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HIERARCHICAL ANALYSIS OF VARIANCE OF SHELF-SEDIMENT TEXTURE

Several geologic inferences are made from studies of the geographic distributions of sediment-texture variables. Evaluation of such distributions requires that information on the total within-station variability be available.

To obtain information on the relative magnitudes of the within-station and among-station variabilities, an extensive sampling program was undertaken on the continental shelf of Washington. Sampling was done in a stratified-multistage scheme on traverses placed by a systematic random system along the coast; 450 stations were occupied. Duplicate samples were taken at each station and duplicate analyses were made on each sample. Compete analyses are available for 130 stations. This sampling design leads directly to a three-level, hierarchical analysis of variance. In this analysis, the F-ratios of the mean square among stations to that within stations are measures of the reliability of distributions. Nine textural variables were measured in each of the analyses. Values of the ratios differed greatly among the variables. Table I indicates the F-ratios for the nine variables analyzed. Each ratio is based on 129 and 130 degrees of freedom.

Table I. F-Ratios for Nine Values Analyzed

Variable	$F_{129,130}$
Percent sand	27.65
Percent silt	22.54
Percent clay	1.71
Sand/mud ratio	15.54
Median phi size	17.74
Mean phi size	7.86
Sorting	5.58
Skewness	9.93
Kurtosis	4.70

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HEAVY MINERALS ON CONTINENTAL SHELF OF NORTHERN BERING SEA

Much of the Chirikov basin floor, which is carpeted with relict sand, has more heavy minerals than Norton Sound where modern fine-grained sediments dominate. In addition, the western section of the Chirikov basin is broadly divisible into two areas with relatively high concentrations of heavy minerals, separated by an area of low heavy-mineral content that trends approximately northwest-southeast. The northern areas seems to be richer in garnet (especially the pink type), epidote, and chloritoid. Staurolite, though present in small amounts, is consistently present in higher proportions in these sediments than in the sediments of the southern area. The northern sediments probably were derived either directly or indirectly from the metamorphic and other rocks of Seward Peninsula, whereas the provenance for the southern sediments is in the rocks of St. Lawrence Island. Compared with Chirikov basin, the heavy minerals of many of the deeper areas of Norton Sound consist of more ortho- and clinopyroxene and lesser amounts of garnet, and are relatively more rounded and suggest a Yukon River source. The Yukon River sediment apparently has encroached on areas of the extreme eastern section of the Chirikov basin. The heavy minerals of the sediments of shallower and nearshore areas of Norton Sound differ from those of the deeper areas and indicate derivation from nearby land sources.

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PROCESSES AFFECTING DISTRIBUTION AND DISPERSAL OF SUSPENDED MATTER IN COLUMBIA RIVER EFFLUENT SYSTEM

The sources of the suspended particulate matter derived from the summer mixing of Columbia River and ocean waters are river-borne particles, phytoplankton growing in the ocean near the river, and resuspended particles. The Columbia River contributes most of the particulate ($\geq 0.45\mu$) matter (8 to 40 mg/l) which consists of lithogenous particles (85–95 percent) and biogenous particles—primarily freshwater phytoplankton with lesser amounts of detritus. Biogenous matter, primarily phytoplankton and detritus (≤ 3 mg/l), constitutes the bulk of the particles found in the ocean. Resuspended particles, mainly lithogenous, are contributed locally into the water column near the river mouth by strong tidal and hydraulic currents.

Positive vertical gradients in particle concentrations are maintained in the low-salinity surface layers near the river mouth by vertical water movements (≥ 1 m/day) and by the relatively greater turbulence of the low-salinity surface layers. The upward component of the water movements is sufficient to retain lithogenous matter ($< 4\mu$) and most biogenous matter in the surface layers while transported seaward (10^3 to 10^4 m/day). Concentrations and modal particle diameters (10 to 30μ) of river-borne lithogenous particles, which differ with the rate of river discharge, decrease seaward by progressive mixing with ocean waters with less suspended matter (≤ 1 mg/l) and by settling of the ($> 4\mu$) suspended load.

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SAND TRANSPORT IN REGION OF SHOALING WAVES

The transportation of sediment by passing waves in the offshore zone has been investigated using SCUBA equipment in the sea off southern California. It has been found that the total grain-size population exposed on a sandy bottom, and not selective size grades, is moved by wave-generated oscillatory currents. Threshold velocities for the transport of sand by individual surges are largely a function of ripple mark relief. The relation between the quantity of sediment placed in motion and surge energy is arithmetic. Even under turbulent conditions almost all sand transportation is within a few inches of the sea floor. The concentration of sand decreases logarithmically above the bottom. The suspension of sandy sediment depends on current strength and ripple-mark dimensions. Although the sediments may be moved preferentially in certain directions, ripple marks are stationary and do not migrate along the sea floor.

The oscillating currents caused by a wave regime are not regular but have a spectrum of velocities. Where the seaward pulses are longer in duration, the highest velocities may be associated with either onshore or offshore flow. In the absence of strong coastal currents, the net water drift along the sea floor may be either toward or away from the beach, and it is influenced by the wave climate, tidal flux, wind, and internal waves. Research currently is in progress to determine the relation of hydrodynamic parameters to directions of sediment migration.

Rip currents also are important agents of sediment transport on the inner continental shelf and they have been studied in the Los Angeles area. Their development is influenced by wave climate, beach morphology, tidal level, and wind. Large rip currents carry significant quantities of sediment seaward. Rips of all sizes winnow fine-grained, low-density sand from the surf zone and thereby concentrate coarse grains and heavy minerals on the beach. The sand transported by rip currents settles to the sea floor beyond the breakers where it is influenced by wave-generated surge.

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Computer Simulation of Nearshore Sediment Transport

Can a heterogeneous mixture of sediment grains of various sizes and specific-gravity values be partitioned effectively into relatively homogenous sedimentary groups by diffusion processes in nearshore areas? If so, where will concentrations of heavy minerals occur, and what will be the relation between mineral concentrations and subaqueous topography, assuming constant wave conditions? A computer simulation model is used to explore these questions. Components of the model include: (1) a rectangular gridwork of cells, which is used to subdivide the region of interest, and provides the framework of an accounting system for keeping track of sediment movement, changes in bottom topography, wave energy and orbital velocities; (2) a wave-refraction algorithm, modified from Dobson which traces wave rays (calculating wave heights at intervals) from deep-water offshore into the shallow-water breaker zone; and (3) a sediment transport algorithm, which uses a two-dimensional diffusion equation with isotropic diffusion coefficients. Diffusion rates may be changed by altering the diffusion coefficients, which are here assumed to be a function of wave energy, grain size, and specific gravity.

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A "Semipro" Revisits Middle Tertiary Foraminiferal Sequence of California Coast Ranges

(No abstract submitted)

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Lineage Genera Classification of Lower Paleogene Planktonic Foraminifera

Current classifications of planktonic Foraminifera rely on rigid structural hierarchies, defining genera as narrow morphologic entities, commonly with long and discontinuous ranges. Such classifications do not satisfy the criteria of either monophyly or practicality. More properly, genera are based on phyletic successions of species through time, thus creating natural (Linnaean), monophyletic, and stratigraphically restricted taxa. Lower Paleocene species are here reclassified into five lineage-genera. These genera partly overlap in gross morphology and in certain iteratively developed analogous structures, but possess adequate diagnostic features (especially wall texture) for recognition.

All presently recognized Paleocene lineages except the chilogümbelinids (including *Globoconusa*) are derived from the early Danian species "*Globorotalia*" *pseudobulloides*, and become sufficiently divergent for generic distinction by late Danian time. This species is derived from, and congeneric with, "*Hedbergella*" *monmouthensis*.

Globanomalina includes smooth-walled, compressed, globorotaloid forms with slit-like extraumbilical apertures; finely perforate peripheral rims (keels) occur in two species. Morphotypes transitional with the Eocene planispiral genus *Pseudohastigerina* occur in the uppermost Paleocene and are best interpreted to be part of the reaction range of *Globanomalina chapmani*. *Subbotina* includes globigerinid forms with pitted, coarsely perforate (reticulate) walls; late middle Eocene populations gave rise to the predominantly Neogene genera *Globorotaloides* and *Catapsydrax*.

An innovation critical for phylogeny was the development of coarsely hispid wall surfaces, which first appeared in neanic chambers of the early Danian form, "*Globorotalia*" *pseudobulloides praecursoria*. Intensification and persistence into adult chambers of hispid ornamentation accompanied the transition of "*G.*" *pseudobulloides praecursoria* to "*Globorotalia*" *inconstans* in middle Danian time. "*G.*" *inconstans* is the phyletic base for two isochronous radiations characterized by densely hispid wall surfaces.

Acarinina includes globigerinid forms with rounded chambers and umbilical to extraumbilical primary apertures. Dorsal sutural apertures appear in two middle Eocene species (*Truncorotaloides* of authors); these forms, however, are phyletic "dead-ends" and are not here afforded generic recognition. *Morozovella* includes globorotaloid forms with conicotruncate chambers and peripheral concentrations of somewhat elongate rugosities (keels). Both radiations diverge into several disparate lineages. Poorly understood problems of intense parallelism and isomorphism preclude for the present more refined delineation of phylogenies.

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Planktonic Foraminiferal Indices Common to Lower Pliocene of Southern California and Italy

Five planktonic foraminiferal relations common to the lower Pliocene marine record of Italy and southern California are: (1) "*Sphaeroidinellopsis*" has an upper limit within or near the top of the lower Pliocene; (2) "*Sphaeroidinella dehiscens*" (Parker and Jones) makes its first appearance within or at the base of the lower Pliocene; (3) *Globigerina woodi decoraperta* Takayanagi and Saito extends through the lower Pliocene into the middle Pliocene; (4) rare specimens referable to *Turborotalia globorotaloidea* (Colom), a typical upper Miocene species, continue to occur in the lower Pliocene; and (5) *Turborotalia puncticulata* (d'Orbigny) appears to be restricted to the lower Pliocene in both areas.