Art. II.—*The Permian of Texas;* by Ralph S. Tarr.

From the time of the publications of Marcou and Shumard on the Geology of the Southwest to the present, the existence of Permian in Texas has been reported by various observers. Many have doubted its existence, but Prof. C. A. White* has brought forward conclusive evidence on this point and it is not now doubted that a large part of Texas is occupied by Permian beds. Much remains to be done in this region before the distribution of these strata through space and time is thoroughly understood. In the first and second annual reports of the Texas Geological Survey, Mr. W. F. Cummins has added many facts of interest to our knowledge of the Permian of Texas, which he estimates to have a thickness of fully five thousand feet.

A detailed study of the Carboniferous beds beneath the Permian, both in the eastern and western side of the basin, and a reconnoissance trip across the Permian deposits are the basis for the following remarks upon the Permian, the excuse for their publication being the limited information on hand in regard to this formation.

The Permian of Texas occupies a broad, gentle syncline in the Carboniferous, the western arm being a part of the Rocky Mountain uplift. Its present boundaries, and consequently its former extension, have not been ascertained. Many hundred square miles are covered by these strata in the sub-humid and arid belt of central Texas, the Pecos River forming, approximately the western boundary, while on the east the strata do not extend much farther than Abilene.

In lithologic character the strata are distinctive and, except near the contact, not to be confounded with the Carboniferous. They are chiefly beds of clay, sandstone and conglomerate, strikingly red in color. Limestone beds also occur, these usually being a pale gray, quite characteristic, though often stained on the surface by the red clay from the red beds. In addition to these strata there are beds of gypsum and of salt, and in the center of the district all the water is rendered unpalatable by the presence of these salts. Most of the beds are unfossiliferous, but Dr. White has described thirty-two species of invertebrate fossils from the Texas Permian, and Prof. Cope fifty-seven species of vertebrates. It is upon this basis that the beds have been referred to the Permian.

It is the object of this paper to indicate the sequence of events which have led to deposition of the Permian beds in

* Am. Nat., xxiii, p. 109, Feb., 1889.

this district. The Carboniferous rocks of central Texas have been divided by the writer* into five divisions, based upon lithological and faunal characteristics, as follows: Richland Sandstone, Milburn Shales, Brownwood Limestone, Waldrip Coal Measures, Coleman Limestone and Clays. The history here indicated is one of gradual submergence until the time of the Brownwood limestone, then an emergence continued through the time of the Coleman strata, which are infra-littoral beds. The Brownwood beds contain the typical marine fossils of the Carboniferous, the Waldrip coal measures combine with these the land flora, and these conditions continue into the Coleman beds.

The latter are the highest of the Carboniferous strata and near the Permian have less character than lower down. The series consists of alternating beds of limestone and clays and the presence of clay is everywhere evident, even in the purest limestones. Shore lines, proved by ripple-marks, reptile tracks, coal seams and other signs, show that at this time the Carboniferous beds were in part subjected to denudation. It is probable that the denudation of these rocks was in large measure the source of supply of the clays of the Coleman beds, and the unconsolidated nature of the coastal strip accounts for the general absence of conglomerates and sandstones.

The shallowness of the water and its muddy character gave rise to or permitted the extension of a new fauna into the seas. That the clear water animals which aided in the formation of the Brownwood limestone still existed in the neighborhood is well proved by their frequent recurrence in certain purer beds of limestone in the Coleman series. They were temporarily forced out by changed conditions and again and again allowed to return. This repeated alternation, both lithologic and faunal, is characteristic of the Coleman beds, but the predominant lithologic character is a muddy water deposit and the fauna a mud-loving one, including such species as Myalina, Pinna, Allorisma, Bellerophon, and the like.

On the western border of the Permian area the same general series of rocks is found in the Carboniferous of the Guadalupe mountains. The lower rocks are here shallow water deposits, followed by deeper water limestones of great thickness, and these in turn by an upper series of alternating beds. Shore lines are absent here, however, proving that this point was not the exact western coast line. Shumard has called these beds Permian, but I have shown in a manuscript report in the hands of the State Geologist of Texas for publication, that they are really Carboniferous, this being proved by palæontologic, lithologic, and stratigraphic evidence.

* First Ann. Rep. State Geol. Survey of Texas, 1890, pp. 201–216.

The Permian occupies the basin between these two Carboniferous areas, which are several hundred miles apart, the basin being a syncline formed by the west dipping Carboniferous of the east and the east dipping rocks of the Guadalupe and other mountains of western Texas. The Permian strata are themselves folded into a very gentle, almost imperceptible, syncline, being almost, if not quite, conformable to the gently dipping Carboniferous beds on which they lie.

The line separating the Carboniferous from the Permian on the east is very indistinct, being traceable only with difficulty. Mr. Cummins reports an overlap or slight unconformity at this contact, though its exact value is not determined as yet. Where seen by the writer there seemed to be an almost imperceptible gradation from upper Coleman to Permian. Small overlaps abound in the Coleman series and it is possible that the overlap reported by Mr. Cummins has but slightly more value, though this is suggested only tentatively.

The facts stated above show in later Carboniferous times a shallow water condition at points several hundred miles apart. In the east, in particular, the conditions are those of a shallow sea skirt by newly made land of unconsolidated strata. It cannot be affirmed from the evidence at hand that this was a Mediterranean sea, but indications point to that conclusion. The great extent of similar beds, in both central and west Texas, are rather against the supposition of estuarine conditions. I conceive for this period a condition not unlike that of the present Gulf of Mexico. The Paleozoic and pre-Paleozoic core of central Texas was skirt with the recently added coastal strip of Carboniferous strata, and the connection with the Arkansas and Indian Territory mountains was complete. What formed the enclosing barrier on the south and west we have no means of knowing in the present meagre knowledge of the geology of these regions.

This is not pure unconfirmed conception, for the subsequent events of Permian time point quite conclusively to this explanation. That the Permian in its most typical development was a completely enclosed sea is proved beyond a doubt by the nature of its beds. In no other way can the numerous layers of gypsum and salt be accounted for. The redness of the clay and sandstone beds is then easily explained, though for this other explanations are possible. The peculiar sickly gray color of the limestone is that of an inland sea deposit, the remarkable absence of fossils in most of the beds points to the conclusion already drawn, and the abundance of vertebrate fossils of land and inland sea types is thus readily accounted for. The presence of extensive conglomerates with very large pebbles

derived from points as far distant as the Indian Territory, seem hardly capable of origin except in an inland sea with a tolerably arid climate, or else by glaciation.

The Permian was undoubtedly deposited in an inland sea in which salt and gypsum were also deposited. The small break, if any exists, between the Permian and Carboniferous, shows that in point of time these two formations were immediately associated, the one succeeding the other. This gradation is also proved by the fossils. One of the distinctive Permian types, Pleurophorus, occurs in the Coleman beds, while the same species of Bellerophon, Myalina and others, are common to the two series of beds. The Permian conditions are, therefore, foreshadowed in the Carboniferous, and probably, also, the conditions which culminated in Permian times in the completely enclosed dead sea were in Coleman times indicated by the gathering in of shore lines and the partial enclosure of a Mediterranean sea. The change of fauna from Carboniferous to Permian, and also the close resemblance of the two in many respects, as well as their wide divergence in others, may be thus explained. An enclosed sea would destroy some species and admit of the introduction of others to meet the changed conditions. A temporary destruction of some part of the barrier might admit marine types which in the lapse of time may have changed to new types.

In summary it may be said that the object of this paper is to show that the Permian of Texas is, like other areas of Permian, such as those in Europe, a deposit in large measure made in an inland sea, at certain times in its history a dead sea. This condition was foreshadowed in later Carboniferous times not only in the lithologic nature of the strata and in the fauna, but also in the topographic conditions, the later Carboniferous being in all probability deposited in a Mediterranean sea more or less completely landlocked. The Permian was the immediate successor of the Carboniferous, being separated, if at all, by a very slight break, the marked difference in the nature of the beds and the character of the fauna being due rather to changed conditions than to actual time break.