POROSITY AND PERMEABILITY IN SILURIAN CARBONATE ROCKS OF ANADARKO BASIN, OKLAHOMA

Ninety Hunton cores have been studied, from which 37 Silurian samples from 21 wells were tested for porosity and permeability. Each sample was examined in thin section and was analyzed chemically for $CaCO_3$, $MgCO_3$, and HCl insolubles. The specimens range from limestones and calcareous mudstones having less than 1% $MgCO_3$ to crystalline dolomites with more than 43% $MgCO_3$. Porosity ranges up to 21%, and permeability to 305 md. Rocks with appreciable porosity and permeability have a circumscribed range in texture and composition: specimens with more than 5% porosity are confined to crystalline dolomites with more than 35% $MgCO_3$ (65% dolomite), and those with more than 10% porosity to dolomites with more than 37% $MgCO_3$ (80% dolomite). Much of the pore space is in the form of fossil molds and vacuities in the matrix surrounding oolites. The fossil molds were formed by leaching, and the porous oolites probably result from a primary porosity increased by dissolution. Not all dolomites have high porosity, and several specimens with more than 35% $MgCO_3$ have less than 1% porosity; the latter condition appears to result from preservation of the fossils by calcspar and dolospar rather than as molds. Leaching of fossils and preservation by spar are confined to crystalline dolomite, thus indicating a genetic relation to dolomitization. A suggested sequence of events in the development of porosity is dolomitization and leaching, followed by some secondary cementation of pore space by spar.

Present information indicates a geographic concentration of these porous Silurian dolomites in the north-central and western parts of the Anadarko basin (data on the deeper parts of this basin are lacking).

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TECTONICS AND DEPOSITIONAL HISTORY OF ROCKY MOUNTAIN INTERMONTANE BASIN

In the Uinta basin of northeastern Utah, the Uinta and Duchesne River Formations are composed of extremely diverse fluvial sedimentary rocks. The rock units overlie extensive lacustrine deposits of Lake Uinta and provide a sensitive record of late Laramide (latest Eocene) tectonic events in this part of the Rocky Mountains. The fluvial deposits are dominantly heterogeneous, laterally discontinuous sandstone lenses and varied amounts of conglomerate and poorly stratified, fine-grained rocks.

Uplift of the Uinta Mountains changed geographic conditions and drainage patterns in the Uinta basin and strongly influenced the characteristics of contemporaneous sedimentary deposits. Important features of the stratigraphic sequence are (1) the oldest major body of sediment (early Duchesnean) produced during uplift of the Uinta Mountains is considerably younger than the youngest preserved deposits of Lake Uinta (middle Uintan); (2) lower (early Duchesnean) and upper (late Duchesnean) conglomeratic rock units record two major episodes of uplift, each composed of several smaller events; and (3) thick volcanic ash deposits, now altered, accumulated during the quiescent period (middle Duchesnean) between major uplifts. This sequence of events imposes some constraints on inferred geomorphic development of the region. The deposits also demonstrate that the latest Eocene (about 40 m.y. ago) was a time of major differential movement of the Uinta Mountains and the Uinta basin, and was not a time of tectonic quiescence in northeastern Utah.

Because of the great distance of the Rocky Mountains from the North American continental margins, detailed knowledge of local tectonic timing affords the best opportunity for plausible speculations relating plate tectonic mechanisms to Laramide events and to early development of the Colorado Plateau and the Basin-Range province.

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SUBTLE SURFACE MAPPING KELSH PLOTTER TECHNIQUES

Studies indicate that the Kelsh stereoplotter is capable of locating subtle surface anomalies using high-altitude photos and ground control.

Petroleum explorationists in the early 1950s used the Kelsh plotter to map in detail known geologic surface structures in order to determine the amount of structural closure and fault throws. In the early 1960s, with the advent of high-altitude photographic coverage over much of the United States, a new role developed for the plotter. The large, 40-sq-mi/print, lateral stereoscopic coverage allows a much wider look at large areas, and thus a new system of geologic reconnaissance mapping with extremely accurate results. Tip and tilt, inherent in all aerial photographs, can be removed. An enlargement factor of 5, together with vertical ground controls for each stereo pair, makes possible dip-magnitude readings of 1/2 degree and accurate structural elevation work. Using the Kelsh plotter to evaluate larger geologic provinces, many previously undiscovered subtle nosings, faulted noses, and independent surface closures become apparent. Cross-section work and measurement of the thickness of formations also may be accomplished. A newly developed system of polarized light makes possible the use of color aerial photographs with the same accuracy as conventional black and white prints.

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OXYGEN ISOTOPE COMPOSITION OF RECRYSTALLIZED CARBONATES ASSOCIATED WITH SUBMARINE VOLCANIC ROCKS

Recrystallized carbonates from the contact zone between sediments and apparently intrusive basalt, and from calcareous xenoliths in eruptive flows in several Deep-Sea Drilling Project cores, are depleted in O^{18} by not more than a few per mil relative to the estimated isotope composition of the original sediment. If this depletion were the result of isotope exchange to equilibrium with seawater in a closed-pore water-sediment system, then the upper limit of the temperature of recrystallization was 100°C, and probably less for most of the samples analyzed. If isotope exchange occurred in an open system, where seawater could readily circulate through the recrystallizing carbonate, the upper temperature limit would be even lower. The possibility that retrogressive isotope exchange or kinetic isotope effects were responsible for the observed isotope fractionations is considered unlikely. The fact that bulk carbonates from the deepest parts of long Deep-Sea Drilling Project cores show only minor effects of diagenesis and apparently have retained their original oxygen-isotope composition suggests that burial and a concomitant moderate temperature increase are not the only factors involved in carbonate remobilization in the deep sea. It is concluded tentatively that chemical changes in the pore water-sediment system resulting from the interaction of seawater with volcanic material may play an important role in the alteration and lithification of carbonates associated with deep-sea basalts and pyroclastic material.

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CHEMICAL COEFFICIENTS FOR IRON, MANGANESE, LEAD, ZINC, AND COPPER IN RIVER WATER AND SUSPENDED LOAD, AND MINERALOGIC COMPOSITION OF SUSPENDED LOAD OF SELECTED KANSAS RIVER SYSTEMS

Concentration levels of the elements in a suspended load, when compared to average reported values for shales, show iron and manganese to be low. The other elements are higher. Values for these elements in the dissolved part are variable, possibly reflecting lithologic differences. Correlation coefficients indicate little relation between trace element content and season in most Kansas streams. X-ray diffraction study of the mineralogic content of the suspended load indicated that montmorillonite was the clay mineral present in all cases. Other minerals present in almost all samples were calcite and quartz. Gypsum, dolomite, feldspar, illite, and kaolinite were present in lesser amounts in some samples. Some question of the source of specific trace elements in these stream waters exists. For nickel and lead, however, pollution is considered the most likely source. Some evidence is present to suggest that the major source of lead is fallout from the atmosphere. The data for partition coefficients suggest that nickel, lead, copper, and zinc are being strongly adsorbed onto the suspended load. The data are less certain for iron and manganese. The iron and manganese levels in the suspended loads of all streams are not unusual. Copper, nickel, lead, and zinc clearly are being concentrated by the suspended load. One source of copper and zinc may be from trace-element nutrient fertilizers.

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OLIGOCENE BIOSTRATIGRAPHY OF LINCOLN CREEK FORMATION, SOUTHWESTERN WASHINGTON

Molluscan faunas of the Lincoln Creek Formation, southwestern Washington, represent 6 provincial invertebrate Opellian zones. Continuous late Eocene to early Miocene sequences have been studied in 6 sections where both mollusks and benthonic foraminifers are abundant. The stratigraphic control on both faunas in these and 7 other partial sections allows for detailed biostratigraphic analysis and the synthesis of superpositionally controlled megainvertebrate zones. These zones, moreover, are correlatable in the same sections with the standard Californian benthonic foraminiferal zones and stages.

The molluscan sequence includes faunas previously assigned by Weaver *et al.* to the Keasey, Lincoln, and Blakeley "Stages." These faunal assignments were made from geographically isolated sections. Durham defined 7 Oligocene megafaunal zones for northwestern Washington on the basis of 7 partial sections and other fossiliferous localities. The lack of superpositional control on boundaries for both these studies suggested the need for further biostratigraphic refinement of the Oligocene of western Washington.

The foraminiferal sequence includes faunas previously assigned by Rau to the Narizian Stage of Mallory, the Refugian Stage of Schenck and Kleinpell, and the Zemorrian and lower Saucesian Stages of Kleinpell.

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CARBONIFEROUS COLONIAL RUGOSE CORALS, BIOSTRATIGRAPHY, AND PALEOECOLOGY, LISBURNE GROUP, ARCTIC ALASKA

The Lisburne Group of arctic Alaska contains coral faunas of Osagian (Early Mississippian) to Atokan (Middle Pennsylvanian) age. Beds of Osagian age have a small fauna of solitary and tabulate corals. Beds of Meramecian and very earliest Chesterian ages contain a large fauna of *Ekvasophyllum* spp., *Faberophyllum* spp., *Diphyphyllum klawockensis* Armstrong, *D. nasorakensis* Armstrong, *Lithostrotion* (*Siphonodendron*) *dutroi* Armstrong, *L.* (*S.*) *sinuosum* (Kelly), *L.* (*S.*) *warreni* Nelson, *L.* (*S.*) *lisburnensis* Armstrong, *Lithostrotion reiseri* Armstrong, *Lithostrotionella niakensis* Armstrong, *L. banffensis* (Warren), *L. mclareni* (Sutherland), *L. birdi* Armstrong, *L. pennsylvanica* (Shimer), *Thysanophyllum astraeiforme* (Warren), *T. orientale* Thomson, *Sciophyllum lambarti* Harker and McLaren, and *S. alaskaensis* Armstrong. Corals are rare in beds of younger Chesterian age; they include *Lithostrotionella* aff. *L. mclareni* (Sutherland), *Lithostrotion* (*S.*) *ignekensis* Armstrong, *Syringopora* spp., and a few solitary corals. Pennsylvanian (Atokan) beds of the Lisburne Group contain *Lithostrotionella wahooensis* Armstrong, *Corwenia jagoensis* Armstrong, a thick-welled syringoporoid, and *Michelinia* sp.

The Lisburne Group limestones are cyclic and were deposited on a slowly subsiding carbonate platform. Colonial corals of Meramecian and Atokan ages are present in carbonate rocks associated with shallow-water shoaling facies. The scarcity of corals in carbonate rocks of Osagian, Chesterian, and Morrowan ages is attributed to regional temperature or salinity changes that inhibited their growth. Beds of Atokan age contain more calcareous algae and Foraminifera, indicating warmer waters. Paleoecologic analysis of the carbonate beds associated with the colonial corals of Atokan age indicates that the corals lived in clear, agitated water between oolitic tidal flats. Carboniferous corals are not known to have formed reef-like masses in arctic Alaska.

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BALDWIN HILLS, LOS ANGELES, CALIFORNIA—RATES OF LATE CENOZOIC UPLIFT

Planktonic foraminiferal biostratigraphy and paleomagnetic stratigraphy of late Cenozoic cores of the North Pacific suggest that the major polar planktonic foraminiferal invasions in southern California occurred in the last 800,000 years. In the Baldwin Hills of the Los Angeles basin, relations of the base of these polar planktonic assemblages and probable water depths at that time, on the basis of associated benthic assemblages, indicate an average rate of uplift of about 0.075 m/100 years.

On the basis of relation of radiocarbon dates with environments of deposition for the late Cenozoic, rates of uplift have increased to about 0.63 m/100 years for the past 36,000 years. Marine waters, approximately 100 m in depth 36,000 years ago, gave way gradually, through sedimentation and uplift, to nonmarine deposition in this area of the basin about 28,000 years ago. These early nonmarine deposits have been uplifted since then to elevations of 145 m atop the Baldwin Hills. Localized uplifts along the Newport-Inglewood fault trend may have formed recently, representing actively rising modern structural features along this trend in the Los Angeles basin.

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LATE PLEISTOCENE DEFORMATION OF CASCADIA BASIN TURBIDITES ALONG WASHINGTON CONTINENTAL MARGIN

A minimum rate of underthrusting of the Juan de Fuca plate beneath North America for the late Pleistocene has been calculated to be approximately 0.7 ± 0.3 cm/yr. This estimate was determined in each of 18 CSP crossings of the continental slope off the coast of Washington by dividing the amount of shortening within the westernmost anticlinal ridge by an approximation of the time elapsed since the beginning of the ridge deformation. The latter estimate was obtained by tracing the late Pleistocene discontinuity as described by Leg 18 of the Deep Sea Drilling Project from site 174 on Astoria fan into the deformed Cascadia basin turbidites of the continental slope. Recent plate-tectonics theories predicting northwesterly movement of the Pacific plate parallel with the San Andreas fault at 6 cm/yr, and the spreading of the Juan de Fuca plate away from the Pacific plate at 6 cm/yr, require an underthrusting rate of 2 cm/yr measured perpendicular to the trend of the Washington continental margin. If the age of the late Pleistocene discontinuity is assumed to be a half-million years, the defor-