7 sections have been examined for sequences of event pairs and no reversed pairs are