orado; and (2) biostratigraphy and correlation of part of the Tongue River Member of the Fort Union Formation, northern Powder River basin, Wyoming and Montana.

The Green River and Wasatch Formations are complexly intertonguing lacustrine and fluvial units that were deposited during early and middle Eocene time in Western Interior basins of Wyoming, Colorado, and Utah. The structure of nonmarine molluscan associations within these strata delineates littoral and sublittoral lacustrine, pond, fluvial, and terrestrial habitats. Littoral and sublittoral lacustrine habitats are characterized by a low-diversity association of prosobranch gastropods and unionid bivalves. Rank and relative abundance of taxa differ in these habitats. Ponds are dominated by a diverse association of aquatic pulmonate gastropods with sphaeriid bivalves. Lowland and flood-plain habitats are characterized by a locally diverse association of terrestrial pulmonate gastropods and a fluvial association dominated by unionid bivalves with prosobranch and aquatic pulmonate gastropods. Comparison with structurally similar molluscan associations from modern habitats, paleosynecology of fossil taxa, and lithostratigraphic data provide bases for paleoenvironmental interpretation. Analysis of paleogeographic and stratigraphic distribution of these Eocene molluscan associations, relative to a detailed lithostratigraphic framework, permits regional paleoenvironmental reconstruction within the Green River and Wasatch Formations.

In the northern Powder River basin, the Tongue River Member of the Fort Union Formation contains diverse, commonly excellently preserved assemblages of Paleocene nonmarine mollusks. Detailed study of the distribution of gastropods and bivalves in the stratigraphic interval from below the Wall coal bed to above the Arvada coal bed clearly indicates the value of mollusks in correlation of sedimentary sequences between the Wall, Anderson, Smith, Roland, and Arvada coal beds. Clinal morphologic variation in shell form and sculpture through time within a lineage of viviparid gastropods provides an additional method for correlation within part of the stratigraphic interval.

These studies clearly indicate the value of mollusks in the interpretation of depositional environments, biostratigraphy, and correlation of Paleogene nonmarine rocks.

HARMS, J. C., Marathon Oil Co., Littleton, Colo.

Alluvial-Plain Sediments of Nubia, Southwestern Egypt

Nubia sandstone strata of southwestern Egypt were deposited mainly on vast alluvial plains with a northward slope and range in age from Jurassic to latest Cretaceous. The unique aspects of the Nubia as compared to most published fluvial models are that: (1) the sequence is composed almost entirely of medium to coarse-grained sand through a thickness of 1,000 to 2,000 m, (2) the stream channels were relatively straight, commonly only 2 to 4 m deep, and occupied by sand-wave bed forms, and (3) the overbank deposits were thin, sandy, and contain fine kaolin clay plates introduced by infiltration of muddy flood waters.

The typical Nubia fluvial cycle is simple and of two parts. The lower part, commonly 2 to 4 m of porous clay-free sandstone, is composed of tabular sets of cross strata 20 to 100 cm thick, with consistent north dips. The upper part, only 1 to 2 m thick, is also sandstone but contains abundant kaolin platelets 1 to 2 μ in size. These clayey sandstones have numerous root traces and commonly lack primary lamination, although remnants of tabular sets are rarely partly preserved. The contact between upper and lower parts is transitional, with downward decreasing root-trace abundance. The basal contact of each cycle is an erosional surface with slight relief, and commonly eroded clayey sandstone clasts are reworked into the overlying sandstone.

Environmental reconstruction suggests that alluvial plains sloped northward from northern Sudan for hundreds of kilometers toward the Mediterranean. The climate was warm and humid or semihumid, judging from the flora. Streams crossing the plain were mostly fairly small, shallow, straight, but not braided. Interchannel areas were densely vegetated by plants typical of the Jurassic and Cretaceous. The sandstone is nearly pure quartz, although the source area is largely crystalline basement. This mineralogic maturity testifies to rigorous weathering and a long time span for fluvial recycling. Three alluvial plain sequences, each several hundred meters thick, are separated by thin marine or marginal marine muddy sediments deposited during extensive southward transgressions into Egypt.

HAUN, JOHN D., Colorado School of Mines and Barlow & Haun, Inc., Golden, Colo.

Oil and Gas Potential of Wyoming

Through 1978 Wyoming had produced 4.6 billion bbl of oil and had a year-end estimated 1.8 billion bbl in known fields (includes proved reserves, NGL, future extensions, revisions, new-pool discoveries, and enhanced recovery). Production and reserves are between 3 and 4% of United States totals. Approximately 55% of past oil production has been from Paleozoic rocks, primarily Permian-Pennsylvanian, and 35% from Cretaceous sandstones. Reserves in Cretaceous rocks probably are greater than those in Paleozoic rocks, but the importance of Jurassic reservoirs is increasing. Three-fourths of past discoveries have been in structural traps, but, with the exception of the thrust belt, future discoveries will be largely in stratigraphic traps.

Through 1978 Wyoming had produced 7.6 Tcf of natural gas and had an estimated 9.8 Tcf in known fields (includes proved reserves, future extensions, revisions, and new-pool discoveries). Production and reserves are between 1 and 2% of the United States totals and are concentrated in Cretaceous sandstones—Cretaceous rocks in stratigraphic traps will dominate future production.

Average annual oil production during the past 20 years has been 139 million bbl. With reasonable economic incentives, future discoveries should permit production at this level to continue to the year 2000.

Average annual gas production during the past 20 years has been 300 Bcf. Development of known gas accumulations and future discoveries should permit an increase in annual production to approximately 900 Bcf by 1990 and this production level should continue to the year 2000.

Estimated undiscovered oil resources range from 2 (95% probability) to 8 (5% probability) billion bbl with 4 billion bbl the most likely quantity. The most promising area for future discoveries (barring bandwagon psychology!) is the thrust belt with an estimated range of 600 million to 3 billion bbl and a most likely estimate of 1.5 billion bbl. Future discoveries in the thrust belt will be in structural traps in Mesozoic and Paleozoic formations.

Close behind the thrust belt in estimated undiscovered oil resources is the Powder River basin with a range of 500 million to 3 billion bbl and a most likely estimate of 1 billion bbl. Future discoveries should be in Pennsylvanian and Cretaceous rocks, in stratigraphic traps, within the central, deeper part of the basin.

Other parts of Wyoming have a wide variety of possible traps and potentially productive formations. There is a long-shot chance for giant oil or gas accumulations in Permian-Pennsylvanian stratigraphic traps in the Wind River and Green River basins, similar to the Cottonwood Creek field in the Bighorn basin. These will be deep!

Estimated undiscovered gas resources range from 35 (95% probability) to 100 (5% probability) Tcf with 56 Tcf the most likely quantity. Future major gas discoveries will be in Tertiary, Cretaceous, and pre-Cretaceous rocks in the Green River and Wind River basins. These basins have an average range in potential from 11 to 47 Tcf and a most likely estimate of 21 Tcf in each basin. The Wyoming portion of the thrust belt has an estimated range in potential of 8 to 20 Tcf and a most likely estimate of 12 Tcf undiscovered, but these estimates are subject to considerable change as developments continue.

A significant portion of the gas potential is in "tight" sandstones that have less than 1 md permeability. Greatly increased wellhead prices and improved fracturing technology would permit ultimate gas production to be larger than the most likely estimates.

HAUSEL, W. D., Wyoming Geol. Survey, Laramie, Wyo.

Powder River Basin Uranium Deposits; History and Production

The historical significance of the Powder River basin uranium deposits is twofold: (1) the first economical Tertiary uranium deposits in Wyoming were discovered in the Pumpkin Buttes area of the Powder River basin, and (2) the surface to near-surface exposure of these ores provided the basic information needed to develop exploration models for prospecting in similar Tertiary basins in Wyoming.

The first commercial production of uranium within the Powder River basin began in 1953 and continued until 1965. Most of this early production came from mining operations concentrated along high-grade (as high as 15% uranium and nearly 3% vanadium) concretionary deposits limited in size and extent. Because of the size of these deposits, only small tonnages were realized, and as many as 55 separate mining operations were reported within the first 15 years. A second uranium boom began in the early 1970s with the discovery of several low-grade disseminated roll fronts near Pumpkin Buttes and in the southern Powder River basin. Production from the low-grade disseminated deposits has totaled nearly 180 times more ore tonnage than that produced from the high-grade concretionary deposits. Total ore production within the basin amounts to more than 5 million tons of ore, and increased production is expected over the next several years.

HAUSEL, W. D., Wyoming Geol. Survey, Laramie, Wyo., and M. E. MCCALLUM and T. L. WOODZICK, Colorado State Univ., Fort Collins, Colo.

Update on Exploration for Diamonds in Colorado-Wyoming Kimberlite Province

The discovery of diamonds in kimberlite diatremes in 1975 led to a joint effort by Colorado State University and the Wyoming Geological Survey to explore for additional kimberlite occurrences within Colorado and Wyoming. Presently, more than 90 separate kimberlite localities are known in the Colorado-Wyoming State Line district and the Iron Mountain district of Wyoming. Additionally, an isolated kimberlite pipe is present west of Boulder, and there is a kimberlite dike in the Estes Park area of Colorado, extending the known kimberlite occurrences in a roughly north-south trend over approximately 120 mi (192 km). Diamonds have been recovered only from diatremes in the State Line district, except for an isolated occurrence of placer diamonds recently identified in stream-sediment concentrates from the Medicine Bow Mountains.

Exploration continues with the examination of the Front Range by available remote-sensing imagery. Target areas given highest priority are those showing apparent relations and similarities to known kimberlite districts. Drainages in these areas are systematically sampled for heavy mineral indicators (i.e., pyrope garnet, magnesium ilmenite, chrome diopside), and the heavy mineral "trains" are traced upslope to potential kimberlite sites. Detailed ground surveys are conducted over several miles around all new discoveries, with special emphasis placed on associated linear trends (faults, dikes, joints, etc). Limited soil and alluvial geochemical sampling has been used with variable success.

Several geophysical methods have been used, but electrical resistivity and magnetics appear to be the most useful. Electrical resistivity methods show that weathered kimberlite is highly conductive (80 to 250 ohm-ft) compared to the enclosing Precambrian granitic host rocks (300 to 7,400 ohm-ft) and that magnetics are variable, showing only small dipolar anomalies ($\pm$ 30 to 150 γ).

HEGNA, EARL T., Hegna, Kerns & Traut, Consulting Geologists, Casper, Wyo.

Hartville Uplift—New Look at an Old Area

The Hartville uplift of eastern Wyoming is a structural arch connecting the Black Hills uplift with the Laramie Range. It displays several periods of tectonic activi-