12. HOWARD R. RITZMA, Consulting Geologist, Denver, Colorado

STRUCTURAL AND STRATIGRAPHIC DEVELOPMENT, WASHAKIE AND SAND WASH BASINS, WYOMING AND COLORADO

The Washakie and Sand Wash basins, southeast segments of the overall Green River basin, are located in central-southern Wyoming and northwestern Colorado. The two basins are bounded by and contain structural elements of varying age. These are: Rock Springs uplift and Wamsutter arch (Late Eocene-Oligocene) to west and north, Sierra Madre and Park Range uplifts (Late Cretaceous-Paleocene) to east, and the White River, Axial and Uinta Mountain uplifts (Paleocene-Eocene) from southeast through southwest. The basins are separated by a low arch and fault zone of late Tertiary age, which parallels the Wyoming-Colorado boundary.

The present obvious structural trends are the composite of many less obvious structural episodes of Late-Cretaceous-Paleocene, early Late Cretaceous, Early Cretaceous, Permian-Pennsylvanian and early Paleozoic time. Structural elements related to these older orogenic episodes are now mostly concealed beneath younger sediments and basin downwarping. Evidence for many structural episodes, particularly those of the early Paleozoic, have been all but effaced by erosion related to younger orogeny. Maximum structural activity occurred from latest Cretaceous through Mid-Eocene time.

The full sedimentary column (Eocene and older) in the Sand Wash basin exceeds 32,000 feet apportioned approximately as follows:

pre-Pennsylvanian	3%
Pennsylvanian-Early Cretaceous	15%
Late Cretaceous	46%
Paleocene-Eocene	36%

The maximum sedimentary column in the Washakie basin may exceed 36,000 feet in the central and northern parts of the basin. Several thousands of feet of late Tertiary sediments and igneous extrusives occur in limited areas of both basins.

Precambrian structural trends are imperfectly known in the bounding Uinta, Park Range and Sierra Madre uplifts, but have had obvious, important influence on subsequent structural trends and movements to the present.

13. WILLIAM J. McMANNIS, Montana State College, Bozeman, Montana

RÉSUMÉ OF DEPOSITIONAL AND STRUCTURAL HISTORY OF WESTERN MONTANA

The western part of Montana is not a depositional basin in the sense of this symposium, but its depositional and structural history are related to events of nearby areas. The decipherable part of this history begins with Late Precambrian (Belt) sedimentation during which the fundamental structural framework of western Montana evolved. Thick Belt strata are present in the western extremities of the state and in an eastward-projecting embayment. Subsequent depositional patterns and present structural configuration are intimately related to distribution of that thick sedimentary wedge. Course arkose conglomerates were deposited along the southern fault-controlled margin of the Belt embayment. Cambrian through Mississippian formations and parts of the Cretaceous section are typically thicker in east-west zones essentially coincident with the old Belt embayment than they are to the north or south of the embayment.

A positive arch existed along the southwestern Montana and Idaho border against which Cambrian through Devonian formations thin and/or disappear. This positive element became strongly negative during Mississippian and later depositional intervals as geosynclinal subsidence encroached on the cratonic margin.

Abrupt changes in stratigraphic units across the northeast trending Greenhorn fault in the Greenhorn-Snowcrest Range suggest faulting or strong flexure along this zone during post-Ordovician to pre-Late Devonian and during Mississippian time. Pennsylvanian, Permian, and Triassic thicknesses also seem to be mildly influenced by relatively negative movements in this area.

Other northeast thickness trends in several stratigraphic units are apparent in the Sweetgrass arch area, where they seem to coincide with known present-day subsurface faults. Northeast structural trends apparently also control the thickness of Upper Cretaceous and Paleocene strata in the Crazy Mountains basin.

In general, successively older (Triassic, Permian, Pennsylvanian, Mississippian) formations underlie Jurassic beds from south to north, a relationship that has been explained as a result of southward tilt and beveling by pre-Jurassic erosion. Irregularities in the truncational pattern and general thinning of each formation beneath the next younger unit indicate that much of the northward pinchout is related to depositional thinning on which southward tilt was superimposed. During deposition of the marine Jurassic several large "islands" remained above the sea for part of all of that interval.

Late in Jurassic time the western seaway along which earlier seas had transgressed the region was destroyed by increasing tectonism in the area west of Montana, and a flood of debris was carried eastward to form the nonmarine Morrison Formation. The basal conglomerate of the Kootenai Formation (Lower Cretaceous) marks a particularly strong uplift in areas that could not have been far west of Montana. When the seas returned to this region, they came from the northeast and east.

In the eastern part of the area, Cretaceous, and Paleocene rocks are generally separable into rock and time-rock units; however, to the west the corresponding sequence is almost entirely nonmarine, sparsely fossiliferous, exceedingly diverse in lithologic character, and subdivision is very difficult.

Four major westward advances of the sea punctuate Cretaceous deposition in an increasingly unstable tectonic setting. Locally, volcanic debris is very abundant in the Colorado Group and rapid increase in thickness westward attests to further encroachment of geosynclinal downwarping onto the cratonic margin.

Laramide orogeny began in the Montana area coincident with deposition of the Eagle-Claggett and correlative units. Local areas of strong uplift, erosion, and volcanism, and the strong influx of andesitic volcanic debris in these stratigraphic units is evidence of the initial stages of orogeny. Accumulation of very thick volcanic sequences in at least two separate fields during Judith River time attests to increasing intensity of orogenic processes. Strong deformation and erosion followed by deposition of coarse erosional products and volcanism in the southwestern and central parts of the area, intrusion of granitic plutons in the west central part of the area, and thick accumulation of coarse gravels in the Crazy Mountains basin, all during Lancian and Paleocene time, coincide with the culmination of orogenic activity. Some intense folding and thrusting post-dates those events just mentioned but is reasonably certain that Laramide compressional deformation had ceased before middle Eocene time in western Montana.

14. E. EARL NORWOOD, Continental Oil Company, Billings, Montana

GEOLOGICAL HISTORY OF CENTRAL AND SOUTH-CENTRAL MONTANA

Central Montana has had a complex structural and sedimentary history, especially the area of today's Central Montana uplift.

Precambrian and Cambrian subsidence allowed deposition of 1300+ feet of clastics in an east-west trending trough roughly coincident with the present-day uplift.

Pre-Devonian uplift and erosion followed stable depositional conditions during Ordovician time. Ordovician has been eroded from the western one-half of the study area. Silurian is absent from the entire study area.

Central Montana uplift area remained high during Lower, Middle and part of Upper Devonian time. Upper Devonian rocks lap onto the uplift and uppermost Devonian finally covered the area. Pre-Mississippian uplift removed these carbonates and shales completely from a large area of the uplift.

Mississippian system is comprised of the carbonate evaporite Madison Group and clastic Big Snowy Group. Stable conditions prevailed through most of Madison deposition, but central Montana began to subside in Late Madison time. The Big Snowy Group was restricted by continued subsidence which downwarped central Montana into a synclinorium.

Early Pennsylvanian streams draining eastern Montana cut valleys in the Central Montana trough. These valleys were filled as the streams attained old age primarily with Big Snowy Group derived sands and shales. This stream-channel deposit, the Lower Tyler Formation, contains the major reservoirs of central Montana, Middle and Late Pennsylvanian sediments covered central Montana, but all of the Late Pennsylvanian was eroded pre-Jurassic time. Pre-Jurassic folding accentuated Mississippian structure.

Jurassic saw uplift in the Belt Mountain area to the west. Jurassic laps onto this high and thickens eastward as well as in the trough area.

Lower Cretaceous deposition was controlled by uplift to the south and thickens from south to north.

The Laramide revolution upwarped the old trough into the Central Montana uplift and also generally folded the old synclines into anticlines as at the Sumatra trend. Isostatic adjustment at basement fault blocks was the force behind the down up down up movements of central Montana.

15. FRANK C. ARMSTRONG and STEVEN S. ORIEL, U. S. Geological Survey, Federal Center, Denver, Colorado

TECTONIC DEVELOPMENT OF IDAHO-WYOMING THRUST BELT

Three stages are evident in the tectonic development of southeastern Idaho and western Wyoming. First, the changing patterns of tectonic elements during deposition; second, development of northward-trending folds and thrust faults; and third, development of block faults that produced horst ranges and graben valleys.

During Paleozoic time about 50,000 feet of marine sediments, mostly limestone and dolomite, were deposited in a miogeosyncline and about 6,000 feet of mixed marine sediments were deposited on the shelf to the east. Detritus came from both east and west recurrently from Cambrian time on. Starting in Mississippian time, the belt between shelf and miogeosyncline, where thicknesses increase markedly, shifted progressively eastward.

During Mesozoic time about 35,000 feet of marine and continental sediments were deposited in the western part of the region and about 15,000 in the eastern, terrestrial deposits becoming increasingly dominant. Western positive areas became the chief source of detritus. The belt of maximum thickening and the site of maximum deposition shifted progressively eastward; maximum thicknesses of succeeding geologic systems are not superposed. In Late Triassic a belt to the west rose and the miogeosyncline started to break up. As Mesozoic time progressed the western high spread eastward, until by the end of the Jurassic the miogeosyncline gave way to intracratonic geosynclinal basins that received thick deposits, particularly in Cretaceous time. Cenozoic sedimentary rocks are products of orogeny in the region.

The second stage which overlapped the first, produced folds overturned to the east and thrust faults dipping gently west in a zone, convex to the east, 200 miles long and 60 miles wide. Stratigraphic throw on many larger faults is about 20,000 feet; horizontal displacement is at least 10 to 15 miles. Lack of metamorphism and mylonite along the faults is striking. From west to east, the thrust faults cut progressively younger beds, have progressively younger rocks in their upper plates, and are estimated to be successively younger. Thrusting started in the west in latest Jurassic and ended in the east perhaps as late as Early Eocene time; detritus shed from emergent upper plates is preserved in coarse terrestrial strata of corresponding ages.

West of the thrust belt is a northwestward-trending area underlain mostly by lower Paleozoic rocks and flanked on east and west by upper Paleozoic and Mesozoic rocks. Scattered pieces of eastward-dipping thrust faults have been reported west of the older rocks. This central area of old rocks has been interpreted as (1) part of a large continuous thrust sheet moved scores of miles from the west, or (2) an uplifted segment of the earth's crust from which thrust sheets to the east and west were derived. Both interpretations have defects: relative thrust ages are difficult to explain under the first; a large positive gravity anomaly, expectable under the second is apparently absent.

Block faulting, the third stage of tectonic development, started in Eocene time. Faulting has continued to the Recent, as indicated by broken alluvial fans, displaced basalt flows less than 27,000 years old, and earthquakes. North-trending and east-trending fault sets are recognized. Old east-trending steep faults in the Bear River Range may be tear faults genetically related to thrusting. Movement along many faults has been recurrent. Patches of coarse Tertiary gravel on the flanks and crests of ranges, for which there is no provenance with present topography, may record reversed vertical movement along some north-trending faults. Present topographic relief of basins and ranges is tectonic.

16. R. J. ROBERTS, E. W. TOOKER, H. T. MORRIS, M. D. CRITTENDEN, and R. K. HOSE, U. S. Geological Survey, Menlo Park, California, and T. M. CHENEY, Palo Alto, California

OQUIRRH AND PHOSPHORIA BASINS IN NORTHWESTERN UTAH, NORTHEASTERN NEVADA, AND SOUTHERN IDAHO

The Oquirrh and Phosphoria basins in northwestern Utah, northeastern Nevada, and southern Idaho are downwarped segments of the Cordilleran geosyncline superposed on a complex structural pattern of Precambrian and early and middle Paleozoic age.