relatively high above background uranium-thorium concentration (11 versus 3 ppm U; 26 versus 8 ppm Th). Previously this zone marked the upper boundary of the pebble shale, however, two horizons are recognizable within the gamma zone, the lower one containing rounded quartz grains and hence pebble shale and the upper one devoid of floating quartz grains.

Clay mineralogy, organic geochemistry, micropaleontology, and sedimentary structures from core and cuttings indicates a stratigraphic sequence through the Neocomian of upper to lower slope facies followed by inner and outer shelf facies and finally deposition of euxunic sediments. The pebbly mudstone facies, derived from a northerly source, is interpreted as a lowstand and subaqueous delta environment formed as the northern provenance was uplifted during Valanginian time. Rapid subsidence of this basin margin was related to the inferred Atlantic margin type downfaulting north of the Barrow arch. The subsequent deposits produced a blanket of sediment 300,000 mi^2 (482,700 km^2) in areal extent. Thin (2 to 9 ft, 0.8 m), fine-grained sands occur within the pebble shale of the Barremian silty shale facies and are restricted to the Barrow area. These sands have an average combined thickness of 45 ft (15 m) and contain traces of oil. Paleogeographic considerations imply better reservoir and coalescing of these sands to the north toward the paleoshoreline and suggest potential for discovery of hydrocarbon reserves from drilling locations on the northern barrier island systems and offshore.

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Radiolarian Biostratigraphy of Hawasina Complex, Northern Oman

The allochthonous Hawasina complex is a sedimentary sequence of both continental-slope and oceanic-basin deposits that were thrust up over shallow-water marine carbonates of the Arabian Shelf during the Late Cretaceous. The Hawasina tectonically overlies the autochthonous Hajar Super Group, and is overlain tectonically by the Samail Ophiolite and associated sedimentary rocks.

The lower thrust units, the Hamat Duru Group, and Wahrah Al Ayn Formations, are generally interpreted as limestone and sandstone turbidites deposited on the continental rise. The Wahrah Formation and lower Zulla and upper Sid'r Formations within the Hamrat Duru Group all contain thick sequences of radiolarian-bearing chert. Samples collected from the Zulla and Wahrah (lower chert member) Formations yielded radiolarian faunas assignable to the Late Triassic (Karnian/Norian) based on key species of the genera *Capnodoce*, *Capnuchosphaera*, *Eptingium*, *Sarla*, *Triassocampe*, and *Yeharaia*. Additional samples from the Zulla Formation indicate an Early Jurassic (Pliensbachian) age based on the presence of *Broctus*, *Canoptum*, *Canutus*, *Droltus*, and *Pseudoheliodiscus* sp.; previous investigators suggested a hiatus in pelagic sedimentation during Early Jurassic time. Radiolarian faunas extracted from two measured sections of the Wahrah Formation (upper chert member) range in age from the Late Jurassic (Tithonian) to Early Cretaceous (late Valanginian/Hauterivian). No suitable radiolarian faunas were obtained from cherts of the Sid'r Formation (Hamrat Duru Group).

The higher thrust units are represented by the conglomeratic Al Ayn Formation, and the deeper water Halfa and Haliw Formations. Radiolarian faunas extracted from a measured section near the type locality of the Halfa Formation range in age from the Late Jurassic (Kimmeridgian/Tithonian) to the Early Cretaceous (Hauterivian/Barremian). All the radiolarian faunas obtained thus far from the Haliw Formation are assignable to the Late Triassic (late Karnian to middle Norian) based on fragments of *Capnodoce* and *Veghicyclia* sp.

Previous biostratigraphic data suggested that the thickest sections of radiolarian chert and mudstone were deposited during Late Jurassic and Early Cretaceous time. Newly obtained paleontologic evidence based on radiolarian biostratigraphy indicates that significant pelagic sedimentation occurred also during the Late Triassic and Early Jurassic.

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Reevaluation of Early Tertiary Radiolarian Faunas from Kellogg and Sidney Shales of Mount Diablo Area, California

B. L. Clark and A. S. Campbell in 1942 published a pioneering biostratigraphic report on the radiolarian fauna from two shale units in the Mt. Diablo area. These shales, called by some authors the Sidney or Sidney Flat Shale and the Kellogg Shale, are about 11 mi apart and were considered to be two different units of the upper Eocene series. They noted that 63% of the Kellogg species are not present in the Sidney Flat and about 58% of the Sidney species are not present in the Kellogg. Sidney Flat was considered younger than the Kellogg by field evidence. Clark and Campbell's paper represented one of the first attempts to use radiolarians as a stratigraphic tool on land geology. The authors described many new species based on few and subtle differences in characters, but with little knowledge of radiolarian morphological variation. Reevaluation of their taxonomy reveals that many characters are now considered nondiagnostic at the species level and that many of their species are synonymous. This result reduces the apparent biostratigraphic difference between the Kellogg and Sidney Flat Shales. Diatom, bethic, and planktonic foraminifers and silicoflagellates have shown that the Sidney Flat and Kellogg are very similar. The foraminifer data indicate that they are the same biostratigraphic unit. Diatoms suggest that the Sidney may be slightly younger. This study (1) reevaluates Clark and Campbell's radiolarian taxonomy, (2) reevaluates their stratigraphic and environmental significance, and (3) illustrates the importance of using characters that reflect evolutionary change in biostratigraphy.

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Distribution of Spongodiscid-Type Radiolarians In Modern Sediments

Spongodiscid-type radiolarians have a spongy appearance (foamy or loosely organized skeleton), are discoidal in shape and may or may not have flat extensions (arms) from the central region of the skeleton. They are common in modern sediments, are cosmopolitan in distribution, and range throughout the Phanerozoic. Their significance in modern sediments has not been fully investigated, especially with respect to their ecology.

Morphologic characteristics are investigated in this study, especially the type of matrix, spines, outer covering, and internal growth, and how it relates to environmental parameters. Spongodiscid-type distributions in the present oceans are evaluated (1) by using published reports on spongodiscid-types in modern sediments and (2) by observing samples material (SEM

and transmitting light microscope) from the Arctic, Bering Sea, Gulf of Mexico, Southern Atlantic, equatorial Pacific, California continental borderlands, Indian and Antarctic Oceans. Three groups of spongodiscid-type radiolarians were identified. (1) *Spongotrochus glacialis* group (robust spongy matrix, with or without spines, without arms) dominates the polar oceans. The diversity is low and the assemblage can inhabit the waters of the shelf as well as the slope. (2) *Stylochlamydium venustum* group (spongodiscid-type with distinct pores, spongy matrix, with or without spines, without arms) plus *S. glacialis*, dominate subarctic assemblages. (3) *S. glacialis* and spongodiscid-type with arms are found in the equatorial region. The diversity here is much greater than in any of the other areas. These results are plotted on a world map comparing the distribution of recent spongodiscid-type with surface-water temperature, water temperature at depth 200 and 400 m (656 and 1,312 ft), surface salinity, surface and bottom currents and bottom topography of the world ocean.

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A New Model of Succession of Middle and Late Pennsylvanian Fossil Communities in North Texas, Mid-Continent, and Appalachians with Implications on Black Shale Controversy

A new model for the succession of Pennsylvanian fossil communities, preserved in cyclothems, is proposed on the basis of more than 200 fossil localities in the Mid-Continent, Appalachians, and north Texas.

Early models for Mid-Continent cyclothems placed the black shales in shallow water, with maximum transgression at the fusulinid-bearing zone in the overlying limestone. The most recent model proposed that the black phosphatic shales, which commonly occur between two subtidal carbonates, are widespread and laterally continuous over great distances and represent maximum transgression.

The black phosphatic shales contain: ammonoids; inarticulate brachiopods; radiolarians; conularids; shark material and abundant and diverse conodonts. This assemblage represents a pelagic or epipelagic community developed in a stratified water column over an anoxic bottom.

The black shales grade vertically and laterally into dark gray-black shales which contain many of the same pelagic and epipelagic forms found in the phosphatic black shales, plus the following: low diversity of articulate brachiopods; large numbers and diversity of ammonoids together with other cephalopods; hyolithids; blastoids; trilobites; corals; and moderate diversity and numbers of bivalves and gastropods. This facies contains the deepest water benthic community. Most of these forms are immature, pyritized, and generally are preserved as molds. The ammonoids include both nepionic and late juvenile–early mature forms with the body chambers. These ammonoids, along with the other immature invertebrates, suggest mass mortality due to fluctuating low bottom oxygen as the deeper water stratification was breaking up.

The dark gray-black facies grades into a medium gray shale facies which contains a mature molluscan fauna. This assemblage contains many of the same benthics as the dark gray facies, but with greater diversity. The pelagics and epipelagics, including plants, are rare to absent, except for the conodonts, which are diverse and abundant.

The medium gray shale grades into a lighter gray facies, which is dominated by brachiopods, crinoids, and corals, with occasional bivalves and gastropods. Fusulinid and coral communities may also occur in the slightly shallower depths. (These facies are interpreted as being a moderate to shallow depth shelf community.)

The brachiopid-crinoid community is succeeded by shallow water communities which may have occupied shoreline, lagoonal, bay, interdeltaic, or shallow prodeltaic environments. These communities are low to high diversity molluscan assemblages, generally lacking ammonoids, and have a very low diversity conodont assemblage. These shallow water assemblages are discontinuous and occur commonly interbedded with sandstone, in the regressive and early transgressive portions of each cycle. In addition, coals are sometimes present that grade vertically into black carbonaceous shales that are non-phosphatic, lack benthic and pelagic forms, and contain plant compressions. These black shales are interpreted as being marsh deposits.

This model is consistent with the findings of Yancey and Stevens with the Lower Permian fossil communities in the western United States. In addition, this model agrees with Calver's work on the succession of communities associated with the cyclothems in the Westphalian of England.

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Geology and Petroleum Potential of Flathead Region, Flathead County, Montana, and Southeastern British Columbia

Discovery of oil seeps in the Flathead region led to wildcat drilling by 1902. Exploration on the U.S. side stopped by 1910 because of the formation of Glacier Park, and the fact that the oil seeps were in Precambrian sedimentary rocks. Exploration continued through the 1930s on the Canadian side with drilling in the vicinity of major oil seeps. Exploration in Canada from the 1950s to present has included seismic work and six wildcat tests in the Flathead region. A land play has been going on in northwestern Montana for the past several years and recently released seismic data have demonstrated major structures that apparently involve Paleozoic rocks. Plans for drilling have been announced.

The Glacier-Waterton and Flathead region are on the Lewis thrust plate. At the Sage Creek, British Columbia, oil seeps, drilling in 1952 penetrated the Lewis fault after drilling 4,400 ft (1,341 m) of Precambrian sedimentary rocks, and then drilled a strongly faulted sequence of upper Paleozoic carbonates and sandstones with several oil shows. The Precambrian rocks on the Lewis plate in the U.S. thin into Canada, eventually to zero where Paleozoic and Mesozoic rocks are carried by the Lewis fault. An area of hundreds of square miles of Paleozoic and Mesozoic outcrop, including the Fernie basin, is present immediately across the international boundary from areas of Montana which have been mapped as containing great thicknesses of Precambrian sediments. In the northern Whitefish Range of Montana, nearly 40 mi (64 km) from the leading edge of the Lewis thrust, is 30 mi^2 (78 km^2) of Paleozoic and Mesozoic outcrop containing several petroliferous units. This sequence is the only part of the extensive Paleozoic and Mesozoic outcrop of southeastern British Columbia which extends into the U.S., but it is important in understanding the involvement of Paleozoic and Mesozoic rocks in complexly faulted northwestern Montana. The Whitefish Range Paleozoic and Mesozoic sequence is cut by several minor thrust faults as well as having been overthrust by the Hefty plate, present now as klippe on the highest peaks of Paleozoic rocks. The Couldry and Tuchuck faults cut these rocks a few miles to the west.

Between the Whitefish Range and the Livingstone Range of Glacier Park lies the Kishenehn basin, a graben to half-graben formed by the listric normal Flathead fault on the Lewis plate. This basin is filled with Oligocene Kishenehn formation, a fluvial