Publications Committee

B272-516-1m

BULLETIN
OF THE
UNIVERSITY OF TEXAS

1916: No. 29

MAY 20 1916

Bureau of Economic Geology and Technology
J. A. Udden, Director

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BY

Charles Laurence Baker

Published by the University six times a month and entered as second-class matter at the postoffice at AUSTIN, TEXAS

PUBLICATIONS OF THE BUREAU OF ECONOMIC GEOLOGY AND TECHNOLOGY

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The Deep Boring at Spur. J. A. Udden, University of Texas Bulletin No. 363, October 5, 1914 . (Out of print.)

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Address all communications to:

J. A. UDDEN, DIRECTOR,
Bureau of Economic Geology,
University Station, Austin, Texas.

ORIGIN OF TEXAS RED BEDS

By Charles Laurence Baker

The origin of "Red Beds" has been one of the most vexing problems in American geology for half a century. The present writer began the investigation of the general "Red Bed" problem some eight years ago. He soon found that the following facts indicated a non-arid condition of "Red Bed" origin:

1 "Red Beds" are not being formed today in any desert region. On the contrary, they are being formed under conditions of warm, moist climates in the southern temperate and tropical regions, as maturely weathered residual soils. They are being formed, for example, in such regions as the southeast Texas Gulf Coastal Plain, the Great Valley of the Southern Appalachians, and as laterite in the sub-tropical and tropical regions.

2...The plant fossils* in the Wichita Red Beds of Texas and some other "Red Beds", show no xerophytic adaptations. On the contrary "Red Beds" are associated with coal deposits in various parts of the world.

3...The amphibians and reptiles of Wichita time and the vertebrate fossils in some other "Red Beds" were land animals which lived part of the time in water, part of the time on land. They did not live in a desert environment.

But the presence of widespread deposits of salt and gypsum, of practically incontestable sedimentary origin, contemporaneous with the red clays, seemed to indicate conditions of aridity in at least later Permian time in Texas and elsewhere. Therefore, two working hypotheses were formulated to account for the conditions: (1) That the "Red Bed" sediments were not originally red, but had in some way been changed to a red color subsequent to their deposition; (2) that the "Red Beds" associated with the salt and gypsum were derived from old residual soils of moist warm climates, transported and deposited without change of color in the arid basins of the later Permian.

At the time of the original investigation it seemed impossible to make a definite choice between these two hypotheses, and so

*David White, Journal of Geology, Vol. XVII, pp. 320-341.

the further investigation was held in abeyance. In more recent years, the examination of samples from deep borings in the "Red Beds" of Texas by Dr. J. A. Udden,* has demonstrated the persistence of the red color in depth. So, although in some instances the red color may be secondary, in the Red Beds of Texas it is almost certainly primary; i. e., contemporaneous with the deposition of the sediments. Lately, a re-examination in the light of late evidence of later Pennsylvanian and Permian geologic history of Texas has shown that the second hypothesis can be consistently advanced as the solution of the problem.

In order to apply the hypothesis to the "Red Beds" of Texas it is necessary to consider the geologic history of the later Pennsylvanian and the Permian times. This history will accordingly be briefly reviewed.

In Texas, Oklahoma, and Arkansas, early Pennsylvanian marine sedimentation was followed by mountain-making movements in the Ouachita Mountains region of Arkansas and southeastern Oklahoma, in the Arbuckle and Wichita mountains of southern Oklahoma, and in the Central Mineral (Llano-Burnet) region and the trans-Pecos country (Marathon, Van Horn, and El Paso regions) of Texas. The newly-formed mountains were rapidly eroded and a large part of the mountain region resubmerged beneath the sea in later Pennsylvanian time. In the western trans-Pecos region a later Pennsylvanian limestone nearly a mile in thickness was deposited and in the Marathon region shales and limestone covered the much-eroded, closely-folded earlier Pennsylvanian and early Paleozoic rocks. In north-central Texas later Pennsylvanian sedimentation began with sandstones, conglomerates and shales, and was followed by shales and limestone. The land-derived sediments seem to have been derived from lands to the east and southeast and for this reason it is believed that the mountains of the Central Mineral Region were then more or less continuous with those of southeastern Oklahoma and west-central Arkansas, and perhaps stretched westward to the Marathon mountains.

All of the North American coal of Pennsylvanian age was

*The Deep Boring at Spur: Bull. Bur. Ec. Geol. & Techn., Univ. of Texas, 1914, No. 363.
Potash in the Texas Permian: Ibid., No. 17, 1915.

deposited east of the line of the One Hundredth Meridian. West of this meridian the sediments were more exclusively marine than to the east. The sea was clearer and deeper to the west and this is why a great thickness of limestone was being laid down in trans-Pecos Texas at the same time as coal, sandstone, shale, and limestone was deposited in north-central Texas. The Pennsylvanian coals of north-central Texas were deposited in a region farther west and farther south than any other coals of the same age in North America.

The Pennsylvanian sea of north-central Texas was never very deep and its waters were seldom free from sand and mud brought to it from land areas on the south and southeast. It was only near the close of the period and then only in the southwestern part of the region, that the sea waters became fairly clear from land-derived sediments. The coal beds, found in the Strawn and Cisco formations, were probably formed in regions of coastal swamps, the surfaces of which lay very close to sea-level. Comparatively rapid oscillations of sea-level must have sometimes taken place because we find beds of coal directly overlain by limestones containing abundant marine fossils.

We may draw for ourselves a fairly vivid picture of later Pennsylvanian times in north-central and west Texas. To the westward lay a great sea with clear waters abundantly teeming with marine animals. On the south and southeast was the land of mountain ranges which came into existence earlier in the Pennsylvanian. Between this land and the western sea was a low foreland and shore line, now submerged beneath a shallow sea, now a marshy land covered by forests of the strange plants of the coal period.

Near the end of Pennsylvanian time there was another period of mountain formation* in west-central Arkansas and southern Oklahoma. The Cisco formation of north-central Texas was laid down after this period of mountain-building. South and southwest of the Arbuckle and Wichita mountains of southern Oklahoma the Cisco sediments are red sandstones, conglomerates, and shales, showing by their structures and vertebrate fossils that they were deposited as land sediments by rivers flowing southward and southwestward from the mountains on a flattish plain

*Taff, J. A., Professional Paper 31, U. S. Geological Survey.

much like the country along the shore of the present Gulf of Mexico. Farther to the southwest the Cisco sediments become marine shales and limestones, indicating rather clear sea waters in that direction.

The beginning of Permian time in north-central Texas was a continuation, without marked interruption, of the later Pennsylvanian. The earliest Permian formation, the Wichita, is very like the Cisco, in the northeast river and shore line deposits of red color, and in the southwest marine limestones and clays. In trans-Pecos Texas the lower Permian is mainly marine limestone with a smaller amount of shale and the sediments here have a thickness of about eight thousand feet. Here again, although the exact relations between the Pennsylvanian and the Permian are not yet known, it is probable that there was no great change in conditions between the later Pennsylvanian and the earlier Permian. The clearer and deeper sea, as before, lay to the westward.

There was a notable change in later Permian time. The upper Permian sediments consist of red clays, and beds of limestone, frequently dolomitic, gypsum and rock salt. The gypsum and rock salt were deposited from the substances carried in solution by the sea water upon the drying up of the sea. The upper Permian basin of the Southwest centered somewhere beneath the region of the Llano Estacado. It is very noteworthy that there are no coarse terrigenous sediments in the upper Permian. The land-derived materials are mainly fine clays. When sands occur, they are fine-grained.

We have in upper Permian time the condition of a nearly or quite land-locked sea gradually shrinking through the drying-up of its waters. The sediments contributed to this sea were fine clays and sands derived partly from the red sediments of the Wichita formation and partly from the maturely-weathered residual soils formed during later Pennsylvanian and earlier Permian times. Transportation of these flocculent clays and fine sands would not remove the thin coating of iron oxide by attrition. Even if it did so remove it, the already highly saline waters would not be likely to dissolve it. And even if they did dissolve the coating, the iron oxide would again be deposited before evaporation of the sea-waters had reached a concentra-

tion high enough to deposit the gypsum and salt. But it is most probable that the iron oxide coating was never removed by attrition or solution. Fine sediments derived from residual soils are transported great distances by rivers of the present day without the removal of the red coating. For instance, the Colorado and Brazos rivers of Texas carry these red sediments for hundreds of miles and they are being deposited off shore by the Amazon for a distance of at least two hundred miles from its mouth.

It is not necessary to assume that all red residual soils are formed from the weathering of limestones. The Tertiary sediments of the southeast Texas Gulf Coastal Plain are not limestones, yet their residual soils are red.

The boundary between the red and non-red clays of the Cisco and Wichita transgresses across the strike of the formations in the region both to the north and south of the Wichita and Arbuckle mountains. This boundary line of color runs at least approximately at the line of transition between marine and non-marine sediments. In other words, when the deposits become marine they lose their red color. For this reason some have thought that sea water exerted a reducing action on the iron oxide. But another explanation seems to be at least as probable and it is that the bituminous matter in the littoral and more purely marine deposits was the reducing agent. As is well known, the marine and littoral portions of the Cisco and Wichita are oil-bearing. There is little chance of finding oil in the arid deposits of the upper Permian, although the evidence is conclusive that the Upper Permian red beds were laid down in at least intermittently highly concentrated sea water. The economic bearing of this hypothesis is obvious. If deep drillings show red bed sediments at depths of two to three thousand feet, the chances of obtaining oil are poor.

The upper Permian beds were land areas during the early and middle Triassic. They are overlain unconformably by upper Triassic terrestrial fluviatile deposits in the Staked Plains region of Texas and New Mexico. The "clay-ball" conglomerate and much of the red clay in the Triassic red beds is clearly derived from the erosion of the underlying Permian "Red Beds". There may also have been red residual soils of Triassic age contributing to the Upper Triassic sediments.

In conclusion, it seems evident that the Texas "Red Beds" were originally maturely-decomposed red residual soils formed under warm and moist climatic conditions. In the older "Red Beds" there is no evidence of arid conditions; in the later Permian "Red Beds" the red residual soils were transported and deposited in arid basins without loss of their color. It is probable that the true origin of all the "Red Beds" in the western interior of North America is from residual soils, or the erosion and redeposition without change of color, of older "Red Beds". If such be the case, "Red Beds" alone are not indications of arid conditions but the reverse. It is only when salt and gypsum deposits were deposited contemporaneously with "Red Beds" that the assumption of an arid climate is correct.