DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

EXPLANATION
FOR FIGURES 2, 4, 6, 8, 10, 12, AND 14

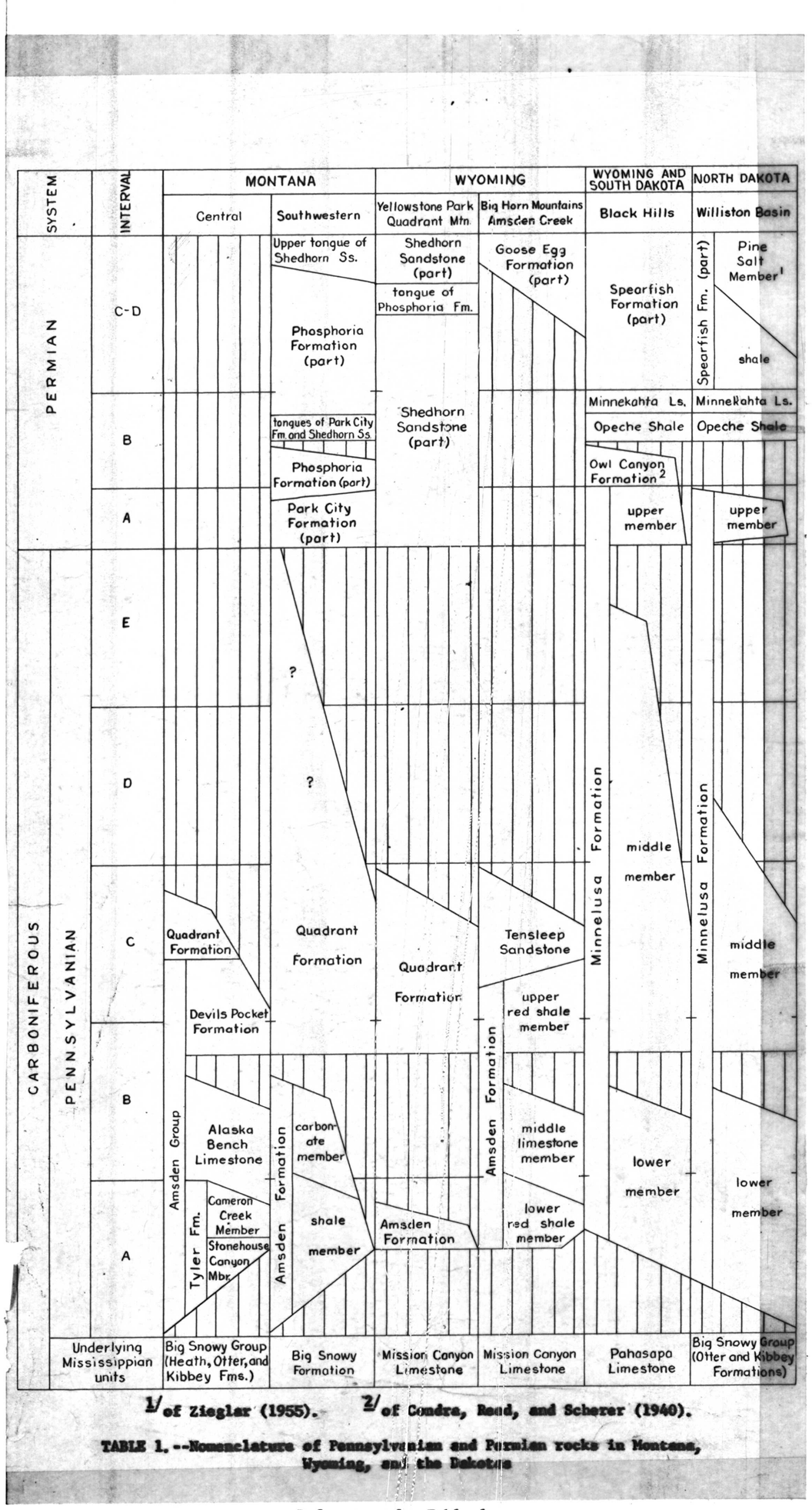
▲ Measured outcrop section

● Subsurface section

Fault
Dashed where approximately located

Isopach line
Dashed where approximately located

Area where rocks older than Pennsylvanian are exposed
(Isopachs are extended in dashes across those areas where rocks of this interval are presumed to have been removed by erosion)



1/ of Zieglar (1955). 2/ of Condra, Read, and Scherer (1940).

TABLE 1.--Nomenclature of Pennsylvanian and Permian rocks in Montana, Wyoming, and the Dakotas

References for Table 1

Condra, G. E., Reed, E. C., and Scherer, O. J., 1940, Correlation of the formations of the Laramie Range, Hartville uplift, Black Hills, and western Nebraska: Nebraska Geol. Survey Bull. 13, 52 p.

Zieglar, D. L., 1955, Pre-Piper Post-Minnekahta "redbeds" in the Williston Basin, in North Dakota Geol. Soc., Guidebook South Dakota Black Hills [3d] field conf.: p. 49-55.

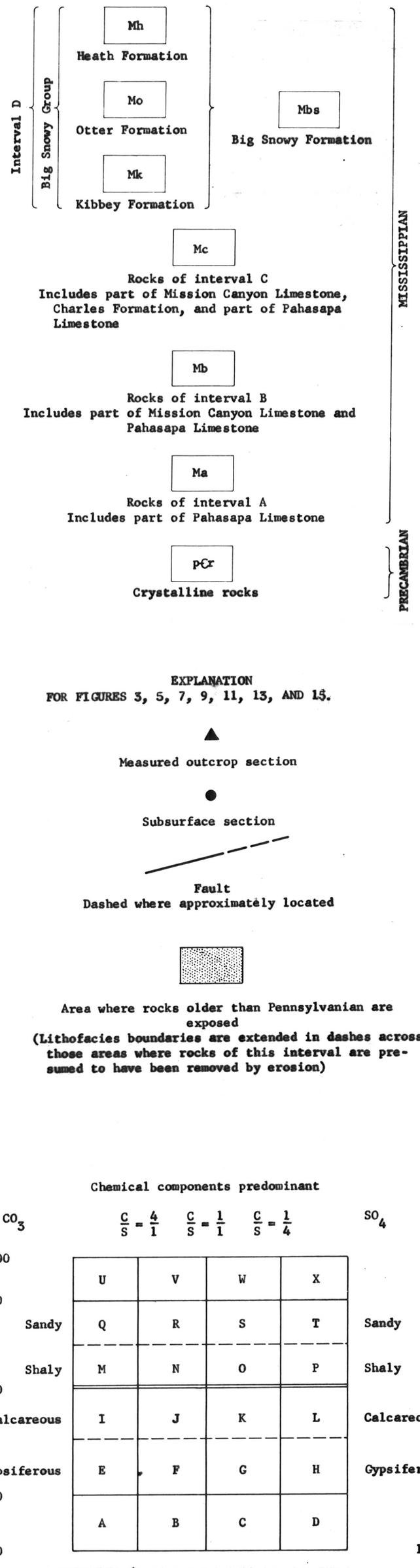
Attached: figures 1-15

EXPLANATION
FOR FIGURE 1

▲ Measured outcrop section

● Subsurface section

Area where rocks older than Pennsylvanian are exposed
(Boundaries are extended in dashes across these areas where these rocks are presumed to have existed beneath the Pennsylvanian, but have been removed by later erosion)



EXPLANATION
FOR FIGURES 3, 5, 7, 9, 11, 13, AND 15.

▲ Measured outcrop section

● Subsurface section

Fault
Dashed where approximately located

Area where rocks older than Pennsylvanian are exposed
(Lithofacies boundaries are extended in dashes across those areas where rocks of this interval are presumed to have been removed by erosion)

Diagram illustrating relations of letter symbols used to differentiate lithofacies

Halite
Shown where chloride to sulfate ratio is greater than 1:3

PENNSYLVANIAN AND PERMIAN PALEOGEOGRAPHY, TECTONICS, AND STRATIGRAPHY IN MONTANA AND THE DAKOTAS*

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Open-file report
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*Abstract and illustrations for talk prepared for the Wyoming Geological Association Symposium on recently developed geological principles and sedimentation of the Permo-Pennsylvanian in the Rocky Mountains, Aug. 31, Sept. 1-2, 1966.

Pennsylvanian and Permian rocks in Montana are included in the Amsden Group (Tyler Formation, Alaska Bench Limestone, and Devils Pocket Formation), Quadrant, Phosphoria, Park City Formations and Goose Egg equivalent. In the Dakotas, equivalent strata are included in the Minnelusa Formation, Opeche Shale, Minnekahta Limestone, and lower part of the Spearfish Formation. To some extent, these names are interchanged by some geologists in eastern Montana and the Dakotas and Amsden, Tyler, and Goose Egg have been used in the Dakotas; and Minnelusa, Opeche, Minnekahta, and Spearfish have been used in parts of Montana. This interchange of nomenclature emphasizes the widespread lateral continuity of these upper Paleozoic formations. These rocks in Montana and the Dakotas may conveniently be divided into four stratigraphic units of earlier Pennsylvanian, later Pennsylvanian, earlier Permian, and later Permian ages that are bounded, except possibly at the top of the Permian, by regional unconformities.

This region was a slightly tectonically active shelf between the craton to the east and the Cordilleran geosyncline to the west. Rocks of Late Mississippian (Chester) age are believed to have extended originally far more widely than they extend at present, and they covered the region at least as far east as the central Dakotas. Their deposition was terminated by epeirogenic uplift accompanied by some faulting and folding--especially in central and western Montana.

The earlier Pennsylvanian unit formed when the sea transgressed in Early and early Middle Pennsylvanian time. The Tyler Formation was deposited as an initial flood of clastic debris, largely derived from erosion of Upper Mississippian strata. The clastic material was swept into and filled relatively low downfaulted and downfolded areas on the shelf. The entire region was flooded by late Morrow and early Atoka time and a widespread limestone, the Alaska Bench Limestone, was deposited as the sea deepened. Fine-grained terrigenous material equivalent to the Alaska Bench in the eastern Dakotas suggests an adjacent land area to the east at that time. Deposition of these sediments was terminated about mid-Atoka time by regional warping. The tectonic disturbance is approximately contemporaneous with major uplift of paleo-features such as the Ouachita region in Arkansas, Oklahoma, and east Texas, the ancestral Rocky Mountains in New Mexico and Colorado, and a geanticline in the Cordilleran geosynclinal belt in Nevada and Idaho. Some or all of the earlier Pennsylvanian rocks were removed from upfolded areas in many parts of the region.

The later Pennsylvanian unit is dominated by dolomite in the middle member of the Minnelusa Formation in the Dakotas and the Devils Pocket Formation in central and eastern Montana, and by sandstone in the Quadrant Formation in western Montana. Deposition seems to have begun in late Atoka and continued without significant interruption through Des Moines, Missouri, and possibly Virgil time on a nearly flat and tectonically stable shelf. Connections to the open ocean were partially restricted. Land raised by geanticlinal folding in the Cordilleran geosynclinal belt was probably the chief source for sand that spread progressively farther eastward across the region in Middle and Late Pennsylvanian time. In Late Pennsylvanian to Early Permian time the Pennsylvanian sea regressed, deposition ended, and the rocks were subjected to erosion as a result of uplift of a broad area centered in north-central Montana, the Milk River uplift.

The earlier Permian unit formed when an Early Permian (Wolfcamp) sea transgressed from the Midcontinent area northwestward and from the Cordilleran geosyncline northeastward around the margins of the Milk River uplift. Lower Permian evaporites, dolomite, gypsum, and possibly halite, that make up the upper member of the Minnelusa Formation in the eastern part of this region formed in a partially restricted basin in this sea. Renewed uplift expanded the area of the Milk River uplift, and forced regression of the Early Permian sea far to the southeast, and the upper member was eroded.

A sea in which the later Permian unit was deposited transgressed into central Wyoming from the Cordilleran geosyncline in the west and flooded across the shelf into the eastern part of the region. Evaporites were alternately deposited with mudstone in the eastern part of the region to a thickness of several hundred feet; these rocks comprise the Goose Egg or the equivalent Opeche, Minnekahta, and lower part of the Spearfish Formations. Concurrently the Phosphoria, Shedhorn and Park City Formations were formed in deeper water in western and central Montana. Halite accumulated in the Williston basin east of the active fault coincident with the later Cedar Creek anticline. These strata, which are later Permian (late Leonard, Guadalupe and Ochoa?), overlap onto a land area peripheral to the Milk River uplift and record mild but diminishing tectonic instability at the end of the Paleozoic Era. Permian rocks seem to be conformably overlain by Lower Triassic rocks that were deposited widely in a seemingly stable region.