

is the relatively high content of particles of less than 1 $\mu$  size in the latter.

It is concluded that the observed variations in the texture of the sediments from various environments of the Godavari delta may serve as criteria in the recognition of environments of deposition of a paleodelta.

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#### AMBIGUITY FUNCTIONS AND CONCEPT OF GEOLOGICAL CORRELATION

A profitable approach to quantitative geology is by identification of the methods currently employed. It is clear, for example, that the intuitive notion of correlation is vastly more general than the mathematical operation of the same name. Most obvious among the differences is the lack of provision for stretching or shrinking of scales during comparison.

The ambiguity function, an elementary extension of cross correlation, includes a scale variable, has a name taken from the parlance of radar engineers, and was devised originally for measuring target velocities or detecting fast-moving targets. Yet these same principles offer an effective means for identifying thinning or thickening stratigraphic sections with the use of well-log characteristics for matching magnetic profiles and following trends, or for estimating dispersion from seismic results.

Other applications will become apparent as the theory is exposed and simple examples studied. The principal accomplishment, however, is to bring the mathematical model of the correlation concept one step closer to the definition implied by actual practice.

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#### COMPOSITION, STRUCTURE, AND ERODIBILITY OF SUBTIDAL MATS, ABACO, BAHAMAS

In the Rock Harbour Cays, near Little Bahama Bank, the composition and microstructure of widespread, subtidal, sediment-binding, mat communities were examined and described. Mat-bound and unbound sediment surfaces were then subjected *in situ* to flume-created direct currents to test both resistance to erosion and breakdown behavior. The mat was removed by bleach treatment and the flume tests were repeated. The mats consist of algae, diatoms, and arenaceous tubes. Algae and/or tubes provide the resistant framework within which grains accumulate and are bound by mucilaginous secretions plus fine algal filaments. Three mat types were distinguished: a fibrous *Cladophoropsis* mat, a gelatinous *Lyngbya* mat, and an aggregated *Schizothrix* mat. Each mat type eroded in a characteristic manner and sequence dependent on mat composition and microstructure. Areas of intact mat withstood erosion better than irregular or broken surfaces. Mat-bound sediment surfaces withstood current velocities of more than 100 cm/sec, more than five times those required to erode mat-free surfaces. These studies indicate that particle size, sorting, packing, structure, and bedding-plane morphology are influenced by the presence of mats. Thus, consideration of mat communities is important when examining depositional and erosional processes at the sediment-water interface, or when making interpretation from ancient rocks which are the products of these processes.

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#### PLANKTONIC FORAMINIFERA FROM BASE OF TERTIARY, MILLERS FERRY, ALABAMA

The lower few centimeters of the Tertiary (Pine Barren) above the Cretaceous (Prairie Bluff) at Millers Ferry, Alabama, contains an assemblage of very small planktonic Foraminifera with largest dimensions of less than 100  $\mu$ . These foraminifers occur in the basal part of the *Globigerina edita* Zone (= *Globorotalia pseudobulloides* Zone) which corresponds in part to the lowest nannofossil zone of the Tertiary, the *Markalius astroporus* Zone. This assemblage occurs at a level similar to that of the central Apennines where Lüterbacher and Premoli Silva described a thin zone, named the *Globigerina eugubina* Zone, of very small planktonic Foraminifera.

A scanning electron-microscope study of the Alabama fossils suggests an evolutionary relation to species of the *Globigerina edita* Zone and to certain Cretaceous species. The Tertiary genera *Chiloguembelina* and *Globoconusa* appear morphologically close to *Guembelitra cretacea* Cushman of the Cretaceous, whose distribution in Cretaceous strata suggests that it was benthonic or had only a partly planktonic life stage. The Cretaceous planktonic species *Hedbergella monmouthensis* (Olsson) has morphologic characteristics similar to those of *Globigerina edita* Subbotina and also seems to be linked phylogenetically to *Globorotalia pseudobulloides* Plummer).

Perhaps the most significant evolutionary change that occurred in Cenozoic Globigerinacea is the modification of the outer bilamellid layers and the appearance of crustlike deposits of calcite in adult forms. These changes are viewed as adaptations to more efficient use of the water column including, perhaps for the first time, use of mesopelagic zone.

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#### SIGNIFICANCE OF PALYNOFORMS AS SEDIMENTATION INDICATORS IN CRETACEOUS STRAIGHT CLIFFS SANDSTONE, UTAH

Palynomorphs, which are abundant in maceration residues of many fine-grained clastic rocks, commonly include spore and pollen exines, waxy cuticles, resinous bodies, and vitrified and fusinized material which is incorporated with mineral grains in sediments. Differences in occurrence and relative abundance of the palynomorphs may be attributed to differential response of the particles to transport and sedimentation because of these parameters: (1) size: range from silt to fine sand; (2) shape: spheroidal, ovoidal, irregular, tabular, platy, or bladdered; (3) specific gravity: range from about 1.2 to 1.6.

Interpretation of the sedimentary environment of the Upper Cretaceous Straight Cliffs Sandstone is based on application of results of studies of the palylogy of several modern sedimentary areas, specifically by comparison of fossil and modern palynomorph residues. The following patterns are indicated for the paralic Straight Cliffs Sandstone:

1. In nearshore neritic beds, species of displaced terrigenous plants are numerous, marine microplankton abundant, resinous bodies and cuticles less abundant, and sorting poor. Apparently, once carried into the site of deposition, organic particles were winnowed little by offshore currents.

2. In nearshore continental beds, species of microfossils are less numerous generally; many beds contain mainly one kind of palynomorph, such as resinous bodies or fusinized material. Possibly this reflects local conditions which favor minimum particle transport and mixing.

3. Bladdered pollen grains occur in varying abundance in almost every bed regardless of other palynomorph abundance. Differing hydrodynamic response of these large grains may govern their anomalous occurrence, in contrast to smaller nonbladdered forms.

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#### PRACTICAL COMPARISON OF METHODS OF COMPUTING GRAIN-SIZE PARAMETERS

Sieved modern coastal sands were used to compute standard grain-size parameters from all known graphic formulas and the method of moments. Progressively greater variation existed in computation of mean, sorting, skewness, and kurtosis. As a group, Folk and Ward's parameters came closest to approximating moment parameters.

The median yielded the greatest deviation from the moment mean, being too fine for coarse-skewed samples and too coarse for fine-skewed samples. Graphic means were very close to the moment mean. Formulas (Folk and Ward, McCammon) considering points near the tails of the distribution and the median produced almost the same values as the moment mean. Formulas (Otto, Inman) omitting the median yielded slightly too coarse means for coarse-skewed samples and slightly too fine for fine-skewed samples. Sampling more than four frequency curve points did not increase accuracy of means or sorting estimates.

Among graphic sorting estimates, Krumbein's  $QD_\phi$  consistently was appreciably lower and Friedman's  $SO_\phi$  and Griffiths'  $PD_\phi$  consistently were appreciably higher than moment standard deviation. Cadigan's  $S$  and Otto's and Inman's  $\sigma_\phi$  produced irregular values averaging higher and lower, respectively, than moment values. Folk and Ward's  $\sigma I$  and McCammon's  $\sigma$  yielded consistent results slightly below moment values. Tanner's  $D_{3,29}$  produced the closest approach to moment values. The non-phi-unit methods (Trask's  $SO$ ; Miller and Zeigler's  $DS$ ; Sharp and Fan's  $Si$ ) showed the same relative change in sorting between samples.

No graphic skewness estimate correlated well with moment skewness, although they usually yielded the same sign. Only Folk and Ward's  $Sk_7$  and Inman's  $\sigma_\phi$  produced fairly consistent results close to the average skewness value. No graphic kurtosis estimate correlated with moment kurtosis, which was consistently higher.

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#### GRAIN AND GRAPTOLITE ORIENTATION IN TURBIDITE GRAYWACKE, CLORIDORME FORMATION (ORDOVICIAN), GASPÉ, QUEBEC

Sedimentary structures, textures, and fabric were studied in eight graywacke beds exposed on the wave-cut platform near Grande Vallée; these beds were traced continuously for 2 mi along the strike which is almost parallel with the average current direction indicated by sole marks.

The direction of current flow during deposition of

the bed was determined from intrabed lineations and grooves, oriented graptolites, and grain fabric. Most beds show large deviations of internal flow directions from sole-mark directions, particularly in distal regions. Internal directions were increasingly divergent from the sole toward the top of the bed. Agreement between dimensional grain orientations and other internal flow-direction indicators proves that grain orientations are depositional, not tectonic fabrics, and that grains generally were oriented parallel with the flow and imbricated in an upcurrent direction. Current-normal orientation was found in a plane-laminated part of one bed. Grains tend to lack statistically significant preferred orientation in proximal parts of the beds but show preferred orientation as the beds were traced distally.

These results suggest that existing concepts of turbidity-current flow are oversimplified and neglect the possibility of large changes in flow direction, perhaps caused by secondary currents within a single turbidity current.

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#### MULTIVARIATE FACIES MAPS

Facies maps are constructed from paleontologic and lithologic data to depict major and subtle depositional environment differences across a region during a specified time span. Ratio maps and three-component maps exhibit a lack of discrimination because they cannot incorporate all available data. Factor analysis and cluster analysis techniques can be used to construct truly multivariate facies maps. Earlier attempts at factor or cluster analysis multivariate facies maps had one or more deficiencies: (1) inability to handle a sufficient number of variables and locations; (2) inability to handle mixed-mode data (presence-absence, coded states, integer counts, and continuously variable measurements); (3) inability to take into account redundant or highly correlated variables; and (4) inability to accommodate to missing data.

A new cluster analysis classification computer program has been written to overcome these deficiencies. The FORTRAN IV program can utilize up to 200 variables on as many as 1,000 stations. It performs a distance function principal components analysis to compute orthogonal (uncorrelated) factor measurements for a distance function cluster analysis of locations. This combination will handle mixed-mode data and will adjust to missing data.

From the resulting multivariate classification of paleontologic and lithological data, a facies map showing the distribution of the various classes was constructed and compared with previously published facies maps. An example using multivariate lithologic data from coded AmStrat sample-description logs from central Montana demonstrates the potentialities of this method.

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MINERAL RESOURCE POTENTIAL OF CONTINENTAL MARGIN OF UNITED STATES

The submerged margin of the continent adjacent to the United States is an asset of great importance to the nation. In the aggregate it is a most promising frontier for exploration and development of mineral resources.

The continental margin, considered here to extend