shear stresses are only incidental to maintaining equilibrium conditions.

The Front Range, judged from the configuration of the associated major faults where they are best known, is more likely the result of vertical uplift of the crust than of horizontal compression. Other ranges in the eastern Rocky Mountains appear to have similar structural origins. An understanding of stress distributions related to vertical uplift may aid in the interpretation of potential oil-producing structures related to these ranges.

Wednesday Afternoon, April 26

Presiding: W. W. MALLORY, H. H. R. SHARKEY

21. Dawson Formation as Expression of Laramide Tectonics: HARRY W. OBORNE, Consulting Geologist, 114 Wood Terrace Drive, Colorado Springs, Colorado.

The Dawson formation was named the Dawson arkose in 1915 by Richardson, the type locality being at Dawson Butte, 6 miles southwest of Castle Rock. Because much of the stratigraphic section contains more fine clastics and carbonaceous material than arkose, the change in name seems desirable.

The writer has differentiated at least six sedimentary members of the Dawson on the southwest flank of the Denver basin in addition to rhyolite flows near and possibly at the top of the formation. On the southeast flank of the basin, eight members have been recognized. Another member develops near the southern end of the southwest flank and spans the trough area of the present basin in its southern part. At the northern end of the present outcrop area, a considerable interval of coarse clastic sediments changes rather abruptly to gray shale with minor amounts of arkose.

The Dawson formation on the southwestern flank of the Denver basin is interpreted as a series of alluvial fans and bajada deposits with some intercalated mud flows, all of which were being spread out by streams from the rising Laramide mountains on the west. These fans were formed in varying areas at differing times as uplift was locally intensified or diminished by the shifting of centers of middle Laramide tectonism. Most of the fans coalesce along strike. The section is replete with unconformities. Sediments just east of the fans are mainly fluviatile, becoming lacustrine and paludal in the eastern parts of the basin. The present northwestern limit of the outcrop area contains mainly gray shale of lacustrine origin.

Total thickness is in excess of 2,000 feet, but at no one locality on the west flank of the basin are all of the members present because of the oscillatory nature of the fan-forming processes. The formation thins to the north, southeast, and east from the area of its maximum deposition near Sedalia toward the areas of finer-grained sediments.

The age of the Dawson was accepted as Eocene by Richardson. He considered it to be the southward and southeastward equivalent of the Arapahoe and Denver formations. Lavington (in 1942) believed there was an unconformity between the Denver and the Dawson, and that the Dawson overlapped the Denver. The present investigation disclosed typical Dawson unconformably overlying the Denver formation. The Dawson unconformably overlies all formations from the Pierre shale to the Denver formation in the Colorado Springs area.

Palynological examinations of cuttings from about 750 feet above the base of the Dawson indicate "late Late Cretaceous" age. Earlier work on fossil leaves from near the top of the formation was reported by Richardson to suggest a Green River Eocene age for the containing strata.

The Dawson is in fault contact with the older sediments and with Precambrian rocks along much of the mountain front. In places, the Dawson strata at or near the faults are nearly horizontal while at other localities they are steeply dipping, vertical, or overturned. Folding and faulting are present in the basin to a greater extent than has been heretofore recognized. Some of the folds have dips of as much as 45°. Faults are of both normal and thrust types.

Deformation took place before, during, and after the deposition of the Dawson. The Dawson formation is thus a good expression of Laramide tectonics both in its origin and in its present structural expression.

22. Development of Geologic Structure in Middle Rocky Mountains: D. L. BLACKSTONE, JR., University of Wyoming, Laramie, Wyoming

Hydrocarbons in commercial quantities are produced within this province from rocks ranging in age from Cambrian to Eocene, and from many different types of traps. The geologic environment which led to the origin and entrapment has been influenced by structural history; by climatic factors resulting from crustal movement; and by evolution of organisms.

Some extant mountain ranges and intermontane basins began to evolve in middle Precambrian time. Intermittent vertical oscillation of the foreland contemporaneous with the dominant subsidence of the trough in western Wyoming and southeastern Idaho characterized the events of Paleozoic time to Pennsylvanian. A northwest-trending structural grain related to the Ancestral Rockies evolved in Pennsylvanian time. Major structural relief developed in central and northern Montana along the Sweetgrass and Big Snowy arches before Late Jurassic time, and gave rise to conditions conducive to hydrocarbon accumulations in stratigraphic-type traps.

Major deformation of the Middle Rocky Mountain province resulted from a series of episodes initiated in the Cordilleran trough during middle Cretaceous time and continuing to a climax in Early Eocene time. Intermontane basins were filled with rocks of local derivation of both continental and lacustrine character at least 18,000 feet thick.

The present overthrust belt of southeast Idaho, western Wyoming, and southwestern Montana developed from a geosynclinal prism of sediments which had accumulated during Paleozoic and earlier Mesozoic time.

The structural elements of the province can be classified in three general categories. The first consists of the east-west-trending fold and fault complexes such as the Big Snowy arch, the Lake Basin fault zone, and the Uinta Mountain uplift all of which are located along sites of late Precambrian subsidence. The second comprises large northwest-trending crustal folds, the crests of which have been eroded to the Precambrian cores and the troughs of which have been the sites of accumulation of thick sedimentary sequences of local derivation. The third includes the low-angle thrusts and long sinuous folds of the overthrust belt in which only the sedimentary veneer is involved.

The mechanisms responsible for the formation of these three categories of structure are not readily ascertainable. The structures may have resulted from differing responses to a regional tangential stress system, in which case the patterns of Precambrian deformation influenced the Laramide deformation to a very large degree. The overthrust belt may have had a separate and unique origin not dependent on lateral compression. Behavior of the crust beneath the relatively thin sedimentary veneer has been more important in structural evolution than heretofore reported.

23. Gas Occurrence in Piceance Basin, Colorado: Clark Millison, Consultant, Denver, Colorado

Mostly gas is produced in the Piceance basin of western Colorado. The basin, containing about 4,000 square miles, is well defined by the Tertiary-Cretaceous outcrop contact beyond which are the surrounding elevated areas. The basin is in the early stages of development with a density of only one well for every 25 square miles. The lack of pipeline outlet prior to 1956 resulted in slow development but now three pipelines serve the area and drilling activity has been at an accelerated pace. Of the total wells drilled, approximately one half are capable of producing gas from the Tertiary and upper Cretaceous rocks. Due to the thickness of the section, 22,000 feet to the basement, only six wells have tested the pre-upper Cretaceous section.

Most accumulations of gas are due to stratigraphic traps. The paucity of subsurface data is the cause for the present disagreement among geologists of the stratigraphy and geologic history. Tentative correlations from the outcrops on the periphery of the basin are carried across the basin, particularly of the Mesaverde and upper Mancos beds, with a discussion of how the depositional history complicates the problem. The development history which includes the identification of the multiple gas-producing zones indicates that this basin will become one of the important gas-producing areas of the Rocky Mountains.

24. Geology and Occurrence of Gas and Oil, Wamsutter Arch, Wyoming: HOWARD R. RITZMA, Dan Turner & Associates, Inc., Denver, Colorado

The Wamsutter arch is a poorly defined, low-order, positive structural element of southwestern Wyoming. The arch plunges eastward from the northeast bulge of the Rock Springs uplift toward the Rawlins uplift and Sierra Madre uplift, but does not definitely join either of these latter structural elements. The stronger south flank of the arch dips into the Washakie segment of the Green River Basin. The north flank fades gradually into the Red Desert segment of the Green River Basin.

The stratigraphic section follows.

Eocene
Tipton tongue of Green River formation
Very gentle unconformity
Hiawatha member of Wasatch formation (minor gas)
Paleocene
Fort Union formation
Gentle unconformity
Upper Cretaceous
Lance formation
Lewis shale (with associated sandstones) (oil and gas)
Mesaverde group
  Almond formation (oil and gas)
  Ericson sandstone (minor gas)
  Rock Springs formation
  Blair formation
Baxter shale

Gas and oil has been found in the Mesaverde group, mostly in sandstones in the Almond formation. To a lesser extent production has been obtained from sandstones within the Lewis shale and near the Lewis-Lance transition zone and from the Ericson sandstone. There is also minor production indicated from sand lenses in the Hiawatha member of the Wasatch.

Table Rock anticline on the southeast flank of the arch is the only structure with demonstrable surface closure. Tertiary gas was discovered here in 1946 with deeper Lewis and Mesaverde discoveries in 1954. Discovery of major gas reserves at Desert Springs in 1958 triggered rapid expansion of exploratory and development drilling which continues to date. Major new field discoveries include Patrick Draw, Arch, Playa, and West Desert Springs. Productive areas have expanded across original Federal unit boundaries and have overlapped and coalesced, causing numerous problems in nomenclature.

Except for Table Rock, all fields discovered to date are stratigraphic traps with minor structural complexities. Usually the oil and gas is found trapped in closed sandstone bodies formed as offshore bars in the shallow Lewis and Almond seas.

The Wamsutter arch is a young upwarp (possibly Pliocene) superimposed across older Tertiary and late Cretaceous structural trends. The older structural patterns are, as yet, imperfectly known and understood.

25. Relation of Latest Cretaceous and Tertiary Deposition and Deformation to Oil and Gas Occurrences in Wyoming: J. D. LOVE, U. S. Geological Survey, University of Wyoming, Laramie; PAUL O. MCGREW, Professor of Geology, University of Wyoming, and HORACE D. THOMAS, State Geologist, Geological Survey of Wyoming, Laramie

Oil and gas have been known in non-marine Tertiary rocks in Wyoming since 1896. Commercial oil or gas pools have been discovered in Paleocene and Eocene rocks in the Green River, Washakie, and Wind River basins. The source of most of this oil and gas is believed to be sediments deposited under lacustrine conditions during Paleocene time and again during Eocene time. Oil and gas production from nonmarine beds of latest Cretaceous age is a recent development.

The diastrophic and depositional history from latest Cretaceous through Tertiary time has a significant bearing on essentially all Wyoming oil and gas fields. The Laramide orogeny began with gentle folding in latest Cretaceous time, reached a climax of intense folding and thrust faulting in earliest Eocene time in most parts of Wyoming, and was essentially completed by latest Eocene time. Conventional Wyoming oil and gas fields are those related to structural traps formed during this orogeny.

The Green River, Wind River, and Hanna basins were sites of deposition of more than 20,000 feet of latest Cretaceous, Paleocene, and Eocene strata. Oligocene, Miocene, and Pliocene beds were deposited across the now completely filled basins and high onto the flanks of partly buried mountains. Volcanic debris from centers within or near Wyoming comprises the bulk of these young strata. Regional uplift, large-scale normal faulting, and rapid degradation that exhumed the mountains and re-excavated the basins occurred in late Pliocene and Pleistocene time. During this episode some of the structures containing oil and gas were significantly modified.

26. Relation of Uplifts to Thrusts in Rocky Mountains: A. J. EARDLEY, University of Utah, Salt Lake City, Utah

The Rockies concerned are those of Montana, Wyoming, Colorado, New Mexico, and the Colorado Plateau of Utah and Arizona, east of the Paleozoic miogeosyncline.

Evidence is presented that suggests that all the Rocky