neously, the percentage of warmer water species shows an increase in the Holocene. *Neogloboquadrina dutertrei* (d'Orbigny) increases from about 5% of the population below the boundary to about 15–20% above, and *Pulleniatina obliquiloculata* (Parker and Jones) increases from less than 1% to 10%.

There is a significant increase in the radiolarian number in sediments of the Holocene.

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LATE QUATERNARY BIOSTRATIGRAPHY OF CORES FROM BENEATH CALIFORNIA CURRENT

A study of deep-sea cores, which approximate the extent of the California Current, indicates that faunal changes occur at or near the lithologic Pleistocene-Holocene boundary off San Francisco and Los Angeles, California, but generally below this boundary off Cedros Island, Baja California. In upper Pleistocene rocks there are (1) a marked increase of radiolarian tests per gram of dry sediment; (2) a sharp decrease in both planktonic foraminiferal tests per gram of dry sediment and in the median size of *Turborotalia pachyderma,* except off Los Angeles, where the trend is reversed; (3) an increase in the percentage of dextral-coiling *Turborotalia pachyderma;* (4) an influx of several rare planktonic foraminiferal species; and (5) a decrease in the relative abundance of *Globigerina bulloides* off San Francisco, of *Turborotalia pachyderma* off Los Angeles, and of *Globigerina quinqueloba* off Cedros Island, with a corresponding increase in relative abundance of *Globigerina quinqueloba* off San Francisco and Los Angeles and an increase of both *Neogloboquadrina dutertrei* and *Turborotalia pachyderma* off Cedros Island.

A period of seasonal warming in the early Wisconsin is indicated in the temperate Pacific Ocean. This assumption is based on the abundance of large temperate planktonic foraminiferal species per gram of dry sediment in the cores from off Los Angeles. This warming period correlates with the "warm interval" reported elsewhere.

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PRELIMINARY REVALUATION OF LATE MIOCENE BIOSTRATIGRAPHY OF CALIFORNIA[1]

Preliminary studies of the type Mohnian and Delmontian Stages and regional biostratigraphic studies of other late Miocene sections of California by the use of benthonic Foraminifera and fish indicate the following.

1. The Delmontian Stage of Kleinpell is correlative with his Mohnian Stage on the basis of the occurrence of (a) *Epistominella gyroidinaformis* (Cushman and Goudkhoff) in the lower part of the type Delmontian (this species does not range stratigraphically above early Mohnian in California); (b) *Bolivina hughesi* Cushman (=*Bolivina sinuata alisoensis* Cushman and Adams of others), *Bulimina delreyensis* Cushman and Galliher, and *Etringus scintillans* Jordan in the upper part of the type Mohnian in California; and (c) Late Miocene megafossils in the Santa Margarita Sandstone, which overlies with apparent conformity beds that are near, and correlate with, the upper part of the type Delmontian.

2. Kleinpell's *Bolivina obliqua* Concurrent-range Zone (Delmontian) overlaps the range of species characteristic of his subjacent *Bolivina hughesi* Zone in the type area of the Mohnian Stage and all other Mohnian zones at other localities in California.

3. Many of the species characteristic of his late Mohnian *Bolivina hughesi* Zone overlap both his subjacent *Bulimina uvigerinaformis* Zone and his superjacent *Bolivina obliqua* Zone.

4. Many of the species characteristic of his *Bulimina uvigerinaformis* Zone overlap both his subjacent *Bolivina modeloensis* Zone and his superjacent *Bolivina hughesi* Zone.

5. *Bulimina uvigerinaformis* Cushman and Kleinpell and *Bulimina delreyensis* Cushman and Galliher have the same stratigraphic range and appear not to range above "middle" Mohnian in California.

Therefore, all of Kleinpell's late Miocene concurrent-range zones are in need of revision or redefinition.

[1] Publication authorized by the Director, U.S. Geological Survey.

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FORAMINIFERA AND RUGOSE CORAL ZONES OF MISSISSIPPIAN-PENNSYLVANIAN LISBURNE GROUP, BROOKS RANGE, ARCTIC ALASKA[1]

Thin-section studies of outcrop samples from the Brooks Range show that the Lisburne Group ranges in age from Osagean (Early Mississippian) to Atokan (Middle Pennsylvanian), and can be divided into 15 microfossil zones (Bernard Mamet's zones 8 through 21). Although the foraminiferal fauna is impoverished, the resolution of the foraminiferal zones is finer than zones based on rugose corals. Also, the Foraminifera are in a much wider range of carbonate paleoenvironments than are the rugose corals.

Colonial rugose corals are relatively abundant in the Lisburne Group in shelf carbonates of Meramecian and Atokan ages. These beds can be subdivided by use of corals into faunal zones and used for regional correlation within the Cordillera of North America. In the Brooks Range, Lisburne Group shelf carbonates of Osagean, Chesteran, and Morrowan ages are relatively poor in colonial rugose corals and are zoned exclusively by Foraminifera.

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LUNAR REGOLITH AT TRANQUILITY BASE

(No abstract submitted)

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BUILDING AND USING COMPUTERIZED WELL-COURSE FILE IN OFFSHORE, GEOLOGICALLY COMPLEX FIELD

Computerization of the directional surveys for the Huntington Beach offshore field aided materially in successful secondary-recovery operations under adverse conditions. A very detailed and accurate geologic study of the reservoirs was necessary for waterflooding and steam-stimulation operations in the thick, intensely faulted sandstone sections.

The computer was used to recalcu'ate the directional surveys, interpolate the geologic markers, and establish

[1] Publication authorized by the Director, U.S. Geological Survey.

a data file. Angle averaging was chosen as the most practical and accurate method of computing the survey. Programs were written to plot tops for maps and to project the tops into a vertical plane for cross sections. The final result was a geologic interpretation that was consistent for 5 maps and 43 cross sections.

The computer also was used to plot the well courses. Many wells had to be redrilled for the secondary-recovery program. The courses have to be controlled closely to avoid collisions and to make effective completions. The data file is searched for wells that might interfere with the proposed course. These are plotted so the drilling engineer will be aware of potential problems.

The software development and computer costs were minor compared with charges for conventional engineering and geologic studies and for data preparation. The method is practical and easy to use, and has been applied to other fields in California.

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Geothermal Exploration in Imperial Valley

A study of the geothermal resources of Imperial Valley of Southern California was initiated by a group of researchers at the University of California, Riverside. The aims of the study program are twofold: (1) to map the areas of abnormal heat flow which may become potential geothermal-energy exploration targets, and (2) to study the fundamental geologic and geophysical factors affecting the abnormal heat-flow regime in the valley.

In the first phase of the Imperial Valley project, shallow-hole temperature gradients of up to 0.78°C per meter were measured; the mean for all readings was 0.184°C per meter. These values are more than one order of magnitude greater than the average value for the entire earth, suggesting that vast amounts of geothermal energy are to be found in the valley at a relatively shallow depth. At least some of the geothermal highs correspond to the gravity highs in the valley, indicating that convective heat flow must have caused densification of the sediments.

Deep electrical-resistivity exploration was useful in confirming the shallow-hole geothermal measurements and in identifying areas of high heat flow. Electrical resistivity proved very useful also in mapping an uncharted system of faults (named "the West San Andreas" system) running through Imperial Valley.

From the preliminary findings it is concluded that the Imperial Valley can be classed as a significant source for geothermal energy in California.

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Sedimentology of Southeast Pacific Ocean Deep-Sea Cores

Cores and bottom photographs from the continental margin and the Peru-Chile trench off Callao, Peru, show large amounts of organic material in the sediments, a direct reflection of the high productivity in the surface waters of the Peru (Humboldt) Current. Organic material ranges from 6.0 to 17.7% by weight and is roughly seven times the amount found in samples seaward of the trench. Values of C/N show a wide range but average 14.2 for sediments of the trench-continental margin and 13.3 for sediments seaward of the trench. Sediment at water depth of 1,000 m has greater $CaCO_3$ content and mean-size diameter, and better sorting than the sediments of the shelf and slope. These changes in chemical and textural parameters are the result of maximum abundance of Foraminifera at this depth. Bottom photographs show the presence of cobble and other coarse clastic material at considerable depths off Callao, and of slumped sediment, scour, "streams" of megarippled sediment, and patches of thin-crested oscillation (?) ripple-marks in the trench axis (5,200 m) off Valparaiso, Chile.

Sediments south of the Nasca ridge are generally brown calcareous clay, buff clay with fecal pellets, manganese micronodules, and interlayered pyroclastics. Dredge hauls and bottom photographs indicate several regions of abundant manganese nodules.

The distribution of $CaCO_3$ is a function of productivity, water masses and currents, bathymetry, and distance from land. Variations of carbonate with time indicate a trend similar to Arrhenius' model of lower $CaCO_3$ production for Holocene and interglacial sediments in the equatorial Pacific. On the assumption that two cores, approximately 500 km apart, have a complete record of Quaternary sediments, a sedimentation rate for the total Pleistocene is calculated at 1.3–1.4 mm/1,000 years. Along the Nasca ridge, as a result of higher carbonate production, Holocene sediments have accumulated at the rate of 1.4–2.7 mm/1,000 years.

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Semblance and Other Coherency Measures for Multichannel Data

The concept of "semblance" is a new likeness or coherency measure, and is related to energy-normalized cross correlation. All coherency measures must be considered from three basic viewpoints—the domain in which they are applied, the philosophy of their design, and their manner of use.

The most familiar of the likeness or coherency measures is cross correlation. Differences in design philosophy mainly involve changes in normalization. The "semblance" concept, thus, contains elements of both. In addition, semblance shares certain features of the summation, or "stack," method—a recently much-used coherence measure.

Several measures, including semblance, have been used in a seismic problem area—the determination of stacking velocities from multiple ground-coverage seismic data. A noise-free synthetic example was developed to compare discrimination thresholds of the various methods. Among the various coherence methods, the semblance calculation, if properly interpreted, has the greatest sensitivity.

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Detailed Geophysical Study of Northwest Norton Basin, Bering Sea Shelf, Alaska

(No abstract submitted)

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Multichannel Mapping Techniques

(No abstract submitted)