	decrease in abundance of primary dolomite grains
Transgressive	Upward decrease in maximum and median grain diameter; upward increase in abundance of primary dolomite grains
Non-marine	Wide range of grain sizes; primary dolomite grains absent; abundant carbonaceous material

These petrographic properties may be used to identify and correlate units in problem areas.

8. DONALD R. BAKER, Marathon Oil Company, Littleton, Colorado

PETROLEUM EVOLUTION: PROGRESS AND PROBLEMS

The three-fold concept of the *origin* of hydrocarbons from organic materials in a source bed, their primary *migration* from the source rock during compaction, and their *accumulation* in traps, has been a part of geological philosophy since the early days of petroleum exploration. But except for adding some substantiating geologic evidence, it was not until the talents of chemists, biologists, and physicists were directed at these problems that new information with profound implications to concepts of petroleum evolution was obtained.

For example, studies of carbon isotopes in sediments and crude oils suggest that terrestrial plants, instead of marine plants and animals, may be the principal primary substance from which petroleum is derived. Further, the discovery of hydrocarbons in Recent sediments demonstrated the early formation and availability of petroliferous materials in depositional basins. However, characterization has revealed differences in the nature and abundance of hydrocarbons in Recent sediments compared with crudes and ancient rocks, indicating that modification and formation of hydrocarbons during diagenesis may be essential for the development of a source rock. Further, the distribution and character of hydrocarbons in ancient sediments indicate that some environments lead to the generation of more hydrocarbons than others, confirming the geologic opinion that there is a considerable range of variation in the nature of petroleum source beds. However, the recognition and evaluation of source rocks on the basis of absolute hydrocarbon content may be an oversimplification in that the hydrocarbons may not be indigenous, or may have formed subsequent to primary migration, or that some rocks may have yielded only a small part of their indigenous hydrocarbons. Finally, comparison of crude oil-source rock pairs indicates that the development of geochemical correlation techniques will be difficult and complicated by the likelihood that primary migration is inefficient, selective, and probably causes considerable modification of hydrocarbons en route.

Although contributions of non-geologists are essential, laboratory results will probably remain obscure unless interpreted in the light of a thorough knowledge of geological factors. The problem of petroleum evolution seems ripe for an integrated attack by geologists supported by physicists, chemists, biologists, and geochemists. The belief that an ultimate comprehension of petroleum evolution can only be developed by the interpretation of experimental and analytical data on a sound geological basis should be the underlying philosophy of future research on petroleum evolution.

9. J. D. LOVE AND W. R. KEEFER, U. S. Geological Survey, Laramie, Wyoming

CONTRASTING TECTONICS OF CRUSTAL BLOCKS IN CENTRAL AND NORTHWESTERN WYOMING

In northwestern Wyoming the northern part of the Green River basin was overridden first by the Hoback Range from the west and later by the Gros Ventre Mountains from the northeast. The fault plane underlying the Hoback Range dips 10–30° westward and southwestward; that under the Gros Ventre Mountains, where observed, dips north and northeast about 45°. Eastward displacement of the rocks in the Hoback Range was of such magnitude that it brought markedly contrasting facies within 2 to 4 miles of one another at the northern end of the Green River basin.

Major folding and faulting of most basin margins occurred during Paleocene and earliest Eocene time, but major deformation of the Gros Ventre Mountains was post-early Eocene. Magnitudes and types of movement are interpreted as follows.

Subsidence (in feet)	*Uplift*	*Heave along basin margin fault (in miles)*
Wind River basin (north-central) 16,000	Owl Creek Mtns. 17,500	2
Wind River basin (northeastern) 16,000	Bighorn Mtns. (south. margin) 16,000	3
Wind River basin (central-eastern) 14,000	Casper arch 7,500	1
Great Divide basin (northeastern) 12,000	Granite Mtns. 20,000	4
Great Divide basin (northwestern) 11,000	Wind River Mtns. (southern margin) 18,000	3?
Green River basin (north-N.E. margin) 17,000	Gros Ventre Mtns. (southeast end) 18,000	4
Green River basin (N.W. margin) 15,000	Gros Ventre Mtns. (west-S.W. margin) 20,000	5
Green River basin (N.W. margin) 15,000	Hoback Range (northeast end) 15,000	15+

10. WILLIAM C. PENTTILA, Atlantic Refining Company, Durango, Colorado

PRE-NIOBRARA UNCONFORMITY AND ITS RELATIONSHIP TO OIL ACCUMULATION—SAN JUAN BASIN

Major oil production in the San Juan basin is from isolated sandstone lenses in the Mancos shale of Upper Cretaceous age. These oil-productive sandstones have been termed Gallup, Tocito, or Horseshoe Gallup and have been described as offshore bars or strand-line features related to the regressive Gallup formation.

Detailed measured surface sections, electric log correlations, and faunal data indicate that the oil production is not from sandstones of the Gallup formation of

Carlile age, but rather from basal sandstones of the Niobrara formation. The basal Niobrara sandstones are not the lithogenetic equivalent of the Gallup sandstone.

Evidence was obtained to establish the presence of an unconformity between the Carlile and Niobrara formations. In the northern part of the San Juan basin, in the vicinity of the Colorado-New Mexico state line, the pre-Niobrara unconformity has truncated approximately 400 feet of upper Carlile. This unconformity rises in the section, southward in the basin to a position approximately 100 feet above the type-Gallup formation.

Basal Niobrara sandstones were deposited on the pre-Niobrara unconformity as the Niobrara sea transgressed southwestward. During deposition of Niobrara sediments, structural uplift in the northern part of the present-day San Juan basin produced minor folding of the sea floor. As the Niobrara transgression progressed, the sea eroded, scoured, and deposited the Niobrara sandstones on the truncated, folded Carlile (pre-Niobrara) surface. Control for deposition of the basal Niobrara sandstones was the configuration of the erosional relief on the pre-Niobrara surface.

11. ROBERT S. HOUSTON, University of Wyoming, Laramie

STRUCTURE OF PRECAMBRIAN ROCKS OF MEDICINE BOW MOUNTAINS AND ITS RELATIONSHIP TO POST-PRECAMBRIAN STRUCTURAL PATTERNS

A basement complex of gneisses and schists in the Medicine Bow Mountains has a northwestern trend that was established during early Precambrian time. On this, a series of sedimentary rocks, typical of a stable shelf tectono-environment and exceeding 30,000 feet in thickness, was deposited. In later Precambrian time all these rocks were deformed, and a northeastern to east-northeastern structural pattern was superimposed on the older trend. During or following this orogeny major northeast-trending faults and shear zones developed, the major one being the Mullen Creek-Nash Fork shear zone that separates the Medicine Bow Mountains into two major segments. During this second orogeny the Precambrian basement yielded by flexure and passive folding and the older northwestern trend is preserved in one small area south of the Mullen Creek-Nash Fork shear zone and in a large block along the northwest slope of the mountains north of the shear zone. The original northwest basement trend did not affect the structural pattern established during the second orogeny. In contrast, structural patterns formed during post-Precambrian orogenies are influenced, in part, by both previously established trends.

Isopachs of Pennsylvanian strata show major north to northwest-trending zones of thinning and less well-developed northeastern zones of thinning, suggesting the two major Precambrian trends were reactivated during the development of the Ancestral Rockies. During the early part of the Laramide orogeny pronounced northeastern fold systems developed in the Laramie basin. These are considered to be basement-controlled. Later major north-south folds that developed in southeastern Wyoming do not appear related to basement structure, but segmentation of the Medicine Bow Mountain front during the final stage of the Laramide orogeny is clearly controlled by basement structure. On the northeast slope of the Medicine Bow Mountains the major thrusts developed during the last stage trend northwest and the cross-faults trend northeasterly, each paralleling one of the Precambrian structural patterns. Similarly, later faulting during Tertiary time is related to these two main basement trends.

12. D. L. BLACKSTONE, University of Wyoming, Laramie

DEVELOPMENT OF LARAMIDE STRUCTURE IN LARAMIE BASIN, WYOMING

The triangular Laramie basin lies between the Medicine Bow Mountains and the Laramie Range, and south of the Como Bluff fold. The stratigraphic column ranges in age from Pennsylvanian to Recent and is more than 15,000 feet thick. Hydrocarbons are produced commercially from fourteen fields and from six stratigraphic zones.

The basin is asymmetric with a gently dipping east and southeast flank, a steeply folded and faulted west margin, and an indefinite northern boundary. Faulted northwest-trending folds interrupt the southern margin of the basin. Fault blocks in which Precambrian is exposed delimit the southwest margin of the basin south of Centennial. Faults bounding the blocks dip both east and west; individual blocks are elevated as much as 8,000 feet; and are bounded by fault complexes which might be anticipated in drilling. North of Centennial the basin is delimited by the Arlington thrust fault.

The Centennial Valley syncline extends north-northwest parallel with the Rock River line of folding. Asymmetry of the anticline changes along strike from southwest at Seven Mile to northeast at Rock River. The Centennial syncline is in part overridden by the west-dipping Arlington thrust fault which dips 15° near Centennial and steepens to more than 45° near Arlington. The hanging wall plate is segmented by northeast-trending tear faults. Cooper Hill appears to be a gravity-emplaced klippe detached from the front of the thrust plate.

The Laramie basin is segmented by the basinward extension of the Mullen Creek-Nash Fork shear zone in Precambrian rocks of the Medicine Bow Mountains. North of this zone the dominant feature is the Rock River line of folding and the Cooper Lake depression. Cross sections of the anticlines reveal a systematic pattern of internal deformation of the anticline, involving Triassic Chugwater and Cretaceous Niobrara and Frontier formations. The position of the major anticline was probably controlled by basement fracturing.

Interference of three structural trends—Como Bluff (N. 30° E.), Seminoe fault zone (N. 65° W.), and Rock River (N. 20° W.) results in the complex of folds characterized by recurved fold axes near Medicine Bow.

The mutual relationships between existent structural trends suggest that the first stage of development was broad crustal up-arching aligned north and south and probably extending to the base of the crust. The second stage developed along northeast-trending basement features and resulted in segmentation of the basement and in limits for the overthrusting. The third stage deformed the west margin of the basin either by faulting and folding (north half) or by development of fault blocks (south half). In this stage east-dipping faults appear to antedate west-dipping faults. The fourth stage involved complex reaction to compression in the Medicine Bow area, resulting in folds with variable orientation.

Rocks correlated with the Hanna formation (Earliest Eocene) but not definitely dated rest with marked angular unconformity on the Cretaceous Medicine Bow formation. The Arlington thrust may be in part overlapped by the Hanna. Rocks of definite Wind River age are slightly folded. Rocks of Oligocene age are offset by normal faults. Younger Cenozoic deposits exist but have not been definitely dated.