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Potential Contribution of Oil Shale to Energy Needs of United States and Other Parts of the World

The present worldwide dependence on imported crude oil may be partly relieved by production of oil from oil shale. More than 3 trillion bbl of oil are contained in known organic-rich shale deposits that will yield 10 or more gal of oil per ton of shale. About two-thirds of this resource is in the Green River Formation that underlies parts of northwestern Colorado, northeastern Utah, and southwestern Wyoming in the United States.

Oil shale, which has been mined mainly utilizing conventional mining and surface-retorting techniques, has produced shale oil continuously during the past century. Although Scotland has the longest history of production (more than 100 years), Russia and China combined have produced about 80% of the approximately 1 billion tons of oil shale mined since 1919. The United States has yet to spawn a commercially viable oil-shale industry; however, since 1919 almost half a million bbl of shale oil have been produced, chiefly from the oil shales of the Green River Formation in Colorado. More than 350,000 bbl of this amount has been produced in large-scale pilot operations since 1964.

Sufficient resources are available on the United States federal prototype oil-shale lease tracts in Colorado and Utah to sustain a 300,000-bbl-per-day industry. Private land in Colorado and Utah, owned by major oil companies, contains enough thick, rich oil shales to produce an additional 550,000 bbl of oil per day. Known deposits outside the United States contain a large enough resource base to maintain a 2.2-million-bbl-per-day shale-oil industry. In addition, some developing countries that have oil-shale deposits of lesser magnitude may establish labor-intensive, less expensive industries with smaller rates of production.

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Deep-Sea Benthic Foraminifera and Their Biostratigraphic Potential

Since the advent of the Deep Sea Drilling Project, late Mesozoic and Cenozoic benthic foraminifera have been recovered from cores drilled in the Indian, Pacific, and Atlantic Oceans. These faunas represent a broad range of low-middle latitude depositional environments from water depths of about 1,500 to 5,000 m. At the present time, analysis of fossil deep-sea benthic foraminifera is in a nascent stage. However, it is evident that many taxa occur in all the world's oceans, have easily recognized shell morphologies, and are generally more preservable than planktonic foraminifera. The major drawbacks to benthic species in biostratigaphic investigations are their long duration per species, compared to planktonic species, and the taxonomic confusion surrounding many taxa.

In the Cretaceous there was little difference between deep ocean and continental slope faunas. Important stratigraphic markers, such as the *Bolivinoides* lineage, *Bolivina incrassata, Gavelinella* and *Gyroidinoides* species established in North America and Europe, were present in the deep ocean. Following a major evolutionary turnover in the early Paleogene, deep-sea faunas became less similar to those of continental margin as many new lower bathyal-abyssal genera evolved. Tertiary stratigraphic boundaries, including the top of the Paleocene, middle Eocene, top of the Eocene, upper Oligocene, and middle Miocene, are readily identifiable. After the middle Miocene, benthic foraminifera changed little and it is difficult to subdivide late Neogene faunas.

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Status of Antler Orogeny in Central Idaho—Clarifications and Constraints from Pioneer Mountains

Structural telescoping of argillaceous lower Paleozoic sequences with coeval calcareous and quartzitic rocks in central Idaho has commonly been presumed to be analogous to the Roberts Mountains thrust in Nevada. However, all datable thrusts in the Pioneer Mountains are post-middle Permian to pre-Eocene in age; if Antler age thrust existed, they were reactivated or obscured by major post-Antler movement. Furthermore, differences in fabric or structural style between thrusted argillaceous pre-Mississippian sequences and calcareous-arenaceous Pennsylvanian-Permian sequences, which have been cited in support of Antler orogenesis, are equivocal. These differences more likely resulted from disharmonic response to entirely later thrusting in rocks of different competencies or at different structural levels.

The Copper Basin Formation, a dominantly clastic deposit requiring an argillite-chert-quartzite western highland source in Mississippian time, remains the only evidence in central Idaho for an Antler highland. The Copper Basin now occurs in two superimposed allochthons which, when palinspastically restored, require that their original depositional basin extended at least 50 to 75 km west from the present Pioneer Mountains. Thus, in Mississippian time, the Antler highland reached no farther east than westernmost Idaho.

Emplacement of the Pioneer Mountains allochthons during mainly Mesozoic time involved (1) tectonic slices of high-grade metamorphic rocks and Precambrian crystalline basement, (2) eastward movement and imbrication of Antler detritus, and (3) thrusting of argillaceous facies lower Paleozoic rocks from the Antler highland over the tectonic remnants of its own debris. At least 100 km of post-Antler eastward translation is estimated; a comparable amount of earlier facies telescoping could be accommodated within the Antler highland based on reasonable facies reconstructions, but thrusting has not yet been demonstrated to have accompanied Antler highland development in Idaho.

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Sands and Sand Transport on Palimpsest Carbonate Shelf

The West Florida Shelf east of Cape San Blas, an area of about 250,000 sq km, is the only major shelf of the continental United States which is presently dominated by carbonate sedimentation. The veneer of sediments which comprises the present surface of the shelf is called the West Florida Sand Sheet. It is composed of greater than 75% carbonate and is the latest expression of a 5 km thick accumulation of carbonate rocks and evaporites of Mesozoic and Tertiary ages which has been cut off from major clastic provenance since Jurassic time.

The West Florida Sand Sheet differs from many great carbonate banks such as those of the Bahamas, the Persian Gulf, and the Great Barrier reef in that it extends as far north as 29°30′ and is composed mostly of residual carbonate, specifically of patches of molluscan shell hash, foraminiferal, algal, and even oolitic sands. Only a few patch reefs and one relatively large deep-water (>20 m) tropical reef, called the Florida Middle Ground, are present. Sediments resemble more closely those of the shelf of the southeastern Atlantic United States, with the clastic components removed, than those in other carbonate banks.

Inshore of the carbonate sands and separated from them by a transition zone of mixed composition lies a mature fine quartz sand, which also comprises the beaches of southwest Florida. The quartz sand appears to have been deposited at lower sea-level stands and then to have been moved up and down the peninsula in a seasonally changing longshore current system.

Side-scan and seismic surveys of the West Florida shelf show that far from being a featureless plain beneath the relatively low-energy gulf, the sand sheet has a full suite of bed forms from giant sand waves to small-scale ripples. These suggest that the seafloor is undergoing major redistribution and reworking of sediments, probably primarily as the result of passage of major storms.

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Shallow-Marine Trace Assemblages in a Cambrian Tidal Sand Body

Two distinctive assemblages of biogenic structures are present in the Mt. Simon Formation, basal Upper Cambrian quartzarenite in western Wisconsin. A *Skolithos* trace assemblage is dominated by specimens of *Skolithos* and *Arenicolites*, which commonly occur in medium to very coarse-grained, cross-bedded sandstones. *Skolithos* traces are typically 10 to 100 mm in length, 1 to 5 mm in width, and are oriented normal or slightly inclined to bedding. Specimens are present throughout the formation, even in basal conglomeratic beds, and thus point to a marine origin for the entire unit. *Skolithos* density increases upward to concentrations of 5 to 7 burrows/sq cm. A *Cruziana* trace assemblage is dominated by specimens of *Cruziana, Rusophycus*, and *Planolites*, which commonly occur in thin beds of very fine to medium-grained, horizontal to ripple cross-laminated sandstones. *Rusophycus* specimens are typically 10 to 100 mm in length and 6 to 60 mm in width, and are preserved in convex hyporelief on the bases of sandstone beds.

Distribution of the two trace assemblages and the associated physical sedimentary structures points to two different environmental regimes present within a shallow subtidal to intertidal setting: (1) a higher-energy tidal channel environment in which coarser-grained, cross-bedded sandstones containing a *Skolithos* assemblage were deposited; (2) a lower-energy tidal flat environment in which finer-grained, horizontal and ripple cross-laminated sandstones containing a *Cruziana* assemblage were deposited. The two subenvironments coexisted within a complex environmental mosaic, because the two trace assemblages are observed to intergrade both laterally and vertically, probably the result of lateral migration of each subenvironment. The pronounced upward increase in trace fossil density indicates a significant upward decrease in energy conditions and a reduced sedimentation rate, probably due to tidal flat progradation.

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Paleotopography's Influence on Porosity Distribution in Lansing-Kansas City "E" Zone, Hitchcock County, Nebraska

The Lansing-Kansas City "E" zone consists of carbonate packstones and grainstones deposited during the shallowest parts of the marine phase of a complex marine–nonmarine sedimentary cycle. The packstones and grainstones are best developed on ancient positive seafloor features (15 to 30 ft or 4.6 to 9.1 m of paleorelief) which were subjected to more wave agitation than surrounding low-lying areas where mud-supported textures prevail.

Postdepositional processes during subaerial exposure (nonmarine phase of the "E" zone sedimentary cycle) led to porosity development on paleotopographic highs and porosity destruction in lows. The mild topographic variations resulted in two distinct diagenetic environments. Percolating meteoric waters dissolved aragonitic skeletal grains and intergranular carbonate mud in the packstones and grainstones on paleotopographic highs. Surface runoff and groundwater collected in topographic lows. Here, large-scale dissolution accompanied by infiltration of nonmarine silt and clay totally destroyed all original reservoir potential.

An isopachous map of the nonmarine terrigenous rocks directly overlying the marine "E" zone carbonate rock is believed to reflect paleotopography. All significant oil production occurs where this interval is thin. Porosity in the "E" zone carbonate rock is nearly nonexistent where overlying nonmarine sedimentary rocks are thick. Therefore, thickness maps of these nonmarine rocks should facilitate future oil exploration and production efforts in this area.

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Trap Spring Oil Field, Nye County, Nevada

Trap Spring oil field, located on the west side of Railroad Valley, Nevada, is a combination structural and stratigraphic trap in the Tertiary Pritchard's Station ignimbrite. The reservoir is mainly in fractures caused by