laminite, tidal-flat unit locally interrupts the marine limestone sequence at the western (more offshore) end of the Grand Canyon.

The 250-500 m Cambrian sequence appears to consist of more than 30 laterally persistent sedimentation cycles that are grouped into 5 grand cycles. The basal Tapeats Sandstone and the clastic and carbonate tidal flats are not cyclic.

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MICROSTYLOLITES, BEDDING, AND DOLOMITIZATION

Microstylolites are fine dissolution surfaces, with a relief of only 20-40 microns, on which a thin film of silicic-clastic clay and platy silt is concentrated. They commonly form in slightly shaly limestone during secondary (overburden) compaction. Two causes appear to inhibit microstylolite growth: the film concentrate of clay and silt chokes the dissolution surface as a pathway for fluid migration, and acts as a glide plane to relieve stress along the surface.

Microstylolites can accentuate or distort primary sedimentary structures and appear to control the pattern of dolomitization. 1. They commonly accentuate stromatolitic or ripple laminations and outline limestone intraclasts. 2. Thinly-bedded, knobbly, nodular, lumpy, braided or boudinage limestones, characteristic of Paleozoic platform carbonates, appear to result from a microstylolitic induced distortion of originally thin, continuous beds of slightly shaly, pelleted lime muds interbedded with limy (now dolomitic) shale. "Swarms" of subhorizontal, interconnected microstylolites are present throughout both the dolomitic shale interbeds and the dolomitic areas between limestone knobbles. Thin swarms penetrate the sides of limestone knobbles, cutting off clots of limestone. The areas between adjacent knobbles have undergone 20-80% solution thinning, with tension fracturing of the brittle limestone knobbles and flowage along microstylolite surfaces into the area between knobbles. Overburden compaction with microstylolitic dissolution and flowage explains the knobbly bedding. 3. Zoned dolomite rhombs (less than 60 microns) are present in intimate association with microstylolites. In knobbly limestones these rhombs are much coarser than unzoned rhombs scattered throughout the limestone, and are so abundant that they cannot be explained as a simple stylolite solution concentration. Rather, some attribute of the microstylolites, *i.e.*, permeability-controlled fluid migration, composition of concentrate, or differential pressure, provided preferential conditions for dolomitization. Much of the fine-scale, primary or stratigraphic dolomite appears to be a product of preferential dolomitization along microstylolites.

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ABYSSAL SEDIMENT BURROWERS—TRACE FOSSILS IN CARIBBEAN CHALKS AND MARLS, DEEP-SEA DRILLING PROJECT CORES

Cores recovered in the Caribbean Sea on JOIDES Leg 15 exhibit a superb assemblage of biogenic sedimentary structures. They are identified as distinctive trace fossils (ichnogenera) similar to those well-known from land-based stratigraphic sections. They represent the burrowing behavior of benthic animals living contemporaneously with sedimentation.

Some of the best examples are at sites 146 and 149 in the Venezuelan basin. These adjoining sites were drilled in abyssal depths of 3,949 and 3,472 m, respectively, and provide a complete section from Coniacian to Pleistocene. Faunal and sedimentologic evidence from the cores suggests that deposition was abyssal.

The most distinctive biogenic structures are *Zoophycus* (a spiral web), *Teichichnus* (a laminated trough), and *Chondrites* (a regularly branched system). These represent the deep-water trace fossil assemblage of Seilacher, which has been documented in rocks of various ages deposited in bathyal and abyssal frameworks from widespread geographic areas.

Because similar trace fossils are present throughout the Phanerozoic, it is disappointing that they are not recognized in modern deep-sea sediments, and the animals responsible for them have not been identified. One reason is that the traces are accentuated only with time. Our material shows a progressive enhancement of biogenic structures, from vague outlines in the softer Tertiary sediments to increasingly marked contrast and detail downward in the cores. Furthermore, little knowledge exists about modern abyssal burrowers and their burrows, and few cores have been taken for the identification of potential fossil traces.

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ULTRAMORPHOLOGY OF CARBONATE AND SILICATE PHASES ASSOCIATED WITH DEEP-SEA CHERT

Deep-sea diagenesis resulting in chert-nodule formation has been studied by scanning electron microscopy, light microscopy, X-ray diffraction, and electron microprobe analysis of core material recovered by the Deep-Sea Drilling Project (DSDP). Nodules in Tertiary chalk are generally cristobalite-rich, except where metastable silica has converted to quartz. At high magnification, fractures through nodules appear smooth, with little indication of intergranular pore space. Several transition zones may separate chert nodules from unsilicified host rock. For example, in DSDP sample 7/64.1/11/CC, a nodule is surrounded by a weakly silicified chalk zone several centimeters wide, in which interstices are partly filled with 10-micron-diameter cristobalite microspherulites (lepispheres). In a high-silica zone directly adjacent to the nodule, lepispheres are more numerous and exhibit hollow centers. At the chalk-chert boundary, the chalk groundmass has been largely replaced by isotrophic silica, which occludes pore openings but not the hollow centers of the lepispheres. These can be traced for several millimeters into the nodule. Chalcedony within foraminiferal chambers is present in cherts and silicified chalks, but is more common toward the centers of nodules. Fracture surfaces, however, reveal no differences in ultramorphology between groundmasses composed of isotropic silica and those of chalcedonic quartz.

Growth of chert nodules causes dissolution and displacement of most (but not all) of the organic calcite which forms the chalk. Some displaced carbonate in reprecipitated as ultra-fine, euhedral calcite grains within chalk interstices adjacent to nodules. These are probably the supposed calcium-silicate intermediary mineral grains, which some investigators have reported at chert-chalk boundaries. Calcite also may be precipitated as secondary overgrowths on radial prisms of some planktonic foraminiferal tests. This produces characteristic euhedral terminations on inner and outer chamber surfaces.

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SEDIMENTATION ON BALEARIC RISE, A FOUNDERED BLOCK IN WESTERN MEDITERRANEAN

The fan-shaped Balearic rise, southeast of the islands of Mallorca and Menorca, lies at the base of the Emile Baudot escarpment at a depth of 1,600-2,600 m. A sparker, 3.5 Khz profiler, and coring survey reveals that the rise, unlike most deep-sea fans, is almost entirely tectonic in origin. It is a post-Miocene, block-faulted terrane with a thin sediment cover. A large valley, heading between Mallorca and Menorca, follows in its upper sector a major, pre-Pliocene, NNW-SSE-trending fault. Its floor is 3-4 km wide at the head and 25 km wide near the base of the rise; at present, the upper valley serves as a funnel for sediment moving downslope. The lower valley, filled by thick (about 700 m) sediment, indicates that the valley served as a sediment trap during most of Quaternary time.

The steep (to 15°), straight, northeast-southwest-trending Emile Baudot escarpment is a young, possibly still active, fault plane to which the main foundering of the rise is related. The down-dropping is so recent that pre-Pliocene bedrock on the rise remains partly exposed. The unconsolidated material on the rise is Quaternary sand and mud, turbidites, and hemipelagites, as well as older sediment reworked from the upper Balearic platform. Some of these sediments presumably originated at the proto-Ebro River system on the northwest and were deposited in deltaic and nearshore environments in an area which now lies between Mallorca and Menorca. The Ebro sediment source was cut off as a result of the separation of the Balearic block from the Iberian Peninsula before the deposition of the Miocene evaporites.

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PHYTOPLANKTON ABUNDANCE AND DIVERSITY DURING THE LATE DEVONIAN AND EARLY MISSISSIPPIAN OF OHIO

The Upper Devonian Chagrin and Cleveland Shales contain a diverse and abundant organic-walled microplankton assemblage of acritarchs and leiospheres with associated spores, whereas the Lower Mississippian Bedford Shale phytoplankton assemblage is greatly reduced. Ten-gram samples were examined at intervals of 10 ft or less for the entire 573 cores through the 3 formations, to determine microplankton abundance and diversity.

In these samples, spores are the most abundant element, followed by leiospheres and then acritarchs. More than 50 species of acritarchs and leiospheres, mostly new, have been identified in 62 samples of the Upper Devonian section, whereas one *Gorgonosphaeridium* species occurs abundantly in all Upper Devonian samples and is present in most Lower Mississippian samples.

General acritarch diversity decreases slightly up-section in the Chagrin Shale, and increases slightly in the basal Cleveland Shale; the decrease is more marked in the upper Cleveland Shale, and is most notable in the Bedford Shale. Acritarch abundance also lessens up-section through the Upper Devonian formations, with minima in the upper fourth of the Chagrin Shale and the upper half of the Cleveland Shale. Acritarchs are very scarce in the Bedford Shale.

As total phytoplankton abundance shows a marked decrease up-section, from the middle of the Chagrin Shale to the top of the Bedford Shale, a drop in net primary productivity is indicated for the Late Devonian and Early Mississippian of Ohio.

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CARBONATE PETROLOGY OF GREEN RIVER FORMATION (EOCENE), UINTA BASIN, UTAH

The Green River Formation contains a diverse suite of lacustrine carbonate rocks comparable to that of carbonate formations of marine origin. Fossils (calcareous algae, ostracodes, gastropods, pelecypods), coated grains, microcrystalline carbonate aggregates, sparry carbonate, microcrystalline carbonate, and terrigenous grains are the main rock-forming components of the lacustrine carbonates. The most abundant allochemical constituents are polygenetic microcrystalline carbonate aggregates (intraclasts, pelletoids) and fragmental algal "plates." Coated grains (ooliths, pisoliths, circumcrusts) are less common and probably are biochemical (algal?) precipitates. Microcrystalline carbonate is the most abundant orthochemical constituent, but neomorphic and pore-filling sparry calcite are present. Dolomicrite is ubiquitous and probably formed as a replacement product of calcium carbonate before lithification. Terrigenous constituents are present in nearly all carbonate rocks; they constitute as much as 50% of some carbonates. The similarity of lacustrine and marine carbonate rocks indicates that the 2 types can not be differentiated solely on the basis of petrographic relations.

Sedimentary structures, stratification, color, and lithologic associations and variations within the Green River Formation indicate that the carbonates were deposited in a wide range of lacustrine environments. Recognized depositional environments include mudflat, lagoonal, shoal, reef, and offshore.

Preliminary $\delta^{18}O$ and $\delta^{13}C$ analyses of carbonate rocks from the Green River Formation indicate a biogenic fractionation for the microcrystalline carbonate of ooliths, pisoliths, and certain microcrystalline carbonate aggregates, and an early diagenetic replacement origin for dolomicrite.

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COMPARISON OF GEOLOGIC CYCLES OF EARTH, MOON, AND MARS

The geologic cycle of a planet depicts the interaction of impact, surface, and internal tectonic processes on the planetary surface. The earth has a "closed-loop" geologic cycle in which source rocks are eroded but are continuously recycled. In contrast, the moon apparently has an "open-loop" geologic cycle in which the primitive crust is irreversibly destroyed. On the earth, impact plays a minor role and surface and tectonic processes are approximately equally active. That is, if averaged over the globe through geologic history, the rate of uplift equals the rate of erosion. On the moon, impact processes are dominant and there are only minor surface and tectonic effects. Preliminary interpretations of the rock cycle and the "ice cycle" of Mars are presented as sources of questions for future analysis. Apparently, the geologic cycle of Mars involves surface and tectonic phenomena as well as impact phenomena.

Surface processes active on Mars include eolian erosion and deposition. The "channels" in the equatorial regions are evidence of intermittent stream erosion. The tectonic processes of Mars have been investigated by mapping regional stress patterns from analysis of observed lineament (fracture) systems.

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FINANCIAL PROBLEMS ASSOCIATED WITH ENERGY CRUNCH

The satisfaction of virtually every human need for goods and services involves the use of energy. Two-thirds of all energy consumed in the United States is for business-related purposes and a third serves private needs. Both business and private sectors utilize energy primarily for essential purposes and there is very little scope for reduced consumption without harm to the nation's economy and its standard of living.

Obviously, an energy shortage would create a critical situation for the United States, and that is precisely the kind of predicament the nation now is in. All primary sources of energy—oil, natural gas, coal, water power, and nuclear power—currently are in short supply. The shortage has not evolved because the United States lacks sufficient energy resources, but rather because of economic and environmental restraints. These energy resources cannot be developed sufficiently under the system of price regulation that has existed for the last 2 decades and without a more realistic approach to the solution of environmental problems. Consequently, the nation will be forced to rely much more heavily on foreign sources of energy in the future. Most imported energy will be petroleum and there are various reasons for believing that the inflow would be subject to