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.

BLACKWELL, DAVID, JOHN STEELE, and DAN HAGEDORN, Southern Methodist Univ., Dallas, TX

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.

BLANCHARD, DAVID C., and IRVIN L. TAILLEUR, U.S. Geol. Survey, Menlo Park, CA

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