major sandstone facies are distinguished on the basis of sedimentary structures, composition and texture. They are, in descending order, (1) a massive to laminated, well-sorted sandstone, (2) a laminated, pebbly sandstone, and (3) a very fine-grained sandstone interbedded with black shale.

Facies 1 is fine-grained (0.21 mm), lacks bedsets, and is mostly massive or indistinctly laminated. Monocrystalline quartz content is high, reaching 95%. Other minerals are minor at 4%, and rock and shell fragments range from 5 to 15%. Facies 1 is only 10 ft (3.1 m) thick and is interpreted as bar or beach deposits formed by reworking of sand by waves at the margins of the delta plain. Facies 2 is composed of conglomeratic bedsets which fine upward from a pebbly erosive base to a parallel or cross-laminated top. Bedsets range from 0.5 to 3 ft (15 cm to 1 m) thick. There is an increase in rock and shell fragments and a decline in monocrystalline quartz from Facies 1, averaging 34% and 63% respectively. The facies remains fine-grained (0.19 mm); however, average grain size and bed thickness increase upward. Facies 2 is interpreted as a complex of shallow, braided, distributary channels. Thickness is variable but ranges from 10 to 20 ft (3.1 to 6.2 m). Facies 3 bedsets are graded and the sequence of sedimentary structures reflects deposition under conditions of decreasing flow regime. The thin, 1 ft (0.3 m), graded sandstone beds are separated by black laminated shale. This facies is very fine-grained (0.09 mm), relatively poor in quartz, 70%, and rich in matrix which may exceed 30%. Facies 3 is interpreted as thin-bedded turbidites deposited in channels and channel margins downdip from the break in slope at the edge of the delta platform. The thin AE, ABE, BE and CDE bedsets alternate with intervals, 1 to 3 ft (0.3 to 1 m) thick, of bioturbated siltstone or rippled sandstone indicative of normal, shallow marine biotic and current activity. There is a sharp, erosive relationship between Facies 2 and 3.

Resistivities are variable and SPs depressed due to extensive carbonate cement (up to 50% total rock) which is also responsible for low porosity and permeability. Dissolution of authigenic carbonates results in secondary porosity up to 17%. Cross-plots of resistivity (R_t) versus porosity are useful in characterizing facies and enable identification of facies in non-cored wells.

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Use of Precise Temperature Logs in Determination of Thermal Properties of Sedimentary Rocks and Investigation of Thermal Evolution of Sedimentary Basins

The temperatures within a sedimentary basin during its evolution are controlled more by the variation in thermal properties of the contained rocks with space and time and with hydrodynamic effects such as dewatering and regional ground-water flow than with transient heat flow variations at the base of a thick sedimentary pile. Although the effect of basal heat flow has been extensively discussed, the effects of thermal property variations and the evolution of fluid flow systems in basins have rarely been addressed. The thermal properties of many sedimentary rocks are not well known and the depth and time variable changes associated with compaction, diagenesis, etc are difficult to evaluate. In one of the dominant rock components, clays, anisotropy, and sampling difficulties make laboratory measurements difficult if not impossible. Hydrodynamic systems associated with basins are just beginning to be understood and much remains to be learned. Heat flow and temperature studies are techniques for investigating these effects.

Accurate temperature logs associated with measurements, where possible and suitable, of the thermal conductivities of the rock result in two quantities which can be used to unravel some of the unknown temperature controls in a sedimentary basin. These accurate data can be sued for correlation of geothermal gradient and thermal conductivity with well log properties such as seismic velocity (travel time), density, and gamma ray activity. These resulting correlations can then be used to infer the spacial variations in heat flow within the sedimentary basin and to accurately evaluate the effects of present fluid motions in the basin. The data can also be used to develop a catalog of thermal property variations as a function of the many variable parameters.

Examples are presented from the Mid-Continent showing the correlation between geothermal gradient, natural gamma ray activity, and seismic travel time for the suite of rocks occurring there. A major result of this study is that the thermal properties of shale have been misestimated in the literature and that the thermal properties of Paleozoic shales appear to be 50 to 100% lower than those assumed in most thermal modeling, leading to a consequent *error* of 50 to 100% in temperature calculations of basin thermal history.

Temperature and heat flow data are used to evaluate regional fluid circulation, with possible associated petroleum migration, in units such as the Madison Limestone and the Dakota Group. In addition, heat flow studies may outline areas where conditions are locally favorable for maturation. An example of large-scale basement heat flow variation in Nebraska is used to illustrate an area of unusually radioactive basement rocks producing local areas of higher temperature.

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Pebble Shale (Early Cretaceous) Depositional Environments in National Petroleum Reserve in Alaska (NPRA)

A "pebble shale" of Lower Cretaceous age occurs across the North Slope and continues into northwestern Canada. This organic shale (1 to 5% organic carbon) is possibly the source for the Prudhoe Bay hydrocarbons and includes localized well-developed sand bodies such as those in the giant Kuparuk oil field. The inferred rifting of the Arctic basin, subsequent subsidence of a northern source area, and the southern orogeny during the Late Jurassic and Early Cretaceous contributed to the unique lithology and regional setting of the pebble shale.

The pebble shale in NPRA consists of black anaerobic-dysaerobic shales, silty aerobic shales, pebbly mudstones, and sandstones. The shales contain matrix-supported, very well rounded aeolian-derived, fine to very coarse floating quartz grains. Deposition of these diagnostic floating quartz grains occurs rarely in the late Oxfordian (Late Jurassic) time by are abundant during the Neocomian (Early Cretaceous). In the south and central area of NPRA on the southern flank of the Barrow arch, an almost continuous sedimentation record of pebble shale deposition exists, as penetrated by the Tunalik 1 well. To the north the "formation" thins in a series of intraformational unconformities converging on the Barrow arch. Overlying the uppermost unconformity on the Barrow arch a pebbly mudstone 3 to 8-m (10 to 26 ft) thick, of Hauterivian-Barremian age contains well-rounded sand grains, pebbles and cobbles, pelletal glaunconite, shell fragments, wood chips, and burrows. Chert pebbles from this pebbly mudstone were processed for radiolarians and recovered spumellarians of probable pre-Late Devonian age. A thin zone, basal to an intra-pebble shale sand at Walakpa No. 2 contains siderite and appreciable phosphate in the form of carbonate fluorapatite. A zone of intense gamma radiation (GRZ), which is an easily traced seismic and gamma-ray log horizon across NPRA, is a black carbonaceous papery shale with a

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