tral Montana. Two of those exposed in the Big Snowy Mountains were selected for a detailed study of diagenesis in ancient carbonate sandstones.

Evidence suggests that these sediments were deposited in a shallow marine-shelf environment. Diagenesis of the carbonate sands began with cementation in the intertidal or submarine environment. Partial cementation was followed by partial silicification of bioclastic debris and ooids. No definite order could be determined for later diagenetic events; they may have proceeded more or less simultaneously. Dolomitization appears to have postdated silicification and shows preferential replacement of ooid coatings and mud. The sandstones are compacted and stylolitized, and pressure solution may have served as a source for the coarse, blocky calcite which fills the remaining pore space. The distinctive red color of the upper grainstone layer may be due to recent weathering.

JORDAN, C. F., JR., Shell Oil Co., Los Angeles, Calif.

Lower Permian Limestones of Southern New Mexico and West Texas

Detailed petrographic and stratigraphic analyses of samples from the Lower Permian (Wolfcampian) of southern New Mexico and West Texas demonstrate the effects of major tectonic elements on redbed and carbonate sedimentation. Regional correlations are based on 3 informal stages (upper, middle, and lower Wolfcampian), as determined by fusulinid zonation.

Uplifted areas, such as the Pedernal landmass, Diablo platform, and the Florida islands, display unconformable surfaces, limestone and chert conglomerates, and shallow-water carbonates facies consisting of foraminiferal-algal packstones and grainstones (shoal water), algal plate wackestones (bioherm), and ostracod-molluscan packstones and wackestones (lagoon). These highs were flanked by carbonate shelf deposits of normal marine wackestones and packstones which rim the Orogrande and Pedregosa basins. The former was a shallow water intracratonic basin in which about 2,000 ft of Wolfcampian sediments accumulated. The latter basin is less understood, but had a well-defined shelf margin and received at least 4,000 ft of Wolfcampian sediments.

Distant uplifts on the north of the Orogrande basin shed thick redbed deposits which intertongued with carbonates on the south. Generally, this resulted in 3 major sedimentary phases (2 carbonate phases separated by a redbed phase) which correspond to the original threefold division of the type Hueco Limestone. This interpretation together with fusulinid zonation permits correlation of stratigraphic units of southeastern Arizona with those of West Texas and New Mexico: youngest Horquilla Limestone with Hueco Canyon Formation, Earp Formation with Abo Redbeds and Cerro Alto Limestone, and Colina Limestone with Alacran Mountain Formation.

KENNETT, J. P., Grad. School Oceanog., Univ. Rhode Island, Kingston, R.I.

South Pacific Planktonic Foraminiferal Biogeography and Late Cenozoic Paleo-Oceanography

Distinct changes in the character of South Pacific planktonic foraminiferal faunas occur at the 2 major water-mass boundaries. The southern limits of at least 10 species occur at or near the Subtropical Convergence which marks the southern limit of subtropical water. An additional 8 species have their southern limits approximately coincident with the Antarctic Convergence, leaving only 1 species characteristic of Antarctic waters.

Micropaleontologic and sedimentologic studies of South Pacific deep-sea cores have enabled partial definition of the climatic and glacial history of Antarctica and the South Pacific. Pliocene and Pleistocene cores can be divided into zones on the basis of upward sequential appearance of planktonic Foraminiferida, upward sequential disappearance of Radiolaria, and stratigraphic succession of calcareous nannofossils. A chronology of South Pacific Pliocene and Pleistocene climatic oscillations has been established, based on paleomagnetic and thorium-230 dating. Alternations of cold and warm water planktonic Foraminiferida distinguish 6 intervals of climatic warming during the last 700,000 years (Brunhes epoch) and 10 between 2.4 m.y. and 700,000 years ago (Matuyama epoch). The relative magnitudes of climatic warmings were considerably greater during the last 500,000 years than between 2.4 m.y. and 500,000 years ago. Cooling was at times as intense during the Matuyama epoch as during the Brunhes epoch. This determination conflicts with previous paleotemperature determinations based on radiolarians which suggest somewhat warmer conditions throughout the Matuyama. Several present subtropical radiolarian species, however, apparently lost their environmental tolerance for subpolar temperatures about 0.7 m.y. ago. Climatic curves for planktonic forams and radiolarians are essentially the same for the late Pleistocene, confirming the usefulness of both groups in paleoclimatic studies. Fluctuations of certain calcareous nannofossil species closely follow radiolarian and foraminiferal paleotemperature oscillations for the last 400,000 years but diverge strongly in older core sections. Abundances of the silicoflagellate genera, *Dictyocha* and *Distephanus*, clearly mark warm- and cold-water intervals respectively in late Pleistocene cores.

The first appearance of ice-rafted quartz in the sub-Antarctic, about 5 m.y. ago, coincides with increases in bottom-transported quartz, suggesting a relation between increased bottom-water activity and Antarctic glaciation. Distinct changes in the radiolarian assemblages also occur at this time.

Studies of land-based marine sections in New Zealand and of deep-sea cores have shown that the first major late Cenozoic cooling occurred during the late Miocene and earliest Pliocene when south-central sub-Antarctic planktonic foraminiferal faunas (approximately 55°S equivalent lat.) spread over central New Zealand. A further major cooling during the middle Pliocene spans the Gauss-Matuyama boundary ($t = 2.43$ m.y. ago). This cooling was followed by more fluctuating climatic conditions in the late Pliocene and early Pleistocene (lower and middle Matuyama; $t = 2.43$ to 1.60 m.y. ago). Evidence of possibly synchronous late Miocene cooling has also been reported in California, Italy, Japan, and the equatorial Pacific.

KENT, B. H., U.S. Geol. Survey, Denver, Colo., and M. GOMEZ, U.S. Bur. Mines, Denver, Colo.

Geologic Factors that Control Thickness and Composition of Upper Pennsylvanian Coals in Appalachian Basin

Most of the sulfur and ash in the Pittsburgh coal of southeastern Greene County, Pennsylvania, are thought to be syngenetic. Variations in sulfur and ash