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Editor: EDWARD S. DANA.

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VOL. II—[WHOLE NUMBER, CCII].

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NEW HAVEN, CONNECTICUT.

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THE

AMERICAN JOURNAL OF SCIENCE

[FIFTH SERIES.]

Art. I.—*The Relation of Isostasy to Uplift and Subsidence;*[1] by William Bowie, Chief, Division of Geodesy, U. S. Coast and Geodetic Survey.

Introduction.

There are many phases of the subject of isostasy, any one of which would make the subject of a paper of an hour. In going over the question as to what I should talk about to-night, I reached the conclusion that it would be better not to tire you with details of the observations and computations involved in the isostatic investigations but to show, in a general way, what are the data, what is their reliability and what are the logical conclusions which may be drawn from the results of the investigations.

The figure of the earth.

We should first consider the shape and size of the earth before we can understand how geodetic observations furnish data for the study of the distribution of densities in what Bailey Willis has very aptly called the "isostatic shell."

If the earth were not rotating and its materials were homogeneous with respect to depth, the actual surface of the earth would be a true sphere. The earth is rotating and, therefore, the combination of the gravitational force and the centrifugal force would make this ideal earth have a surface which would be a spheroid of revolution.

As a matter of fact, the densities, at least in the outer

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[1] Paper read before the Geological Club of Yale University, February 10, 1921.

portion of the earth, are heterogeneous and our spheroid of revolution which depended on the assumption of normal densities, will depart somewhat from this mathematical surface. The mountain masses and the deficiency of mass in the ocean volumes will cause the actual water surface to be higher or lower than the mean surface which we shall call the spheroid of revolution.

It would be well to conceive of sea-level canals cut into the existing areas of the earth. The surface of the oceans and of the waters in these canals will form a figure of equilibrium which we call the geoid. The deviation to this imaginary surface over land areas from the mean spheroid of revolution will be a maximum of possibly 100 meters. This maximum occurs under the great mountain masses.

The fundamental problem of the geodesists is to determine the shape and size of the mean sea-level surface of the earth and the deviations from this mean surface of the geoid or water-level surface. The only way in which to determine the shape and size of the earth is by means of astronomic observations which are connected by triangulation or direct measurements. The shape, but not the size, can also be obtained from gravity measurements.

Deflection of the vertical.

Some years ago, when attempts were made to determine the figure of the earth, it was found that the direction of the plumb line at the astronomic stations was materially affected by the masses above sea-level and the deficiencies of mass in the ocean areas. Corrections were applied to the deflections of the vertical for the positive and negative attractions of these masses, but then it was found that the directions of the corrected plumb lines had anomalies of opposite sign to those which obtained before what might be called the topographic corrections had been applied.

It is easily seen that if we should have a spheroid of revolution without any local disturbing influences, three or four latitude stations, somewhat widely separated along a meridian. with triangulation connecting them, would furnish us data from which to compute the elements of the ellipse, which would be the meridional section of the spheroid. Owing to the irregularity of the actual surface of the earth, the problem is not so simple, and we must extend our data over large areas in order to eliminate the local effects of the topography.

The theory of isostasy.

Some years ago the idea was advanced that a mountain mass had under it a deficiency of material that was practically equal in amount to the mass of the mountain and that under an ocean area there was an excess of matter equal in amount to the deficiency of material in the ocean. This balancing of the mountains and oceans by deficiency and excess of material, respectively, in the outer portion of the earth was termed isostasy by Major C. E. Dutton. No comprehensive tests of this theory were made until the early part of this century when Prof. John F. Hayford made his splendid investigation in the figure of the earth and isostasy. There were many papers written on the subject of isostasy prior to Hayford's work, among the most important being those by Putnam and Gilbert.[2]

The fundamental principle of isostasy is that, at some depth below sea level, the pressure on equal areas is the same throughout the earth. Hayford adopted this principle but it was necessary for him to make other assumptions in order to carry on his investigations. His assumptions were, first, that isostasy is confined to a certain definite zone, with a uniform limiting depth, which he termed the depth of compensation; second, that the compensation is complete, that is, that it exactly equals in amount the excess or deficiency at the surface; third, that the compensation is uniformly distributed with respect to depth; and, fourth, that the compensation is directly under the topographic feature. Hayford did not believe that these assumptions are strictly true but he thought them to be as logical as any other simple assumptions which are necessary to be made in order that the vast amount of computations may be undertaken.

Let us get a clear idea of how the topography and compensation are used in the determination of the figure of th earth. We must correct the astronomic observations in order to eliminate the local attraction of the topography and the compensation, and after these corrections have been applied we have data from which to determine the lengths of degrees of longitude and latitude, at various

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[2] Appendix 1, U S. Coast and Geodetic Survey Report for 1894; and vol. 13, Bulletin, Washington Philosophical Society.

places within the area where the observations have been made. It is not necessary for us here to go into details of the determination of the figure of the earth for they can be consulted in articles which are easily accessible. But let us see what we do at a single astronomic station.

Let it be supposed that we have a mountain mass close to the astronomic station, say within 100 miles. This mountain mass will have an attractive effect on a particle at the astronomic station. As a result of this attraction the plumb line to which all astronomic observations are referred will be deflected towards the mountain. It is a simple matter to compute this effect and apply it to the observed latitude and longitude. We next compute the effect of the isostatic compensation of the mountain mass and apply this as a correction to the latitude and longitude. We actually have many mountain masses which must be taken into consideration for each astronomic station. What we use in our final data are the resultant effects of all of the topographic features, whether land or water, within 2564 miles of the station, together with their isostatic compensation.

Investigations of the effect of isostasy on the deflection of the vertical.

When Hayford had corrected all of his astronomic stations, more than 500 in number, he made a mathematical solution of the results from which he derived the dimensions of the spheroid of revolution and the depth of compensation. The most probable depth for the United States from the data available was found to be 122 kilometers. A depth obtained previously by Hayford from fewer data was 113.7 kilometers. It is very interesting to note that the depths differ about 8 kilometers, which is quite a large per cent of the depth itself.

Hayford found from his investigations that the resultant deflections of the vertical after the effect of topography and isostatic compensation had been applied were, on the average, about one-tenth of what they would have been if the earth were rigid and there were no isostatic compensation.

Investigations of the effect of isostasy on the intensity of gravity.

After Hayford had completed his investigations of the figure of the earth and isostasy he began a second investigation in the subject of gravity and isostasy. Shortly after he began this he severed his connection with the Coast and Geodetic Survey and for a short time the investigation was conducted by Dr. Hayford and the writer, and later by the writer alone.

The investigations in gravity and isostasy confirmed the results obtained by Hayford from the investigations of the figure of the earth and isostasy. Isostasy was found to be in about as complete a state from the gravity investigations as from the figure of the earth investigations. The depth of compensation computed from the gravity investigations was found to be approximately 96 kilometers. This agrees with Hayford's determination of the depth of compensation from the figure of the earth investigations when he used only data in mountain regions. The depth of 96 kilometers was obtained by the writer from gravity stations in areas of high relief. It is not necessary to go into details in regard to the computation of the depth of compensation, but when we consider the fact that a disc of material, of uniform density and thickness and of infinite horizontal extent, has the same attraction on a particle, regardless of the distance of this particle from it, we can see that it is difficult to obtain a value for the depth of compensation in a flat area, such as the coastal plain or a plateau. The determination of the depth from data in mountain regions is very much more sensitive.

Reliability of geodetic data.

Some question has been raised at various times as to the reliability of the geodetic data. It is safe to assert that the accidental and systematic errors in the astronomic observations, in the triangulation, and in the pendulum observations are so small that they need not worry us at all. For instance, if we should say that the observed deflection of the vertical is 5″.5 in the meridian or in the prime vertical, it is reasonably certain that its error is not greater than 0″.5. Similarly, if the gravity observations give an intensity of 980.025 dynes, it is practically certain that this value is correct within three or four in the last place of decimals. No one will doubt but that these degrees of accuracy are well within the limit desirable in geodetic investigations. Published reports on the investigations of the figure of the earth and of gravity consider, in some detail, the question of the accuracy of the data.

As to the question of the reliability of the computations of the effect of isostatic compensation we have a different proposition. In the first place, we may say that as far as the mathematical work is concerned the results are reliable and accurate, but the effect of the compensation will vary somewhat depending on the assumptions made. It should be pointed out that the effect of the compensation will be approximately the same for all methods of distribution, vertically, which have the center of gravity of the compensation approximately 50 kilometers below the surface of the earth. Methods of distribution which deviate materially from this condition will not give as accordant results as those based upon this requirement.

Uniform distribution of compensation vertically.

We should consider here the question of distribution of the isostatic compensation with respect to depth. Uniform distribution appears to the geodesist to be a logical or reasonable assumption, for, in the first place, the geodesist is not supposed to know anything about the geology of the isostatic shell, except in so far as information may develop from geodetic investigations. It seems probable that, if one had never heard of isostatic compensation and he was told that a mountain mass or a plateau is balanced by a deficiency of mass in a column directly under the topographic feature and that this compensating deficiency extends to a certain definite depth, he would conclude that the deficiency of mass is distributed uniformly throughout the column. He would see no reason why compensation should be greater in one part of the column than in another, although one would be apt to believe that the compensation ends gradually rather than abruptly at the lower end of the column.

We could distribute the compensation in any one of a number of ways, with respect to depth, and still have the center of gravity of the compensation approximately at 50 kilometers. But who is to decide and upon what data is the decision to be made as to what the actual distribution is, that is, the one that is in accordance with the truth?

As a matter of fact, the writer believes that compensation varies in its distribution, vertically, from place to place, but that the average distribution for any large area such as that of the United States approximates uniform distribution. One can see that, if we took the mean of all possible distributions, approximately uniform distribution would result.

Distribution of compensation horizontally.

An attempt was made by the writer to show whether it was better to have the distribution of the compensation directly under the topographic feature or to have it distributed regionally within certain limits of distance from the station. The evidence seems to be strong that the distribution could not be extended to as great a distance as 100 miles in all directions from the station, but that results as accordant, or nearly so, were obtained when the distribution was extended about 40 miles in all directions from the topographic feature as when the compensation was assumed to be local.

Effect of ignoring compensation for small areas.

An attempt was made to show whether gravity anomalies could be more nearly eliminated if we assumed that local areas near gravity stations did not have their topographic features compensated.

Computations of the effect of the isostatic compensation out to distances of 18 miles and 36 miles in all directions from gravity stations were made. These effects were subtracted from the total effect of compensation of all topography. The results indicated most clearly that the gravity anomalies were largely increased by this method, showing conclusively that we cannot ignore the compensation of the topography for even small areas. Of course, we may ignore the isostatic compensation of the topography near a station where the relief is very low. But the tests were made for stations having elevations greater than 1000 meters (about 3300 feet).

Relation between isostatic anomalies and topography.

Tests have been made to show whether there is any relation between the sign and size of the gravity anomalies and the character of the topography. No such relation has been found for the isostatic anomalies but decided relations have been noticed for the anomalies obtained by the two older methods of correcting gravity observations. One of these is the Bouguer method, based on the theory that the earth is rigid and that the topographic features are actual excesses or deficiencies of mass supported by the earth. The other is the free-air method of reduction in which no account whatever is taken of the topography and the isostatic compensation. It is the same as if we assumed that the topographic features were compensated for at zero depth. Of course this is an artificial method but it was adopted in order to reduce some of the anomalies by the Bouguer method.

Anomalies greatly reduced by considering isostasy.

The investigations of the figure of the earth and isostasy showed that the topographic features were compensated to such an extent that the residuals or the unexplained deflections of the vertical were only one-tenth of what they would have been if the earth had been rigid. Therefore, we may assume that the columns from the surface down to the depth of compensation are compensated within approximately ten per cent of the topography at the top of the column, in some cases land above sea-level and in others deficiency of matter in the oceans.

An attempt was made to show what reduction has been made in the gravity anomalies as a result of applying the isostatic theory. Two methods were employed. One considered the effect of the topography for the whole world and the other considered the effect of the topography out to a distance of approximately 100 miles from the stations. By the first method, it is found that the isostatic gravity anomalies are only 17 per cent of what they would be with a rigid earth. By the second method, the average isostatic gravity anomaly was found to be only about 13 per cent of what would be the average anomaly on the rigid earth.

In the first test, all stations of the country were used, whether at high elevations or at low ones, but the data for the effect of the topography on the opposite side of the earth from the station were not as reliable as we should have liked them to be. This is due to the fact that the data for the effect of topography and compensation for the very distant areas were not computed separately but in combination. In the second test, only stations having an elevation greater than 2000 feet were used, and we considered the topography out to about 100 miles. The topography for 100 miles farther has little or no effect on the station because of the great distance and the fact that the topography is nearly in the same horizon as the station, thus making the vertical component very small. We may conclude, I think, that the second method gives the better result. By it the average gravity anomaly is about 13 per cent of what it would be on a rigid earth. This is so close to the ten per cent obtained by Hayford as the relation between the isostatic deflection and the rigid deflection that I shall, in the remainder of this paper, adopt ten per cent as the relation between isostatic and rigid anomalies, both deflection and gravity.

Relation between isostatic anomalies and areas of erosion.

It has been found that there is no definite relation between the sign and size of the isostatic gravity anomaly and areas of erosion. There may, of course, be areas of erosion where the gravity anomaly tends to be negative or to be positive, but we may say that no definite relations can be found that are general in their application.

Relation between isostatic anomalies and recent geological formations.

We have found a very definite relation between areas of recent sedimentation and gravity isostatic anomalies, and this definite relation applies to stations on all the sub-divisions of the Cenozoic formation..

For a number of years the negative gravity results along the coasts and in inland areas of recent sedimentation were thought to be an indication of a lack of isostatic equilibrium in those areas. It was early found, in the investigations by the writer, that there is a definite relation in sign between the gravity anomalies and the Cenozoic formation. In the report[3] on gravity investigations, published in 1917, the writer arrived at the conclusion that the Cenozoic anomalies were negative because the material of this formation, extending some distance below sea-level, is much lighter than normal. In most cases it is probably more than 10 per cent less than normal. It is apparent that if we have very light

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[3] Investigations of gravity and isostasy, spec. publ. 40, U. S. Coast and Geodetic Survey, 1917.

material close to the station, its attractive effect will be less than if we should have material of normal density occupying the same space. This opinion of the writer was accepted by Col. Burrard, former Superintendant of the Trigonometrical Survey of India. He has recently published a very important book dealing with this subject, entitled "Investigations in Himalayan and Neighbouring Regions" (Professional Paper No. **17**, Trigonometrical Survey of India, 1917 Sup. 285, February 1921 of this Journal). The writer had stated that possibly the columns under the Cenozoic formation are in isostatic equilibrium, for it is inconceivable that the load of sedimentation added to the column should make it have less material than normal. Col. Burrard made computations to show whether the idea of isostatic equilibrium of the columns under sedimentary areas is a reasonable one. He concluded that the negative gravity anomalies can be caused by the presence of Cenozoic material near the gravity stations and that, probably, the Indo-Gangetic plain is in isostatic equilibrium.

Relation between isostatic anomalies and the Pre-Cambrian formation.

The writer has found that there is a very definite relation between the sign of the gravity anomaly and the Pre-Cambrian formation. Here we can account for the positive character of these anomalies by the presence of extra heavy material close to the gravity stations which is probably compensated for by a deficiency in the column below. I shall not take time to discuss the Pre-Cambrian formation and its relation to the gravity anomalies, but I have dwelt upon the relation of the gravity anomalies to the Cenozoic formation because it is important in throwing light on some phases of mountain formation.

The datum used for isostatic investigations.

A subject that I should like to discuss at some length is the datum used for computations of the effect of topography and compensation, but I shall not take the time to do so here, because of more important phases of isostasy that must be considered. I may say that it makes very little difference in the conclusions arrived at from isostatic investigations whether we use some other datum than mean sea-level for the computation of the effect of topography and isostatic compensation. I simply raise the point here because attempts have been made to show that the isostatic results are made somewhat unreliable by some other datum not having been adopted. The principal reason why this subject should be considered is that the question of the percentage of completeness of compensation is involved in it. You will notice that I have not previously made any statement in regard to the percentage of completeness of compensation. I have simply shown that the isostatic reductions reduce the anomalies to a certain per cent of what they would be if the earth were rigid. It is difficult to interpret the results in terms of mass.

The actual distribution of compensation cannot be proved mathematically.

The statement was made by McMillan, in his article on the "Hypothesis of Isostasy" (Journal of Geology, February-March, 1917), that

> "From a purely mathematical point of view any set of a finite number of observations of the intensity and direction of gravity can be satisfied, not approximately, but exactly in infinitely many ways by a proper distribution of the density of the earth."

Speaking mathematically, this statement is justified, but any distribution of the densities in the earth that is not general in its application, which would exactly eliminate the anomalies of the deflections of the vertical and of the intensity of gravity, would be so artificial as not to be at all reasonable. It seems to be logical to assume that the only reasonable hypothesis regarding the distribution of the densities in the outer portion of the earth is one which will be very general in its application. We cannot accept methods of distribution which are designed simply to eliminate the anomaly by having one distribution at one gravity station, another distribution for a second station, and so on throughout the list of stations.

Prediction as a test of isostasy.

The results of the investigation into the theory of isostasy have been very striking and this is brought out clearly in a recent article entitled "A Brief review of the evidence on which the theory of isostasy is based" by Col.

Burrard (The Geographic Journal, Royal Geographic Society, London, July, 1920). Burrard shows that the isostatic method can be used to predict what the intensity of gravity or the deflection of the vertical will be before observations have been made. This prediction cannot be made with any degree of reliability if the condition of isostasy is ignored. The methods adopted by the geodesist can stand the test of prediction. Some other method, not yet formulated, may work equally well but it cannot depart materially from the one now in use.

The density of material in the isostatic shell.

It has been held by some that the geodesist assumes a density of 2.67 for the density of the material in the isostatic shell. Geodesists have never postulated the density of the material below sea-level, except in so far as attempts have been made to show that the presence of Cenozoic and Pre-Cambrian formations affect gravity anomalies. What the geodesists have done is to compute the deviations from normal densities in the column down to the depth of compensation. We may assume that the normal densities for the various zones are A_1, A_2, A_3, etc. The geodesist computes the deviations from these unknown densities.

The theory of isostasy is based on the idea that the mean density in a column times the volume of the column is a constant. Each column is assumed to have the same cross section and to extend from the depth of compensation to the surface of the earth.

The volume of the column and the density of the material are supposed to be normal under the coastal plains. The column under a mountain mass will be longer than normal, its volume will be greater and, therefore, its density of material must be less. Under the oceans the column of material is shorter than normal, the volume will be less and the density of material will be greater.

River deltas as a test of the strength of the earth's crust.

In his series of papers entitled "The Strength of the Earth's Crust," Barrell attempted to prove that the crust or isostatic shell is able to hold large masses as extra loads, because it is able to hold up the sedimentary material deposited at the mouths of rivers. He used the Niger and the Nile in his tests. He showed that the present configuration of the bottom of the ocean at the mouth of the Niger indicates that there is much material present in a space formerly occupied by water. He concluded that this material is an extra load and is a measure of the earth's strength. It appears to the writer that we may have an explanation of the presence of this sedimentary material which will be consistent with the theory of isostasy and the view that the earth's crust is not excessively strong.

The apparent maximum depth of the sediments in the delta of the Niger is approximately 10,000 feet. The density of this material is probably about 2.4. The density of sea-water is slightly over 1.0. Therefore the weight of water displaced by sediments is approximately the weight of 40 per cent of the material deposited. There remain 6000 feet of sedimental material which Barrell claimed is the overload.

If we should have a sinking of the sedimentary material in the isostatic shell, as we find has taken place in many parts of the earth, then we should expect to have some sediment above the former position of the bottom of the ocean. The sedimentary material is approximately 20 per cent lighter than the material whose space it occupies and, therefore, as a thousand feet of sediment is deposited, we can expect 800 feet of this material to sink into the earth and 200 feet to stand out. We can explain the ten thousand feet of material above the former ocean bed if the total thickness of sediments under the surface of the Niger delta is 34,000 feet. There would be 24,000 feet below the original position of the base of the sediments. This does not seem to be an excessive depth of sediment, judging from what has been found in other parts of the earth.

Barrell has found a depth of 7000 feet of sedimentary material under the surface of the delta of the Nile. If we use the same reasoning in regard to the Nile delta as for the Niger, we shall require only 24,000 feet of sediments to enable 7000 feet to project above the surface coinciding with the former bottom of the Mediterranean.

A test of this theory that the delta formation is not an overload could be made by gravity observations. Unfortunately, we have only one gravity station on a well-defined delta. This is at New Orleans, La. Here the gravity anomaly is −0.013 dyne. This is certainly an indication that the Mississippi delta is not an overload, for if it were the anomaly would unquestionably be positive.

The writer predicts that there will be a decided tendency for the isostatic gravity anomalies to be negative at delta stations.

Contraction of column under sediments.

In discussing the question of the delta formations, we assume that as the sediments are deposited, the surface of the sedimentary material gradually increases in elevation. There are cases where this is not true, for we find evidences of very thick sedimentary material, all of which was deposited in very shoal water. In such a case we have to assume that there must have taken place an increase in the density of the material of the column as sedimentation progressed. It is only by doing this that we can have a column under sedimentary material in equilibrium, because the material deposited is lighter than the material whose space it occupied. This change in density in the column is entirely apart from the isostatic adjustment. It must be due to some chemical or physical action of which we have no knowledge. It is possible that the decrease in density in the material in the column with resulting subsidence of the surface began before sedimentation started and really decided the region in which sedimentation should occur.

If we should have sediments to the depth of 40,000 feet, all deposited at about sea-level, and if the column were in equilibrium before sedimentation began, then we must have had an increase in the density of the material of the column and a consequent shrinking of the original material which is equivalent to about 8000 feet of sedimentary material. This sedimentary material is not above the sea-level surface and, as the sediments are not able to lower the former surface of the column except by their weight, we must assume that the space occupied by the 8000 feet of sedimentary material must have resulted from the contraction of the column. There undoubtedly is a small amount of contraction in the original material of the column, due to the pressure of the sedimentary material on the column, but this contraction would be a small percentage of the total contraction necessary to have all of the sedimentary material deposited close to sea-level.

I have given the question of sedimentary areas considerable space in this paper because of its fundamental importance to the theory of isostasy. If we can prove that the areas of sedimentation which have gravity anomalies of a negative sign, often of large size, are in isostatic equilibrium, then we would be justified in concluding that we have local rather than regional isostatic adjustment and the earth's isostatic shell would be shown to be far weaker than many are now willing to admit. The writer believes that we have proved that the large Cenozoic gravity anomalies are due to the presence of light material close to the station and that we are justified in assuming that the columns under the Cenozoic material are in approximate isostatic equilibrium.

Compensation exists under small areas having high relief.

I have not given space in this paper to a discussion of the gravity anomalies at stations on the Pre-Cambrian formation, but it is believed that the tendency of the anomalies at stations on that formation to have positive signs is an indication that the columns under the Pre-Cambrian may be in isostatic equilibrium. If we can eliminate or account for the anomalies on the Pre-Cambrian and Cenozoic formations then we have taken a long step forward in proving that local isostasy exists. It is, of course, a question of how local the area may be that is in isostatic equilibrium. This is a question that cannot be mathematically solved but as isostatic investigations are extended the areas which may escape a high state of equilibrium (at least in elevated regions) become smaller and smaller. They appear to be well within 100 miles square in mountain areas. This question of the size of an area which may be in equilibrium has an important bearing on the question of mountain formations.

Uplifted masses due to vertically rather than horizontally acting forces.

From a consideration of the discussion above we may assert that columns under mountain masses and under areas of sedimentation are in equilibrium. Therefore, if a mountain mass is formed over a column which was subjected previously to heavy sedimentation, the mountain mass will not be an extra load on the column. It is evident that this is the case, for the area of sedimentation must have been in isostatic adjustment or at least not lighter than normal, and we find that the mountain mass is not an extra load judging from the results of the investigations of the deflections of the vertical and the gravity observations.

If this mountain mass is not an extra load, then it could not have been brought from some other area to the one it now occupies. If it is not an extra load, it could not be due to horizontal thrusts operating in the earth's isostatic shell and extending far beyond the mountain areas. We are led to the conclusion that the cause of the mountain formation is a local one, and the only local cause seems to be a change in density in the column. This change must have been the result of a local expansion in the isostatic shell under the sedimentary material which was thrown up to form the mountain mass. In most cases the mountains are formed in areas where heavy sedimentation previously existed.

The mountain mass is not a permanent feature on the face of the earth as is shown by the fact that areas that are now high were once at or below sea-level and other areas, which at one time were high, are now depressed. The mere fact that we have had this oscillation of the crust and that all types of topography in areas where geodetic investigations have been made are in equilibrium leads us to conclude that there has been, in the past, changes in density in a column. At one time the density would increase, at another decrease.

It is not known just how these changes have been brought about but, in an area of sedimentation, the base of the sedimentary material may have been depressed as much as five miles. This would lead us to believe that all of the material below the base of the sediments down to the zone of isostatic flow had been depressed an equal amount and that the temperature of the material had been raised several hundred degrees Fahrenheit over what it was in its original position.

The isogeotherms may be depressed with the sinking of the column and, after the sinking has ceased, the lines of equal temperature may rise to their normal positions. In any event, the material of the column has been depressed to hotter zones and probably chemical and physical action has resulted, which may cause the expansion of the columns.

What is the cause of an increase in density in the column is, of course, not known, but when a column under a mountain mass is elevated as erosion takes place, we are bringing up material to colder zones than they formerly occupied and this may lead to some chemical or physical action which would contract the materials sufficiently to account for a depression of what was formerly a mountain area.

Horizontal movements may be incidental to vertical uplift.

There is abundant evidence that there have been horizontal forces at work distorting the sedimentary strata in a mountain area and we have evidence of overthrusts which extend for a number of miles. This, on first thought, might lead one to conclude that the mountain formation could not have resulted from vertically acting forces. The apparent answer to this objection seems to be that the base of the mountain system is usually large.

The Appalachian system is approximately 200 miles wide, on an average. This appears to be a sufficiently large area to permit of development of horizontal movements incident to the uplift. It seems reasonable to suppose that the sedimentary material was of widely varying thicknesses, that it was laid down at different rates at different places and that the base of the sediments gave way at different places at different times and at different rates. No doubt the sedimentary strata were somewhat distorted in the process of subsidence.

When uplift begins it is probable that it takes place in different sections of the area affected at different rates and at different times. There would be more resistance to the uplift in some parts of the area than in others. The isostatic shell just beyond the zone of uplift would undoubtedly have considerable effect on the upward motion of the materials of the column adjacent to its edges. It seems probable that the uplifted material would follow the line of least resistance and, at least near the surface, some of the lines followed by the material would be horizontal or nearly so. It is conceivable that in the process of uplift in a large area we should get distortions such as are found in most areas of mountain uplift.

We have evidence that much material of the earth has been uplifted without distortion. The great plateaus of the west have their strata practically horizontal and in some cases they extend for miles. These plateaus were originally at or below sea level and it is improbable that the material of the column of the isostatic shell under them was less dense than normal. Therefore, when they have been elevated, and the geodetic data prove that they are now in approximate equilibrium, we must conclude that no additional material has been added to the columns under the plateaus.

Barrell recognized the necessity for having a decrease of density under the Colorado plateau. In the "Strength of the Earth's Crust" he said:

> "It is known that a region like the Colorado plateau, which now stands markedly high, tended to lie near sea-level from the beginning of the Paleozoic to the end of the Mesozoic. Presumably a decrease of density within the zone of isostatic compensation has taken place here during the Cenozoic and the uplift has accompanied or followed the internal change."

Great changes in elevation not due to isostatic adjustment.

It must be clearly borne in mind that the theory of isostasy cannot explain great changes in elevation. There will, necessarily, be some changes in elevation which can be attributed to the theory of isostasy. These changes result from lighter material than normal being deposited and sinking to take the place of material of normal density. If no other action than isostatic adjustment acted in the column under the sediments we should expect the surface of the sedimentary material to increase gradually in elevation. If, for instance, we had 30,000 feet of material deposited we should expect at least three thousand feet to project above the original position of the base of the sediments. As a matter of fact, it is probable that the elevation of the surface would be even higher than that, because the difference in density between the sedimentary material and material displaced by the sediments is undoubtedly greater than ten per cent.

As erosion continues in a mountain area the surface should become gradually lower as the result of the isostatic adjustment. The reason for this is that material is brought into the column under the mountains heavier than the material that is eroded from the surface. If we should have 10,000 feet of material on the average eroded from the mountain mass, we should expect an equivalent mass of material to flow by isostatic adjustment into the column, probably at the base of the column. This material would, undoubtedly, be at least ten per cent heavier than the material eroded from the mountain. Therefore the mountain surface should be lowered at least 1000 feet, if 10,000 feet of material is eroded from it.

Aside from these changes in the elevation, I do not know of any others which are caused by isostatic adjustment. They must be due to other causes which, I believe, are decreases and increases of density in the isostatic shell. They are not believed to be due to transference of material horizontally from one region to another. Of course, I am speaking here of comparatively large areas for we do have evidence of transference of material in local areas.

Zone of horizontal movement.

Barrell in the "Strength of the Earth's Crust" presented arguments in favor of a zone of weakness below the isostatic shell which he calls the asthenosphere. He held that the isostatic movement, horizontally, takes place in the asthenosphere. Willis agrees with Barrell on this point. The writer has no very clearly defined ideas on this subject, but he believes that the views of Barrell and Willis are reasonable and justifiable.

If the earth's crust were weak enough to permit isostatic adjustment to take place comparatively near the surface, then we should expect that the materials would be so weak that masses of different densities would tend to flatten out and adjust themselves in strata, each with a uniform density.

That the isostatic compensation extends to considerable depth is an indication of a certain amount of resistance, horizontally, to movements. It seems probable, therefore, that the horizontal movements necessary to effect the isostatic adjustment take place below the isostatic shell. Whether the flow is very deep seated or in the outer portions of the asthenosphere cannot, of course, be determined, but the writer believes that the flow takes place just below the isostatic shell, in the outer portion of the asthenosphere.

Topography compensates deficiency or excess in isostatic shell.

Mr. R. D. Oldham, in discussing a paper[5] on isostasy presented before the Royal Geographic Society by Col. Burrard, emphasized the importance of stating clearly whether a mountain is compensated for by the deficiency of material in the column under it, or whether the mountain is a compensation of the light material of the column. Geodesists have spoken of compensating deficiencies of material under the continents and compensating excesses of material under the oceans, but it is the writer's belief that the mountain masses and the deficiency of matter in the oceans compensate the abnormal conditions of density which exist in the columns under them.

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[5] A Brief Review of the evidence on which the theory of isostasy is based. Geographic Journal, July, 1920, London.

ART. II.—*New Amynodonts in the Marsh Collection;*[1]
by EDWARD L. TROXELL.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

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THE AMYNODONTIDÆ.

Summary of Species and Relationships.

Orthocynodon Scott and Osborn (1882, p. 223), *Amynodon* Marsh (1877, p. 251), and *Metamynodon* Scott and Osborn (1887, p. 164) constitute a group of rhinoceros-like ungulates found in America alone. Authors have placed *Cadurcotherium* in the family Amynodontidæ, apparently on the basis of the great premolar reduction, but this seems wholly inharmonious when we judge this genus from the figures of its teeth (Abel 1914, p. 239).

Metamynodon planifrons Scott and Osborn and *M. rex,* sp. nov., come from the lower *Oreodon* beds, from a zone of river sandstones characterized by and named from the genus. Only two of these interesting specimens have been described and but few skulls are known to exist. The holotype of *M. planifrons* is in the Museum of Comparative Zoology at Harvard University; it consists of a skull and jaws. A fine complete skeleton in the American Museum of Natural History has been fully described by Osborn (1898, pp. 80-94).

The genus *Amynodon* is better known, because it is represented by several species: *A. (Orthocynodon) antiquus* (Scott and Osborn) is found in the Middle Eocene or Washakie; *A. advenus* (Marsh) and *A. intermedius* Scott and Osborn, together with *A. erectus,* sp. nov., represent the Uinta beds of the Upper Eocene, and are in general more advanced in their evolution. The Yale specimens come from the region of White River, Utah.

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[1] This is the first of a series of four articles on the rhinoceroses in the Marsh Collection; the three others deal in turn with *Hyracodon, Cœnopus,* and *Diceratherium.*

A. antiquus may be distinctly separated from the others, perhaps subgenerically, by the presence of both upper and lower functional first premolars, and by a marked difference in the general proportions of the teeth. The new species, *A. erectus,* is small and primitive, and in this respect approaches *A. antiquus,* but it has lost all trace of the first premolars and is of a later geological horizon. *A. intermedius,* the largest and most progressive of the species, resembles *Metamynodon* in the form of its canines and molars and approaches it in the size of the teeth, and in the stage of the premolar reduction also, where the premolar series measures half the molar length.

In progressing to the state of *Metamynodon,* an undoubted lineal successor, besides the slight further reduction of the premolars, we note the gradual lengthening of the skull behind the orbits, the widening of the molar teeth, the tendency toward complicated folds on the premolars, the increase in the size of the canines, the closing of the external auditory meatus below, and the general crowding and concentrating of the hinder part of the skull near the condyles or fulcrum, this last made necessary by the enormous increase in weight of the skull as a whole.

Adaptations to Physical Environment and to Feeding.

Most of the characters which distinguish these animals from the true rhinoceroses are thought by Osborn, Scott, and others to be a response to the needs of a semi-aquatic life. This is borne out especially by the observations on (1) the posture of the naso-maxillary opening, governed by the short nasals; (2) the position and form of the posterior nares; (3) the high, anterior position of the orbits; (4) the broad, spreading feet and their ability to fold backward; and (5) the great increase in size.

The naso-maxillary opening, or anterior nares, which depends upon and at the same time determines the form of the nostrils, taken together with certain features to be discussed later, suggests a prehensile, or very mobile lip such as one sees in the hippopotamus and other water animals. The depth and position of the posterior nares seem to facilitate breathing, by making a closer connection between the larynx and the nasal passages when the mouth is full of food or water; and further, they prevent the entrance of foreign substances, water, etc., into the larynx and windpipe while the mouth is open under water as in the act of gathering food.

An intimate connection of the epiglottis with the pharynx, as enclosed by the soft palate, is seen in the modern horse, where no passage of air is possible through the mouth in ordinary breathing. In this recent animal, it is thought to be a provision against breathing the dust from the grasses which constitute a greater part of its food. There is a resemblance in the form of this opening in the amynodonts and in the horse.

A further adaptation to a watery habitat is seen in the forward and high position of the orbits, which serves to keep the periscopic eyes out of the water for swimming or for observation while hiding; this finds its greatest development in *Hippopotamus,* in which the orbits actually rise above the plane of the face, and here also, as well as in *Metamynodon,* we find the broad spreading feet suited for walking on the softer ground near and in rivers and lakes—feet which are so constructed that the toes fold together backward as they are lifted and carried forward through the resisting water.

In speaking of the hippopotamus, Roosevelt and Heller say that the semi-aquatic habits have favored its development to an enormous bulk. This is no doubt true of *Metamynodon* also, and while locomotion would be difficult and clumsy on the land, it would be greatly facilitated by the buoyancy of water even if the beast were only partly submerged.

In both the genera of the Amynodontidæ the skulls show fossæ in the roof of the mouth, the purpose of which is problematical; but together with the deep antorbital depressions, they certainly constricted the nasal passages to a considerable degree and must have interfered with the organs of smell—of minor importance to an aquatic beast.

The following points may be interpreted as evidence of a prehensile lip at least in *Metamynodon:* (1) the roughened supra-orbital ridges, together with the conspicuous tubercles just in front of the eyes, and (2) the large cheek depressions, possibly indicative of large face muscles; (3) the moderately large infra-orbital foramina, doubled in the holotype of *A. erectus,* and required in order to furnish plentiful nourishment and nerves to the facial organs; and finally (4) the nature of the narial opening which, especially in *Metamynodon,* is triangular in form, broad above and constricted below, and situated well back on the maxillaries, due to the abbreviated nasal bones.

We may judge further of the living conditions of the Amynodontidæ by the character of the teeth. The canines and molars have developed with the skull and are larger than those of any other rhinoceros of the period, but the incisors and premolars have not kept pace and are scarcely larger than in *Amynodon,* showing but slight need for cutting teeth in these animals. The upper canines of *Metamynodon* and of *A. intermedius* were strongly procumbent and diverging; they were not erect in the jaw like the canines of *Archæotherium.*

The molars are broad and flat and in their use must have been comparable to those of an elephant, serving to grind up the food secured by the canines; this may have consisted of bark, tuberous roots, nuts, or leaves, gathered near the aquatic haunts, in the mastication of which the molars were used, leaving no need for premolars of the cutting type.

There seems to be little wear relatively on the narrow premolars; most of it comes on the middle of the cheek series, on M^1 especially. There is naturally less wear on M^3 which appears last, though on this molar one sees the vestigial extension of the ectoloph beyond its junction with the metaloph, which serves to prolong the period of usefulness of the tooth by furnishing a longer grinding surface.

In comparing these metamynodonts with the other groups of rhinoceroses of the period, we see that *Cænopus* and *Diceratherium* developed their molars more like the horses, i. e., for grazing, had sharper edges on the ectoloph for cutting the food, and the premolars were much more advanced and more molariform than in any of the amynodonts.

DESCRIPTION OF NEW SPECIES.

Metamynodon rex, sp. nov.

(Figs. 1, 2.)

Holotype, Cat. No. 10274, Y. P. M. Lower Oligocene (*Metamynodon* zone), Pine Ridge Agency, South Dakota.

This fine specimen was purchased from Mr. C. H. Little of South Dakota in 1889 by Professor Marsh; only recently has it been freed from the stony matrix and identified.

Skull characters.—The malar-temporal suture begins in the orbit; the zygomatic arch is concave internally in both directions and is very broad. The strong sagittal crest rises an inch or more above the cranium. The posterior nares lie entirely behind the last molar, with the opening very deep and well guarded by the broad pterygoids. The wide spacious articular glenoid surface extends onto the heavy postglenoid process, which curves forward and away from the paramastoid to which it is closely joined. The basicranial angle is large, a progressive character. The roof of the mouth is arched into a deep fossa between the premolars. There are deep cheek depressions, but they are restricted in area. The nasal bones are short.

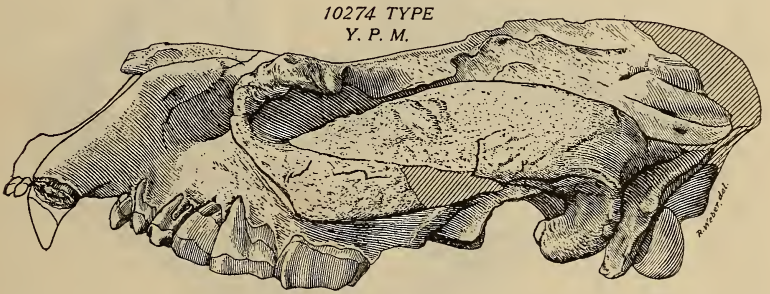

Fig. 1.—*Metamynodon rex,* sp. nov. Holotype. Side view of skull of the ponderous aquatic rhinoceros. Note heavy zygomatic arch, deep facial pit, strong outward curving canine (restored), and short face. × 1/6.

Dentition.—The incisor teeth, absent here, are known to be small in the type of *M. planifrons*. A diastema of 3 mm. separates the canine from P^2. P^1 is obsolete. P^2 forms an irregular pentagon; it is probably three-rooted, and is made up of crests and ridges like the other premolars, but appears in its natural posture to have been rotated through an angle of 80 or 90 degrees; thus the protoloph and metaloph extend directly backward instead of transversely.

P^3 is broad transversely and short antero-posteriorly, the diameters being 31 by 21 mm. The ectoloph is broad and in the present state of wear occupies about half of the surface of the tooth; the metaloph is very narrow, joins the protoloph through the deuterocone, and surrounds a central lake across which there is a very narrow bridge or small fold of enamel. Because of the small metaloph and the receded position of the tetartocone, the worn surface of the tooth forms a triangle.

P^4 presents equally strange characters: it is extended transversely but is squeezed in between P^3 and M^1 so that it is longer on the inner side than along the ectoloph. The wide extension inward forms a gentle slope from the deuterocone, but more especially from the tetartocone to the cingulum. The metaloph is relatively larger than that of P^3 and widely separated from the protoloph. On the right tooth, a sharp ridge, on the left a low broad one, unites the two inner cones. There is a sharp crista dividing the internal lake (medisinus), and numerous small folds on the metaloph represent the crochet.

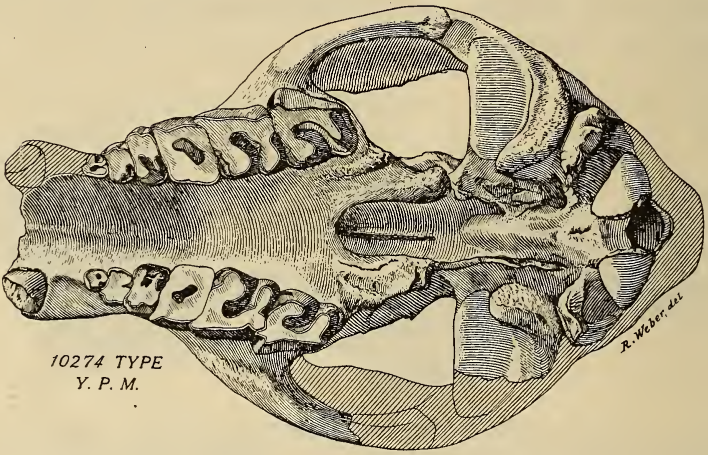

Fig. 2.—*Metamynodon rex,* sp. nov. Holotype. Palatal view of skull showing great reduction of premolars with P^2 rotated, deep posterior nares, heavy canine, and posterior extension of ectoloph on M^3. × 1/6.

The outer wall of the ectoloph on each premolar shows a heavy central buttress set off by vertical grooves in front and behind; this represents the central protocone, with the tritocone and parastyle behind and in front respectively.

M^1 is so worn that no characters remain except a faint cingulum on the outer side, together with a small lake or remnant of the diagonal medisinus. The tooth forms a parallelogram elongated transversely; its diameters are 37 and 53 mm.

M^2 has its back, inner, and front sides at right angles, but the outer side is an oblique line. The longest dimensions are, on the outside, 51 mm., and the front side, 60 mm. The medisinus forms a deep sharp groove, directed inward and then forward, uninterrupted by a cingular ridge or basal cusp on its outer end; the postsinus is rather deep, with a sharp fold inward. M^1 and M^2 show no groove, at the present state of wear, separating the parastyle; thus the outer walls are smooth and flat. M^3, however, shows this groove distinctly.

In form, M^3 is very much like M^2, but it has a narrower posterior side; it has the postsinus formed by the extension of the ectoloph, so typical of the family and so different from all other Oligocene rhinoceroses. On this tooth the internal basal cingulum swings into the medisinus, partly filling the groove. The posterior cingulum is much lighter than that of *Amynodon.* In contrast to the premolars, there are no folds of enamel on the walls of the transverse crests, but the enamel of the molars is generally thick and heavy.

A portion of the right ramus No. 12043 of a fossil rhinoceros may belong to a *Metamynodon;* the three teeth are probably P_4, $M_{1\cdot 2}$; they increase rapidly in size so that the M_2 is larger than that of any Oligocene rhinoceros known to the writer. Its great length and high crown are very striking features. The small premolars and the probable lack of P_1, perhaps of P_2, lend weight to the identification as *Metamynodon.*

Summary of Metamynodon rex, sp. nov.—The main differences between the two species of *Metamynodon* may be summed up as follows: premolars of *M. rex,* sp. nov., only submolariform; the type has no postorbital prominence rising from the malar such as appears in *M. planifrons;* the zygomatic suture either forms a sharp angle or leads from within the orbit; P^2 has three fangs instead of two. The much smaller molar length, relative to the premolar length, results partly from the greater age and wear, especially on M^1.

Measurements.

	M. planifrons Scott & Osborn 1887. mm.	*M. rex* Holotype mm.
Skull, length, incisor to condyles	550	520+
Width across arches	365	360
Face, orbit to premaxillary, ant.	170	? 111
Cranium, ant. of orbit to occiput	385	350
Molar-premolar series, length	225	202
Molar series, length	160	140
Premolar series, length	65	61
Diameters of teeth:		
C^1, ant.-post.	35	28.6
C^1, transverse	35	36
P^4, ant.-post.	25	23
P^4, transverse	45	43.4
M^1, ant.-post.	47	36
M^1, transverse	68	56
M^3, ant.-post.	60	58
M^3, transverse	64	60

Amynodon erectus, sp. nov.

(Figs. 3-6, 7*b*.)

Holotype, Cat. No. 11453, Y. P. M. Upper Eocene (Uinta beds), White River, Utah.

The type of this new species is the well preserved skull and jaws used by Professor Marsh in amplifying the description of *A. advenus* (1877, p. 251), figured by him in his work on the Dinocerata and used in the study of brain capacities in extinct mammals (1884, p. 62, fig. 72). The valuable internal cast of the cranium is still available for

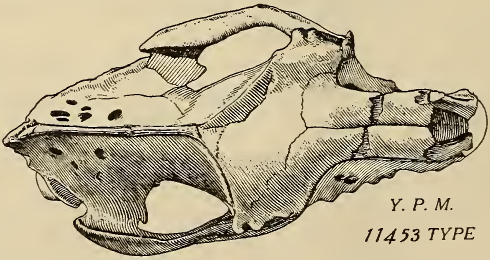

Fig. 3.—*Amynodon erectus*, sp. nov. Holotype. Top of skull showing left side crushed forward. × 1/6.

comparison and study. The specimen itself has been improved recently by further preparation and now becomes the holotype of a new species.

The genus *Amynodon* is much smaller than *Metamynodon*, and its skull has lighter parts, as shown by the zygomatic arch, the occipital condyles, the proportions of the teeth, etc.

Skull.—The posterior nares extend forward to the second molar, otherwise they resemble those of *Metamynodon* in form, in the depth of the opening, and in the prominence of the pterygoids. The external auditory meatus is open below in this genus, as shown by *A. erectus*, sp. nov.

The basicranial angle (17.5°) is lower than in *Metamynodon* (25°); this is considered a primitive character generally, but here the decrease is partly due to crushing. The premaxillary appears as a narrow strip, barely visible externally; the nasals fold down one third of the distance on the sides; they bear no horn rugosities such as are found in *Colonoceras* (Marsh 1884, p. 62). The deep antorbital depressions are rather broader and more open than in *A. intermedius*, where they are abrupt. There are two suborbital foramina on the right side, through which the nerves and blood-vessels reached the face. The supra-orbital ridge is roughened, and tubercles extend over and in front of the orbits.

Dentition.—There still remain the roots of the second and third upper incisors measuring about 9 mm. in diameter; the median incisor is broken away entirely. The canine alveolus measures 19 by 12 mm. In all probability this tooth was not procumbent as in *A. intermedius*, but was more like that of *A. antiquus* (Scott and Osborn 1883); its shape and position can best be judged by the lower canine, which rises and curves backward almost as in *Archæotherium* and is worn in a similar manner on the posterior side. From the canine to the second premolar there is a diastema of 23 mm.

The total measurement of the premolars, 50 mm., equals half that of the true molars, 98 mm. They are therefore almost as reduced as are those of *A. intermedius*, but that species includes its vestigial P^1, which is absent in the new species. It is seen from the wear on the lower teeth of *A. antiquus* also that P^1 was present. P^4 measures 31 by 19 mm.; the outline is well preserved and the worn enamel indicates a broad shelf on the postero-internal corner. Remnants of the internal lake indicate the presence of the two transverse crests as in other specimens.

M^1 is subquadrate in form and is much shorter, antero-posteriorly, than it is wide (27 by 38 mm.). M^2 forms an irregular quadrilateral with the longest sides anterior (42 mm.) and exterior (43 mm.). The outer side of its ectoloph is apparently entirely smooth, the cingulum and the groove marking off a parastyle both being lost by wear. On M^2 and M^3 there are heavy posterior cingula inclosing depressions (postsinus) and the broad inconspicuous antecrochets are set off by grooves extending down the protocones.

M^3 has three sides at right angles, while the side of the ectoloph runs on a diagonal. The diameters are: antero-posterior, 36 mm., and transverse, 39 mm. The outer side of the tooth is divided into two areas, or grooves, by a strong ridge opposite the paracone. There is a distinct parastyle. The continuation of the ectoloph beyond its union with the metaloph offers one of the distinguishing features of the Amynodontidæ.

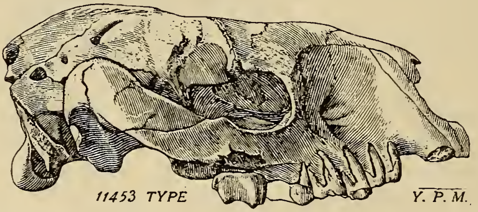

Fig. 4.—*Amynodon erectus,* sp. nov. Holotype. Side view of skull. × 1/6.

The postsinus is much deeper than that in the holotype of *A. advenus* Marsh (Cat. No. 11763, Y. P. M., fig. 7). In the latter the cingular ridge does not inclose a depression, anterior or posterior, nor does the cingulum extend across the end of the median valley. On the other hand, M^3 of *A. erectus,* sp. nov., in fact, each of the molars, has a strong cingulum anteriorly and a decided internal basal ridge extending across the medisinus which rises into a small cusp, as in certain diceratheres.

Lower jaws.—One ramus of the mandible is almost complete, including its dentition. The body is narrow and somewhat rounded, as in *Equus;* the horizontal portion is deep and strong, the ascending ramus is wide (cf. *A. antiquus*) and has a thick anterior border with a deep depression exteriorly.

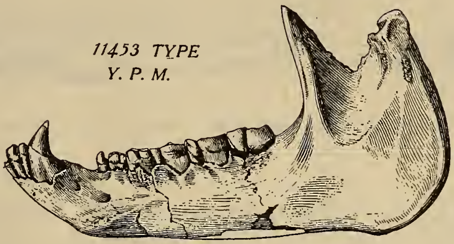

FIG. 5.—*Amynodon erectus,* sp. nov. Holotype. Side view of lower jaws showing erect canines and reduced premolars. × 1/6.

The lower teeth of this new species are of especial interest, furnishing new features of *Amynodon.* The first lower incisor is largest, and is worn off squarely on the end like those of the horse, while the third incisor is smallest and shows the spatulate, subconical crown with a strong cingular ridge on the posterior side. *M. planifrons* is said by Scott and Osborn (1887, p. 167) to reverse this order in the lower jaw, but to follow it in the upper incisors, a rather unusual thing.

The canine leaves the alveolar border directed forward but curves upward to an erect position. It is worn on the front side by the third upper incisor; more significant still, however, is the wear on the posterior side by the superior canine, which must therefore have been much more nearly erect than that of *A. intermedius.* It resembles in this respect *A. antiquus,* which is shown to have had an erect lower canine (Scott and Osborn 1883, pl. 5). The transverse diameter is 16 mm., the antero-posterior 18.5 mm. There is a diastema of about 35 mm. between C_1 and P_2, P_1 being obsolete.

The length of the series of three existing lower premolars is 45.7 mm., of the three molars 97.4 mm. P_2, the first of the series, is small, conical, vestigial; it has two depressions on the inner side, and a basal ridge. P_3 is intermediate in size, but has a form similar to P_4, which in turn is submolariform.

Most of the enamel is broken away from M_1. It is slightly smaller than M_2, which is similar in size and shape to M_3. The last is but little worn and shows well the two crescentic ridges so characteristic of the rhinoceroses.

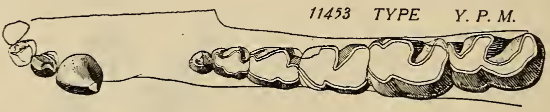

FIG. 6.—*Amynodon erectus,* sp. nov. Holotype. Crown view of lower teeth. × 1/3.

Summary of A. erectus, sp. nov.—The holotype is based on a very well preserved skull and jaws, more primitive than *A. intermedius,* but more advanced than *A. (Orthocynodon) antiquus.* It is smaller than any of the other species. It presents evidence of erect canines both above and below, and in this respect resembles *A. antiquus;* from this species it differs, however, in its later geological age, smaller size, and especially in the absence of both upper and lower first premolars.

The holotype of *A. advenus* Marsh, Cat. No. 11763, Y. P. M., consists of a single third upper molar. *A. erectus,* sp. nov., may be distinguished from it by the stronger cingula both fore and aft, the deeper postsinus, the much narrower medisinus with a basal cingulum and cusp obstructing its opening, and finally, its smaller size.

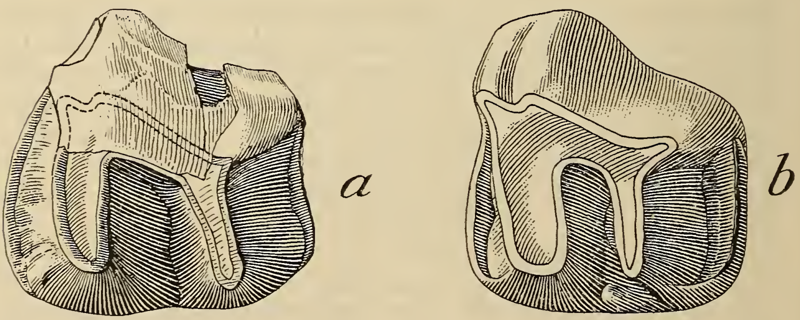

FIG. 7.—*a, Amynodon advenus* Marsh. Holotype. Cat. No. 11763, Y. P. M. *b, A. erectus,* sp. nov. Holotype. Cat. No. 11453, Y. P. M. Third upper molar of each species. Note the differences of size and form: the variation in the anterior and posterior cingulum, median valley, and internal basal cusp, and the ectoloph extended backward. Nat. size.

Measurements of Holotypes.

	A. erectus sp. nov.	*A. antiquus* (Scott & Osborn) 1883	*A. intermedius* Osborn 1890
	mm.	mm.	mm.
Skull: Length	350		
Length of molar-premolar series	145		187
Length of molar series	96	104	
Diameters of upper teeth:			
P^4, ant.-post.	20	22	
P^4, transverse	32	33	
M^1, ant.-post.	28	37	44
M^1, transverse	39	37	43
M^2, ant.-post.	37	45	53
M^2, transverse	42	37	52
M^3, ant.-post.	36	28	46
M^3, transverse	38	30	46
Lower jaw:			
Length, incisor to angle	356		
Width, body of ramus	45		
Depth of ramus below M_3	74		
Length of premolar series	46	80	
Length of molar-premolar series	142		
Same without M_3	104	165	
Length of molar series	98		
Diameters of lower teeth:			
I_1, transverse	13	9	
I_3, transverse	10		
C_1, ant.-post.	18	15	31
Diastema, C_1 to premolar	34	40	
P_2, ant.-post.	10	19	15
P_3, ant.-post.	15	23	21
P_4, ant.-post.	22	29	26.5
P_4, transverse	16	17	18
M_1, ant.-post.	29	37	35
M_1, transverse	19	24	22
M_2, ant.-post.	34	44	46
M_2, transverse	23		24
M_3, ant.-post.	38		47 ?
M_3, transverse	20		24

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ART. III.—*New Species of Hyracodon;* by EDWARD L. TROXELL.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

INTRODUCTION.

Hyracodon, a genus of rhinoceros-like animals, is known only in the Oligocene. Because of the slender limbs, long neck, and relatively small skull, it was early characterized by Scott and Osborn as cursorial, and it is probable that these light-running ungulates held the place in the economy of nature now filled by the antelope and others of the small ruminants.

Because of the already great reduction of the lateral toes, *Hyracodon* had reached a state of development almost equal to that of *Protohippus,* and, the race persisting, might well have become monodactylous, like the modern horse.

Four species of *Hyracodon* have been made known, only one of which has had figures accompanying the description. Leidy in 1850 gave us the first information of these animals; his later drawings (1852, 1854) have shown a widely diversified group, therefore *H. nebrascensis* in its broadest sense may apply to almost any hyracodont, and the species is virtually synonymous with the genus. The other known species are: *H. arcidens* Cope, *H. major* Scott and Osborn, and *? H. planiceps* Scott and Osborn.

Discussion of Known Species.

Hyracodon nebrascensis (Leidy).

> ''A species founded upon a great portion of the face, containing all the superior molar teeth; an inferior maxilla with six molars; and three superior, apparently deciduous molars. It is about the same size as the *R. minutus* of Cuvier.

''Length of line of seven superior molars	4 7/10 inches [119.4 mm.]
Length of line of six inferior molars	4 2/10 inches [106.7 mm.]
Breadth of jaws from the first superior true molar teeth of one side to the other	3 8/10 inches [96.7 mm.].''[1]

It is evident from this and subsequent descriptions that Leidy did not limit himself to one single species, but included specimens with varied features.

Hyracodon arcidens Cope.

The holotype is primarily based on a maxillary with the premolars and M^1 of a very young animal. Cope says:[2]

> ''The species is about the size of the *H. nebrascensis*, and differs in the form of the inner lobes of the molars and of the first premolar. All the molars have the outer longitudinal and inner transverse crests, the posterior short, the anterior much curved backward round it, and thus forming the inner boundary of the tooth-wall.''

This is apparently the first true specific description we have of a hyracodont; it is obviously similar to certain phases of *H. nebrascensis*—it could hardly be otherwise —but applies to that distinctive group, moderate in size, which have the anterior crest much curved backward.

Hyracodon major Scott and Osborn.

The type of this species is a fairly complete skeleton in the Princeton Museum. The species description[3] is based on a fore foot and therefore can not be compared to the new species described later in this paper; unfortunately it does not give any tooth characters and so we know little more than the proportional size of the specimen.

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[1] Joseph Leidy, Proc. Acad. Nat. Sci. Phila., 5, 121, 1850.

[2] E. D. Cope, Pal. Bull. No. 15, 2, 1873.

[3] W. B. Scott and H. F. Osborn, Bull. Mus. Comp. Zool., vol. 13, 170, 1887

The published measurements show this species to be a half larger than "*H. nebrascensis*"; it even surpasses the large *H. leidyanus*, sp. nov.

? Hyracodon planiceps Scott and Osborn.

This is a very large rhinoceroid which, by the authors,[4] is doubtfully referred to *Hyracodon*.

Description of New Species.

Hyracodon arcidens mimus, subsp. nov.

(Fig. 1.)

Holotype, Cat. No. 11174, Y. P. M. Oligocene, Deadwood, South Dakota.

The holotype consists of both maxillaries with all premolars in excellent preservation. It is evident that this is near the species Leidy first described in 1850, because the measurements are close; it corresponds in turn to the specimen figured in plate XII A, 1852[5] and resembles the maxillary shown in plate XIV, figs. 4-6, 1854.[6] Cope's description of *H. arcidens* shows it to have the same sort of looping protoloph, but his slightly larger holotype is not figured, so no close identification is possible.

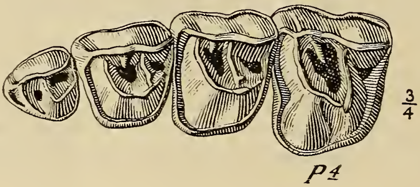

Fig. 1.—Upper premolars of *Hyracodon arcidens mimus*, subsp. nov. Holotype. Cat. No. 11174, Y. P. M. × 3/4. Note especially the continuous internal loops, the cristæ, and the prominent deuterocone of P^4.

A summary of the distinctive features is: strong crista on the larger premolars; protoloph joins the tetartocone and on $P^{2.3}$ it completely encloses the thin straight metaloph; deuterocone and tetartocone united in P^4 but with a deep double groove on the outside; cingula completely

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[4] Scott and Osborn, op. cit., p. 171.

[5] Joseph Leidy, in Owen's "Report of a geological survey of Wisconsin, Iowa, and Minnesota," etc.

[6] Joseph Leidy, Smithson. Cont. Knowl., vol. 6, art. 7.

surrounding all teeth; deuterocone very prominent on P⁴ and set off by vertical grooves; this tooth is subtriangular. None of the premolars can be said to be molariform.

Hyracodon selenidens, sp. nov.

(Figs. 2-3.)

Holotype, Cat. No. 11173, Y. P. M. Middle Oligocene, Colorado.

This new species of *Hyracodon* is especially notable for its small size and the crescentic form of the deuterocone, hence the specific name. The holotype is about three fourths the size of *H. leidyanus* described later, and is therefore the smallest of the Oligocene rhinoceroses. The species possesses certain features typical of *Cænopus* of an entirely different family, indicating parallel or convergent evolution; the complete enveloping of the metaloph by the protoloph, and the diminution of the former are seen in *C. allus* and reach an extreme in *C. nanolophus*, new forms described in a later paper of this series.

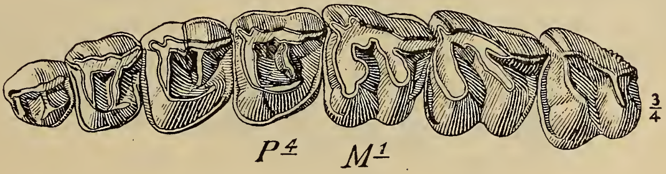

Fig. 2.—Upper cheek teeth of *Hyracodon selenidens*, sp. nov. Holotype. Cat. No. 11173, Y. P. M. × 3/4. The smaller cross crest is completely encircled by the other on the premolars of this very small species.

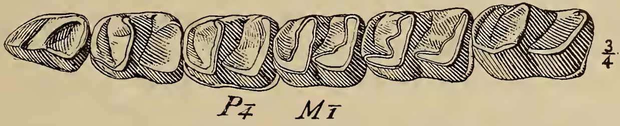

Fig. 3.—Lower molars and premolars of the small *Hyracodon selenidens*, sp. nov. Holotype. × 3/4.

P¹ departs from the pattern of the other premolars; its protoloph is scarcely more prominent than the cingulum posterior and is separated from the inner main cone; the metaloph bisects the tooth and ends in a cross on its outer end. The tooth forms roughly the half of an ellipse.

The anterior premolars increase rapidly in size and P^2 is a third wider than P^1. P^2 is subquadrate, having three sides at right angles. On this tooth the protoloph exhibits the prominence which in part characterizes the species. Its form, however, is not that of a perfect crescent, for it shows an irregular curve and a ridge or pillar where it joins the tetartocone. The metaloph is a thin straight wall dividing the equal-sized medi- and postfossettes.

P^3 resembles P^2 in nearly every respect, but shows a greater decrease in the size of the metaloph and a smoother crescent. On P^4 the deuterocone is set off by vertical grooves running up the sides; this cone shows a strong tendency to lean toward and to occupy the central portion of the tooth. The prominence of the base of the cone gives the tooth a somewhat triangular outline.

There is a small crista on P^3 and a small crochet on the metaloph of P^4 near the tetartocone, partly separating a portion of the medifossette or valley. There is evidence of a faint crista on M^2, but the crochet seen on other specimens is undeveloped. The antecrochet is not so conspicuous as in *H. leidyanus,* Cat. No. 11169.

The molars are smooth on their inner cones, and in general show extreme simplicity. The crowns are relatively low.

Hyracodon leidyanus, sp. nov.

(Figs. 4-5.)

Holotype, Cat. No. 11169, paratype, Cat. No. 11168, Y. P. M. Middle or Lower Oligocene, Crow Buttes, South Dakota.

The holotype of this species consists of a maxillary and ramus with tooth series P^1 to M^2 and P_2 to M_1, inclusive. The paratype material includes two specimens; one may be a part of the holotype but that can not be demonstrated. The parts preserved are: second upper molar, atlas, vertebræ, numerous toe bones, tibia, astragalus, navicular, metatarsus, and broken parts of the calcaneum, radius, metacarpal III, another tibia, and a second metatarsus.

The holotype is unusual in its large size, smooth teeth, molariform premolars, and high crowns, together with the following additional features: The protoloph of P^1 joins more intimately with the metaloph than with the ectoloph and is very much decreased in size. The metaloph of P^2, which is only submolariform, extends at right angles from the ectoloph and at its end hooks backward in a way peculiar to *Hyracodon* alone. At a later stage of wear, the two inner lophs unite by a narrow bridge.

On the molars and large premolars there are developed sharp cristæ and crochets, a feature which is well known in the totally unrelated later rhinoceroses, where the medifossette in its extreme form becomes a lake. New characters like these seem generally to arise on the outer edges of the cusps, and then in the course of evolution appear gradually more deep-seated. They are therefore quickly worn away from the tooth of a more primitive type.

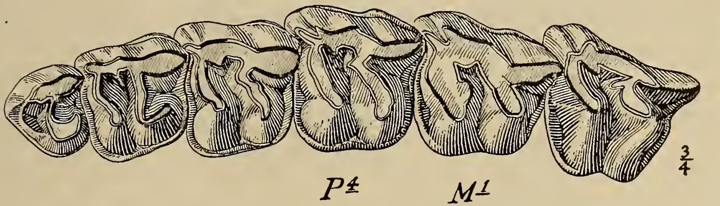

FIG. 4.—*Hyracodon leidyanus,* sp. nov. Holotype. Cat. No. 11169, Y. P. M. × 3/4. In this large specimen the ridges of the premolars are parallel and the median valleys uninterrupted.

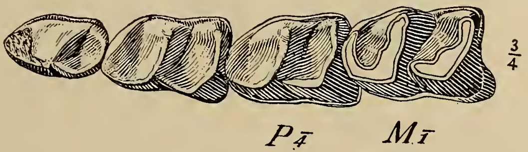

FIG. 5.—Lower molars of *Hyracodon leidyanus,* sp. nov. Holytype. × ¾.

The antecrochet on $M^{1\cdot 2}$ is very strong and a sharp vertical groove divides it from the protocone. Two grooves thus mark off the protocone, while one appears to limit the hypocone. The cingular ridges do not cross the bases of the inner cones of the molars as they do the premolars.

The lower cheek teeth, like the upper, are notable for their general simplicity, subdued cingula, high crowns, flat outer surface, and lack of angularity. In *Hyracodon* there is not a great difference in the height of the anterior and posterior lobes of the lower molars, as there is in *Cœnopus* or even *Trigonias.*

In the lower jaw, an alveolus reveals the former presence of P_1 or Dp_1, which as a permanent tooth is seen in no other specimen of *Hyracodon* at hand, indicating in general the advanced evolution of this genus.

The external vertical groove of the lower teeth curves backward in a way unlike that of any other specimen observed, and, especially in the two larger premolars, continues into the cingular ridge instead of ending abruptly against it.

SUMMARY.

There are three families of extinct rhinoceros-like animals: the true Rhinocerotidæ, giving rise to our modern animals; the Amynodontidæ, culminating in *Metamynodon* in early Oligocene time; and finally, the Hyracodontidæ, represented by the single genus *Hyracodon,* found in the Lower and Middle Oligocene of the Great Plains. This genus is easily distinguished by its small size, its slender proportions, and the presence of all canine and incisor teeth. The trend of its evolution seems to have been toward the loss of the lateral toes, a cursorial adaptation.

Two new species and one subspecies have been established here in order to set forth features which either have been ill defined, or are entirely new in the genus.

Measurements of Holotypes.

	H. mimus mm.	*H. leidyanus* mm.	*H. selenidens* mm.
Upper jaw:			
Premolar series, length	67	74	57
Molar premolar series, length	129*	142*	110
P¹, length	13	14	11
Width	14	16	12
P², length	16	18	14
Width	19	21	16
P³, length	18	21	15
Width	23	25	19
P⁴, length	20	22	16
Width	26	27	21
M¹, length		24	19
Width		25	21
M², length		27	20
Width		27	21
M³, length			17
Width			21
Lower jaw:			
Length of three premolars		61	46
Length of three premolars and M_1		85	63
Length of molar premolar series			101

*Estimated.

ART. IV.—*Cænopus, the Ancestral Rhinoceros*; by

EDWARD L. TROXELL.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

INTRODUCTION.

Until very recent times there were two great groups of extinct rhinoceroses mentioned in the literature, *Aceratherium* Kaup and *Diceratherium* Marsh, and specimens from Lower Oligocene to Middle or Upper Miocene, both in the Old and New World, were classified according to the nasal bones, whether or not they had rugose thickenings designed to support horns. Due to the work of Osborn, Scott, Loomis, Cook, and especially of Peterson, it now appears that the two classes are simply the hornless females and the horned males of a variety of genera. There are, however, two important exceptions to this general rule: (1) the early Oligocene species which did not show the horn rugosities in the males, and (2) those recent animals (excepting *Rhinoceros sondaicus*) in which both males and females may have horns.

Peterson shows that in *Diceratherium cooki* the horns belonged to the mature males alone; the females and young males were hornless. In the Peabody Museum there are horned and hornless specimens of *Diceratherium* from the John Day beds of Oregon. The mature animals may be either, but the very young individuals always have smooth nasals. Osborn (1898) has demonstrated that *Cænopus tridactylus* also has this sexual distinction, following the discovery by Hatcher (1894) of "*D.*" *proavitum* with horns in the males in a very primitive state. The name of *Diceratherium* therefore ceases to have its original sense, all inclusive, and is now limited to one phase of the horned rhinoceroses, the type of which is *D. armatum* Marsh. Other species of "diceratheres" may be, and some are, widely separated in their classification, as will be shown later.

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[1] For obvious reasons, space is not given to the publication of all references; the reader is therefore directed to the memoirs by Osborn ("The extinct rhinoceroses", Mem. Amer. Mus. Nat. Hist., vol. 1, 75-164, pls. 12A-20, 1898) and by Peterson ("The American diceratheres", Mem. Carnegie Mus., vol. 7, 399-477, pls. 57-66, 1920), in which detailed descriptions, fine reproductions of all important types, and full bibliographies are published.

Likewise the word *Aceratherium,* heretofore considered to stand for a genus incorporating all aceratheres or hornless rhinoceroses, loses its etymological significance, and by exact definition, based in great measure on the teeth and parts of the skull other than the nasals, comes to be the name of a group which may be and probably is limited to the Old World.

CLASSIFICATION OF SPECIES.

Trigonias osborni Lucas 1900. Genoholotype.
Cænopus mitis (Cope) 1874. Genoholotype.
Cænopus pumilis (Cope) 1886. Synonym of *C. mitis.*
Cænopus (*Leptaceratherium*) *trigonodus* (Osborn and Wortman) 1894. Subgenoholotype. Leads to *C. platycephalus.*
Cænopus trigonodus allus, subsp. nov. Figs. 1, 2.
Cænopus copei (Osborn) 1898. Leads to *C. tridactylus.*
Cænopus occidentalis (Leidy) 1851. Inadequate.
Cænopus tridactylus (Osborn) 1893.
Cænopus dakotensis Peterson 1920. Synonym of *C. tridactylus.*
Cænopus tridactylus proavitus (Hatcher) 1894 .
Cænopus tridactylus metalophus, subsp. nov. Fig. 4.
Cænopus tridactylus avus, subsp. nov. Fig. 5.
Cænopus platycephalus (Osborn and Wortman) 1894.
Cænopus platycephalus nanolophus, subsp. nov. Fig. 3.
Cænopus simplicidens Cope 1891. Of doubtful validity.

DISCUSSION OF GENERA AND SPECIES.

Trigonias Lucas.

The earliest species of the true rhinoceros is made the genoholotype, *Trigonias osborni* Lucas. As summarized by Hatcher (1901), the upper teeth are unreduced, C_1 alone absent, simple superior premolars, P^1 large, P^2 with non-parallel lophs, four digits on the manus. Its geological age is that of the lower Titanotherium beds (lowest Oligocene). The ancestry of the genus is obscure, but it undoubtedly gave rise to *Cænopus* Cope.

Cænopus Cope.

Cænopus is a genus which includes all of the White River (Middle and Upper Oligocene) species; it is based upon the holotype of *C. mitis* (Cope), a fragmentary lower jaw quite indeterminate specifically. The species is usually represented by the paratype maxillary with molars and premolars (No. 6325, A. M. N. H.).

In general, the genus is distinguished by the presence of two upper incisors, the absence of the canines (see *Leptaceratherium* below), the presence of rudimentary horn cores or none at all, parallel lophs on P^2, and the tendency toward this arrangement in other premolars in later species.

The generic group is composed of *C. trigonodus* (Osborn and Wortman), and *C. copei* (Osborn), two species which seem to lead respectively to *C. platycephalus,* the terminal member of its line, and to *C. tridactylus,* which probably furnished the source of all later forms, certain possible immigrants excepted.

Cænopus (*Leptaceratherium*) *trigonodus* (Osborn and Wortman) as a type possesses the upper canine and thus forms the connecting link between this genus and *Trigonias.* This species has a further important primitive feature, a loop uniting the cross lophs of the premolars through the deuterocone and tetartocone, which are so blended as to appear as one element; in this respect also it approaches *T. osborni,* while on the other hand it trends toward *C. platycephalus*, its probable successor.

A new subspecies of *C. trigonodus* is described on a later page in this paper. It illustrates an advanced step in the evolution: has already lost I^3 and C^1, and has developed a very prominent deuterocone on P^4 which envelops the thin sinuous metaloph (Cat. No. 12052, Y. P. M.).

Cænopus platycephalus (Osborn and Wortman) is typically an Upper Oligocene species, but smaller and more primitive specimens have been reported. Its type is marked by a broad low cranium and nearly obsolete sagittal crest; the species is also noted for the distinct separation of the tetartocone from the metaloph, the great reduction of the latter, the simplicity of the molars, and generally for the large size of the individuals.

A new subspecies will be proposed (Cat. No. 12489, Y. P. M.) which, because of the extreme reduction of the metaloph and the expansion of the deuterocone to occupy the whole inner portion of the larger premolars, is thought to be the termination of its line, and to be in no way related to later genera.

Cænopus copei (Osborn), although it is barely distinguishable from *C. occidentalis* (Leidy) (heautotype, the holotype being lost), except in size, and although it resembles very much the paratype maxillary of *C. mitis* (Cope), yet should take precedence over either of these because their types are not adequate nor dependable. *C. copei* holds a very important place in taxonomy, since to a large extent it has usurped that of *C. occidentalis,* which is so frequently mentioned in our literature, and stands at the very beginning of that branch of the genus *Cænopus* which gives rise to *C. tridactylus* and probably many of the later genera of American rhinoceroses. Its geological level is the base of the Oreodon beds (early Oligocene).

Cænopus tridactylus (Osborn) is a very important species having a variety of characters which are strongly emphasized in later forms. One is therefore convinced that this is a pivotal point in the racial evolution, and from it there arise two or more lines of descent. Throughout this species the following are notable features: (1) the development of the parallel lophs on the premolars, (2) the greater complication of the enamel of the molars by the presence of cristæ and crochets, (3) the loss of all trace of C^1 and I^3, (4) the reduction to the tridactylous manus, and (5) the first appearance in the males of the thickened and rugose nasals for the support of horns.

The development of horns here is in a very primitive state, but a considerable advance is made in the next stage, *D. armatum,* where the horn supports are much more rugose and elevated, but still widely separated and situated well behind the tips of the nasals.

Other subspecies are chosen to illustrate more fully the variety of forms in *C. tridactylus* and the trend of that species toward the true *Diceratherium,* especially with regard to the simple parallel cross lophs on the premolars. Specimen No. 10254, Y. P. M., is taken as the holotype of one new subspecies, and specimen No. 10251 of another; both are described on a later page.

DESCRIPTION OF NEW SUBSPECIES.

Cænopus trigonodus allus, subsp. nov.

(FIGS. 1 and 2.)

Holotype, Cat. No. 12052, Y. P. M. Middle Oligocene (White River beds), Nebraska.

The type material consists of the anterior portion of the face and the larger part of the lower jaws, not including the symphysis. The tooth series (fig. 2) is larger by the length of M^3 than that of the holotype of *C. trigonodus* or of *C. copei.* Other distinctive features consist of the small ridge in front of the protoloph and the great extension of the ectoloph forward on P^1, the reduced tetartocone of P^2 and its union through a broad ridge with the deuterocone, the strong deuterocone of P^3 and more especially of P^4, and the weak metaloph which on P^4 is a thin band so narrow that a wide space is left in front and behind it for the deep fossæ.

Fig. 1.—*Cœnopus trigonodus allus,* subsp. nov. Holotype. Side view of skull. × 1/3.

The cingula are weak around the bases of the deuterocones, but on the molars the cingula are discontinuous across the bases of the protocones and hypocones. Irregular tubercles and ridges obstruct the entrance to the medifossette or central valley. There are no sharp secondary folds on the molars, but the antecrochet is prominent.

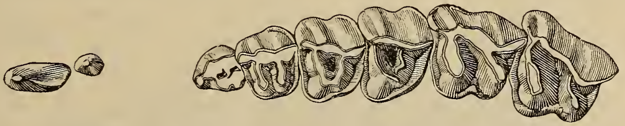

Fig. 2.—*Cœnopus trigonodus allus,* subsp. nov. Holotype. Molar-pre-skull. × 1/3.

$I^{1\text{-}2}$ are present, but the third incisor and the upper canine are obsolete. The nasals are smooth, slightly expanded over P^1, and notched. There is a broad, shallow depression in front of the orbit.

The specimen is from layers later geologically than *C. trigonodus* but about the same age as *C. copei.*

Cænopus platycephalus nanolophus, subsp. nov.

(Fig. 3.)

Holotype, Cat. No. 12489, Y. P. M. Middle or Upper Oligocene, Colorado.

This new subspecies is founded on a holotype consisting of the permanent upper molars and premolars of a young individual. The new name has reference to the dwarfed condition of the metaloph. It represents an undescribed species of rhinoceros near *C. platycephalus* but because of its incompleteness is ranked as a subspecies.

The tetartocone in each premolar except P^1 is closely joined to the deuterocone, and in P^4 these constitute a single element. P^2 varies from the others in having a groove on the outer side defining the two cones, which in this case are united to form a continuous loop of the inner lophs. On P^1 the metaloph is large and curves backward to enclose the postfossette; the protoloph is short and straight, while the ectoloph is broad and heavy and occupies the greater part of the tooth.

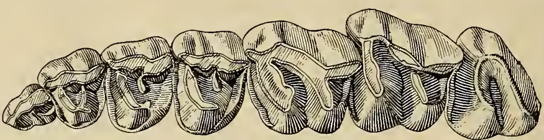

Fig. 3.—*Cænopus platycephalus nanolophus*, subsp. nov. Holotype. Molar-premolar series. × 1/3.

In most species of *Cænopus* the anterior side of the larger premolars is greatly lengthened by having a prominent protocone antero-exteriorly, and a tritocone so subdued that this part of the ectoloph is smooth exteriorly, as in the molars. In the specimen under discussion, however, the equal prominence of the two outer cones gives this side of the tooth a squared form; the ectoloph is at right angles to the anterior and posterior sides of the tooth. The premolars (except P^1) are thus subquadrate, with the inner sides rounded. The parastyle and metastyle are separated by grooves from the prominent exterior cones.

The anterior cingulum is strong on each tooth except P^1 but it does not encircle the inner border completely. On

P^4 the postero-interior cingulum rises high on the tetartocone, and forms a veritable cusp or cone; it descends sharply on the inner side and becomes broken along the base of the deuterocone. On P^3 it becomes an integral part of the tetartocone, and on P^2, antero-interiorly, the cingulum blends with the deuterocone, rising high on the side to do so. The posterior cingulum of each molar is much less extended than is usual in the rhinoceroses of this time, so that not only is the hypocone a smooth rounded base, but the median valley also is uninterrupted by cusp or cingulum, in this respect differing from *C. platycephalus.* The postfossette is very small on $M^{1.2}$ and on M^3 is entirely lacking. The antecrochet on the molars is low and broad, while an inconspicuous crista is present on each of the larger premolars.

An unusual feature is seen on these premolars, in that the postfossette is larger than the medifossette and the two are confluent, due to the short metaloph; the median valley opens backward instead of inward and this, together with the dominance of the deuterocone, constitutes the chief feature of the subspecies. The type of the subspecies is about five sixths the size of that of *C. platycephalus.*

Cænopus tridactylus metalophus, subsp. nov.

(Fig. 4.)

Holotype, Cat. No. 10254, Y. P. M. Probably Middle Oligocene, Rushville, Nebraska.

The holotype of this new subspecies shows a strong tendency to have the cross lophs of all the premolars parallel and unconnected. The form of these lophs would seem to link it with *C. tridactylus* (Osborn) and remotely with *Diceratherium* Marsh. There is evident a close sim-

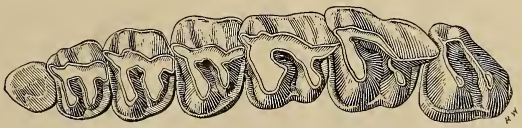

Fig. 4.—*Cænopus tridactylus metalophus,* subsp. nov. Holotype. Molar-premolar series. × 1/3.

ilarity to the skull of *C. proavitus* Hatcher in the form of the wide area between the parietal ridges on the sagittal crest. These ridges for a considerable distance are almost straight, converging at an angle of about 30° up to a point 8 or 9 cm. from the occiput, whence they run uniformly parallel. The occiput rises well above the plane of the face.

Both the proto- and metalophs are straight; the latter are especially thin and the terminating cones are not intimately connected with the strong postero-internal cingulum. The metaloph does not increase the length of its surface with wear, but with advanced age it may unite with the protoloph, at a point, however, scarcely more than halfway along the latter. The tetartocone, though small, is not recessive; it stands near the outer edge of the tooth crown, thus giving the great length to the metaloph.

The deuterocone, as it terminates the protoloph, swings forward, away from the tetartocone, in decided contrast to the *C. trigonodus* or *C. platycephalus* type of premolar, in which it curves backward, envelops the central part of the tooth and sometimes even the metaloph itself. The cingula are interrupted for short distances on the protocones and hypocones of the first and second molars, but the one is continuous on the protocone of the third molar. On P^4 there is a small crista. The antecrochet is prominent on the molars, giving a strong curve forward to the median valley. There is a small groove running up the protocone.

The slender premaxillaries supported the first incisor teeth only, which were found separated from the skull. The nasals, extending out to the ends of the premaxillaries, are unusually slender. This is commonly considered a sexual difference, but it is here presumed to be a feature of the earlier stages of the evolution, for no Middle Oligocene forms are known to have the rugose horn supports.

This specimen is probably one of the progenitors of *C. tridactylus* which leads ultimately to the parallel-lophed rhinoceroses of the Great Plains, where in each succeeding stage the enamel folding becomes more and more complicated. *C. tridactylus* is longer in the tooth series by the length of M^3; *C. copei* is shorter by that amount.

Cænopus tridactylus avus, subsp. nov.

(Fig. 5.)

Holotype, Cat. No. 10251, Y. P. M. Upper Oligocene (Protoceras beds), South Dakota.

Cænopus tridactylus avus, subsp. nov., is very probably a true form of this species, but as a subspecies shows a decided trend toward *Diceratherium armatum* (see fig. 6.) The type material consists of the skull of a young animal still retaining the last milk tooth, Dp^4, and having the last molar uncut. The first three premolars (P^4 is also uncut) are notable for the parallel, separate lophs, uniting only with wear. The metaloph is at first longer, but because of the extended base of the deuterocone, the protoloph soon surpasses it in length. P^1 has two parallel, backward curving crests, but the metaloph does not encircle a lake (postfossette) as does Osborn's paratype (1898, pl. 13). On the larger premolars, small sharp folds appear on the ectoloph, and on P^3 (left) one has an unusual position behind the metaloph. On P^2 and P^3 (right), there is a fold in the anterior angle between the two lophs.

Fig. 5.—*Cænopus tridactylus avus,* subsp. nov. Holotype. Premolars and first and second molars. × 1/3.

Cristæ and crochets may be seen on the molars, and the latter, especially on M^1, have encroached so far on the median valley as to isolate a small lake (medifossette). On the protoloph of M^1, two vertical valleys, anterior and posterior, partly separate the protocone from its protoconule; the posterior valley emphasizes and sets off the moderate antecrochet. The inner cingula are broken across the bases of the protocone and hypocone, and are peculiarly offset where the two ends join in the median groove.

Not only in size but in the general form of the skull does this specimen resemble *C. tridactylus*; it has the rising and double parietal ridges extending into the sagittal crest. The nasal bones are long and slender, slightly wide over P^1, where there appear actual shoulders or barbs resembling in this feature *C. copei*. Another specimen in the collection, Cat. No. 12059, Y. P. M., has the broad thick nasals, presumably of the male, but they do not show the rising protuberances so typical of the later *Diceratherium.*

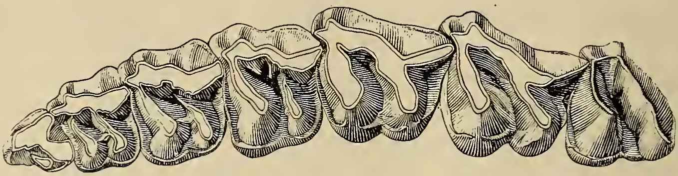

FIG. 6.—*Diceratherium armatum* Marsh. Holotype. Molar-premolar series. × 1/3. (See Peterson 1920 for reproduction of complete skull.)

Measurements of New Subspecies and also of D. armatum.

	C. allus No. 12052 Y. P. M. mm.	*C. nanolophus* No. 12489 Y. P. M. mm.	*C. metalophus* No. 10254 Y. P. M. mm.	*C. avus* No. 10251 Y. P. M. mm.	*D. armatum* No. 10003 Y. P. M. mm.
Molar-premolar length ...		205	194		254
Premolar series, length...	98	98	98	111	129
Molar series, length		115	102		139
P^4, width, base	37	39	39		50
P^4, length, center	27	28	26		34
M^1, width, ant.	37	43	39	44	53
M^1, length, center	33	38	33	38	44
M^2, width, ant.	39	48	40	45	56
M^2, length, center	38	41	35	39	50
M^3, width, ant.		43	39		50
M^3, length, inner side.....		39	35		48

SUMMARY.

With further study of the great family of rhinoceroses it becomes evident that they can not be classified on the presence or absence of horns, a sexual variation; the female and young diceratheres had no horns; probably the male acerathere had them, at first in an incipient stage.

The genus *Cænopus* Cope includes nearly a dozen distinct species and subspecies, representing a long line of ungulate evolution extending throughout the Oligocene. Clearly separated from the Hyracodontidæ and Amynodontidæ, this gave rise to all later forms, including the modern genera of rhinoceroses.

Four new subspecies are proposed: *Cænopus allus* is noted for its strong protoloph and weak metaloph; *C. nanolophus* is so named from the dwarfed or incomplete metaloph on the premolars and the large posterior fossa. *C. metalophus* reverses the conditions of the others mentioned and has a metaloph as long as the protoloph and the two are parallel. This is probably one of the progenitors of *C. tridactylus*. *C. avus,* although a valid subspecies of *C. tridactylus,* yet shows a very definite similarity to *Diceratherium* Marsh and is ancestral to it. It is notable for the parallel cross lophs, complicated enamel bands, and its late Oligocene age.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *A Recalculation of the Atomic Weights.*—Dr. Frank Wigglesworth Clarke, chemist of the U. S. Geological Survey, has now published the fourth edition, revised and enlarged, of this important work in the form of a volume of 418 quarto pages. The data of atomic weight determinations are presented very fully and the various ratios, with the exception of some that appear to be undoubtedly inaccurate, are calculated in connection with their mathematical probable errors. Then the available ratios are combined, with weightings according to their probable errors, in order to find the atomic weights. The author admits certain deficiencies in this mathematical method of calculation, due to the effect of constant errors in the determinations, such as the effect of impurities in the substances weighed, but it appears that his method is the best one available. A final table of atomic weights is presented in which the greater part of these constants are carried out to five figures. The table varies in this last respect from that of the International Committee, and there are also other appreciable variations in the two tables. For instance, Clarke gives 27.039 for aluminium, while the International Tables give 27.1, and it is interesting to observe that Richards has found, just recently and too late for Clarke's use in the work under consideration, that this atomic weight is probably about 26.96.

The work is a very useful one for the purpose of reference to what has been done in atomic weight determinations, and it will be a valuable aid to future workers in this field. Chemists should be grateful to the author for the prodigious amount of labor and the careful study that he has devoted to its preparation.—*Memoirs Nat. Acad. of Sciences,* Vol. **16**, *Third Memoir.*

H. L. W.

2. *The Fundamental Processes of Dye Chemistry;* by HANS EDWARD FIERZ-DAVID; Translated by FREDERICK A. MASON. 8vo, pp. 240. London, 1921 (J. and A. Churchill).—This is the English translation of an important Swiss work on the practical side of dye chemistry. The book gives very full details for the laboratory preparation of many important intermediate products and dyes, and in connection with these descriptions there are interesting notes on the technique and practice of the factories. There are 49 excellent illustrations, including 19 plates, showing laboratory and factory apparatus. The book gives in a separate section a general discussion of various technical details, including vacuum distillations, the construction and use of autoclaves, structural materials, works management, and the calculation of costs. A section is devoted also to analytical details.

The book appears to be a very excellent one for the use of students of dye manufacture, both as a guide for laboratory work and a work of reference. It should be very interesting also to other students of organic chemistry as it well displays the high degree of perfection to which organic synthesis has been brought in this highly developed chemical industry.

H. L. W.

3. *Organic Chemistry for the Laboratory;* by W. A. NOYES. 8vo, pp. 293. Easton, Pa. 1920 (The Chemical Publishing Company).—This is the fourth edition, in which there are but few changes in comparison with the last issue of four years ago. As is well known, the book is an extensive laboratory manual for organic preparations including preliminary chapters on ultimate organic analysis and general operations, and a final chapter on the qualitative examination of carbon compounds. The processes are clearly described and there are abundant references to the literature in connection with them. The first edition of this book appeared in 1897, and it is evident from the frequency with which new editions have been issued that the book is extensively used.

H. L. W.

4. *Qualitative Chemical Analysis;* by M. CANNON SNEED. 8vo, pp. 198. New York, 1921 (Ginn and Company).—This text-book has been prepared by the head of the division of general inorganic chemistry in the University of Minnesota. Its presentation of the subject differs very much from the usual methods. A large part of the text is devoted to a decidedly

mathematical presentation of physical chemistry, particularly such aspects of it as lead up to and discuss the theory of electrolytic dissociation or ionization in solution. Such topics as physical and chemical equilibrium, ionic equilibrium treated quantitatively, are also rather elaborately presented. The author states that the book is designed for the use of students who have had a rather thorough course in general inorganic chemistry, and hence extended explanations of simpler processes, interpretations of many elementary reactions, and almost all equations have been omitted. He makes the further statement that reference books of qualitative chemical analysis and general inorganic chemistry are assumed to be available at all times. The importance of instruction in physical chemistry is admitted, but it may be questioned whether the student should not first learn the facts connected with qualitative analysis and afterwards apply them to the study of theories, rather than to attempt to explain facts on the basis of theories; for it is certain that theories are based upon facts, not facts upon theories. A course in qualitative analysis is usually employed as the best opportunity to give the student of chemistry a thorough drill in the writing of chemical equations. This feature is practically neglected in the book under consideration.

The book displays many good features, and is probably well adapted for the use of certain classes of students, but it seems doubtful that its plan of teaching qualitative analysis will be widely followed. H. L. W.

5. *Factory Chemistry;* by Wm. H. Hawkes. 12mo, pp. 59. New York, 1921 (Longmans, Green and Co. Price $1.00 net).—This very small text-book comes from the Department of Chemistry, Ford Institute of Technology, Detroit, Mich. It is said to be intended for the use of "factory men interested in the study of chemistry as it bears on the various operations in factory processes," but an examination of the book fails to reveal any such practical bearing. There are brief statements and definitions of some of the principles, laws and terms of chemistry, but the book is devoted chiefly to an explanation of valence in connection with the writing of formulas and equations and to a condensed outline of qualitative analysis. The attempt to teach the writing of equations in connection with the laws of valence alone appears to be unsatisfactory, for in one place, under the heading "*Oxides and Acids=Salts and Water,*" the student is directed to complete the equations of a number of oxides, including PbO_2, SnO_2, As_2O_5 and Sb_2O_5 with acids H_2SO_4, HNO_3, HCl, $HC_2H_3O_2$, H_2CO_3 and H_3PO_4. In these cases most of the expected "salts" do not exist, or else the oxides do not dissolve in the acids, so that nearly all of the equations would represent impossibilities. There appears to be no information given in the book as to the fact that many reactions are reversible, nor

any explanation of the fact that some of them are practically complete in one direction.

The qualitative analysis is presented in the form of equations of the reactions—a praiseworthy feature—but it seems that the condensation of these tables is too great, and that too few details of the operations are given to make the course a satisfactory one for students. H. L. W.

6. *Neon Lamps for Stroboscopic Work.*—When a disk having a pattern which is exactly duplicated in successive sectors is revolved uniformly the pattern will coincide with, or so to speak be superimposed upon, its initial position a certain number of times each revolution. If the disk were to be illuminated only at these instants the pattern would appear to be fixed in position. In other words, if such a disk is illuminated n times per second by very short flashes the disk will appear at rest whenever the number of revolutions is an exact multiple or submultiple of n, depending upon the number of times the pattern is repeated on the disk. As the frequency of the flashes may be kept very constant by the use of an electrically-driven tuning fork this principle affords the most accurate method of calibrating a revolution counter. In practice the success of the method will depend upon the duration and character of the intermittent illumination as indicated in the following report of a study by F. W. Ashton at the Cavendish Laboratory.

The spark obtained by a Leyden jar discharge was not found to be a satisfactory source of illumination as it is noisy in operation, feeble in intensity, and caused a rapid and excessive eye strain. The author accordingly devised a form of neon filled bulb to replace the condenser spark. The electrode spaces were connected by a long capillary tube, coiled or doubled back on itself several times, thus forming an analogue to the filament of an ordinary incandescent lamp. The light comes from the positive column within the capillary and, as the brightness increases with the current density, the reason for concentrating the discharge within the tube is obvious. A further advantage from the length and coil of the capillary was that the discharge was practically unidirectional and free from any travel of the luminous effect.

The color of the neon discharge is a brilliant orange-red confined to the region 5700 to 6700 A. U. and is in such striking contrast to daylight illumination that observations may be made without darkening the room. The actual luminosity is perhaps not so great as may be obtained from some other gases but the *fovea centralis* is known to be extremely sensitive to red so that its real effectiveness is greatly enhanced, and the experiments showed that the eyestrain mentioned in connection with the Leyden jar spark was wholly absent.

An investigation of the duration of the working flash was made by observing the broadening of the filament when seen in a revolving mirror and the conclusion was reached that it was not over a ten millionth of a second.

In addition to the determination of the velocities of revolution the author mentions two other applications which have been made of the use of the neon lamps. If a rapidly revolving mechanism such as an air propeller is illuminated by a lamp which is lit automatically by a break at each revolution, the mechanism will appear at rest, so that strains or movements of parts at speeds well over 1000 R. P. M. may be accurately examined under actual working conditions. In another case an internal combustion engine was illumined 99 times every hundred revolutions in which case the engine appeared to be turning smoothly at only 1/10th of its actual speed and consequently the movements of the valves, springs and other parts could be studied with ease.—*Proc. Camb. Phil. Soc.* **19**, 300, 1919. F. E. B.

7. *Harmonics in the Siren.*—A source of sound of considerable intensity and affording a pure tone whose frequency may be varied at will is an important desideratum in acoustics and not easily obtainable. The investigations of E. A. Milne and R. H. Fowler on the tone production of the siren, originally undertaken while working on the problem of locating air-craft by sound, are of interest in this connection. In its simplest form, commonly designated the Seebeck siren, the instrument consists of a series of circular holes in a plate which are made to pass in front of a circular orifice from which a stream of air is issuing. The sound vibrations result from the variable flow of air. For purposes of calculation it may be assumed that the oscillations arise from a flux which at any instant is proportional to the area of the orifice exposed. The authors have computed this area in terms of the spacing of the holes as a function of the position of the disk. Their graph shows a notable departure from the form of a sine curve and it is apparent at once that some of the lower harmonics of appreciable intensity must be present in the disturbance. By expanding the expression for the latter in terms of a Fourier series they are able to determine the energy associated with each harmonic. Numerical computation showed that the proportion of the energy concentrated in the fundamental depended significantly on the ratio of the diameter of the holes to the distance between their centers and became a maximum when this distance was about twice the diameter of the hole.

The question of the relation between the intensity of the fundamental and the first harmonic was submitted to experimental investigation by the aid of a Tucker hot wire microphone and when allowance is made for the fact that the aural impression of loudness is not exactly proportional to the square of the amplitude a fair verification of their theory was obtained. At least it was sufficient to justify its use in their attempt to design a new siren which would give a purer tone. The authors proceeded to do this by modifying both the shape of the holes in the disk and the shape of the orifice of the supply tube so that the area of the efflux stream should be proportional to the sidewise displacement of the disk. The idea was carried out by choosing a rectangular orifice for the supply pipe and calculating such a shape for the hole in the plate that it should produce a harmonic disturbance for the sound vibrations. A disk was constructed with the irregular shaped hole indicated by the calculations, and the experimental tests showed a very satisfactory improvement in the resulting tone. At a low frequency of from 80 to 90 vibrations per second the ratio of the intensity of the octave to the fundamental was only 30 per cent. which is a reduction of the intensity of the first harmonic to about one seventh of its value in the Seebeck siren. At a frequency of 350 vibrations the octave was found to possess only 6 per cent. of the intensity of the fundamental which is a notable gain for the new design.—*Proc. Roy. Soc.* **98**, 414, 1921. F. E. B.

8. *An Introduction to Technical Electricity;* by S. G. STARLING. Pp. xii, 181. London 1921 (Macmillan and Co.).—This is one of the *Life and Work Series,* a book of a new type designed to meet the requirements of elementary instruction in continuation and vocational schools. The writer is well known as the author of what is perhaps the best mathematical treatise on Electricity and Magnetism in the language.

In the present work however the treatment is developed from the purely experimental side and requires no mathematical knowledge beyond multiplication and division. The subject is approached by the study of the magnetic effect of a current produced by a simple cell and its application in the electric bell and the telegraph sounder. This is followed by experiments on magnets and a description of magnetic fields arising from various sources. Succeeding chapters explain the generation of the electric current and illustrate its most common and important applications.

The illustrations are simple and clear and the typography admirable. Experiments, precisely described, are introduced at every stage of the course to secure for the boy actual acquaintance with electrical phenomena, and numerical examples where introduced are fully worked out. Each chapter is supplied with a set of exercises for home study by which the solitary learner may test his knowledge. F. E. B.

II. GEOLOGY.

1. *Thirteenth Annual Report, Florida State Geological Survey;* 307 pp., 43 text figs., 1921.—The state geologist, HERMAN GUNTER, here reports (pp. 1-32) on the activities of the State Geological Survey, and on the mineral production for 1918.

J. A. Cushman writes on the Foraminifera from the deep wells of the state (pp. 33-70). The most extensive paper is by Roland M. Harper on "The geography of central Florida" (pp. 71-307).
C. S.

2. *The Fossil Crinoid Genus Dolatocrinus and its Allies;* by FRANK SPRINGER. U. S. Nat. Mus., Bull. **115**, 78 pp., 16 pls., 6 text figs., 1921.—This is a detailed morphologic and taxonomic study of a common and very variable group of essentially Middle Devonian crinoids. In 6 genera, 2 of them new, there are recognized 41 species (7 new), and about as many more formerly described forms are thrown into synonymy. The specific characters, reliable in the Onondaga, become nearly worthless in the Hamilton, where a "rampant growth" takes place, and the genus *Dolatocrinus* dies out. C. S.

3. *A Contribution to the Description of the Fauna of the Trenton Group;* by P. E. RAYMOND. Canada, Geological Survey, Mus. Bull. No. **31**, 64 pp., 11 pls., 1921.—The author here revises the terminology of the subdivisions of the Trenton group of the Ordovician system for Ontario, Quebec, and New York, and describes 11 species of Cystoidea (1 new), 16 of Brachiopoda (8 new), 3 of Gastropoda (1 new), and 12 of Trilobita (2 new).
C. S.

4. *The Genesee Conodonts, with Descriptions of New Species;* by WILLIAM L. BRYANT. Bull. Buffalo Soc. Nat. Sci., vol. **13**, No. 2, 59 pp., 16 pls., 7 text figs., 1921.—In this interesting paper are described 37 species (19 new) of conodont teeth derived in the main from the basal layer, a few inches in thickness, of the Genesee formation, at the base of the Upper Devonian. This basal layer is a part of the Styliola limestone, and together they have "a maximum thickness of more than two feet." By some this limestone has been thought to be "a typical pteropod ooze" but the author now shows it to have been formed within the depth of active wave action. He says that the basal layer is "the remains of an ancient sand bar," evidently, however, one formed within a very shallow sea. In regard to the animals whose remains are here described, he does not believe that conodonts are the teeth of annelids, but rather that they belong to "some primitive type of fishes." C. S.

5. *The Trigoniæ from the Pacific Coast of North America;* by EARL L. PACKARD. Univ. Oregon Pub., vol. **1**, No. 9, 59 pp., 11 pls., 1921.—The author has studied all of the Pacific Coast Trigonias found in the Jurassic and Cretaceous formations. These bivalves have always interested stratigraphers because of their significance in Historical Geology. There are 29 recognizable forms (11 here newly described) along the west coast of North America, and these are arranged in 7 groups based on the character of the ornamentation. C. S.

6. *Iowa Geological Survey, Annual Report,* 1916. Pp. 568, 12 pls., 92 text figs.—This much belated annual report, received in May, 1921, presents the director's administrative work and the mineral production of the state for 1916; also the detailed geology of Ringgold, Taylor, Clarke, Cass, and Adair counties, by Melvin T. Arey, John L. Tilton, and James E. Gow, and a short paper on the bowlders of the Kansan drift, by Professor Kay. The most interesting part of the volume for the general geologist, however, is that by W. H. Norton on the brecciated nature of the basal Upper Devonian (pp. 357-547). This condition of the deposits is said to cover an area of about 1,000 square miles. Norton's conclusion is that the Wapsipinicon formation, through lateral tectonic pressure, was thrown into low troughs and arches, resulting in more or less of brecciation. The movement is said to have occurred not earlier than the subsequent Upper Devonian formation, the Cedar Valley limestone. C. S.

7. *Ninth Biennial Report of the Commissioners of the Connecticut Geological Survey;* HERBERT E. GREGORY, Superintendent. 1919-1920. Bulletin No. **32**, pp. 18. Hartford, 1920. —Thirty-two bulletins are included in the series already issued (see this Journal, **1**, 286, March, 1921). Of these No. 2, on the Protozoa of the fresh waters of Connecticut, by W. H. Conn; No. 6, Manual of the Geology of the State, by W. N. Rice and H. E. Gregory, are both out of print and should be reprinted. No. 7, Preliminary Geological Map of Connecticut, by H. E. Gregory and H. H. Robinson, is nearly exhausted.

Two papers nearly ready for publication are mentioned, viz.: Geology of the Stonington-Westerly region, by Laura Hatch; Geology of the Guilford Quadrangle, by Wilbur G. Foye.

Also (but not quite so complete) are the following: Hemiptera of Connecticut, W. E. Britton in charge; Decapods of Connecticut by A. E. Verrill; Vegetation of Connecticut by G. E. Nichols.

The plans for the future are also presented in detail. In this connection it should be stated that the place of Professor Gregory (now in Honolulu) has been taken by Dr. H. Hollister Robinson.

8. *The Tin Resources of the British Empire;* N. M. PENZER. Pp. 358, London, 1921 (William Rider and Son). Illustrated by numerous maps and photographs of tin deposits.—This is the second volume of a series devoted to a description of the raw materials of industry. As the British Empire produces two-thirds of the total output of tin of the world, the present volume contains a description of the large majority of the important deposits and forms a most useful handbook on the subject. The deposits of Bolivia are the only large producers that are not included. A large portion of the book is devoted to the description of the tin districts in Cornwall, the Malay States, India and

Australia. The book closes with brief chapters on the "Industrial Applications of Tin" and the "Prices, Sale of Tin, and World's Output." An exhaustive bibliography is added.

W. E. F.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE

1. *Symbiosis: A Socio-Physiological Study of Evolution;* by H. REINHEIMER. Pp. xii, 295. London, 1920 (Headley Brothers).—The author's thesis is that biological coöperation, rather than a struggle for existence, is the key to the true explanation of the phenomena concerned in progressive organic evolution. He shows that the more advanced types of plants and animals exhibit a harmonious reciprocity, or "organic civilization," comparable to the social organization of mankind. The law of "Concord in Nature" leads to progress, while competition tends to parasitism which is the forerunner of degeneration, disease, and death.

The book consists of an assemblage of essays on various topics more or less relevant to the subject, leading from a discussion of the origin of morality, evolutional psychology, the value of abstemiousness, the bio-economics of the internal secretions and "pathologia physiologiam illustrat" to "maladie et symbiose." In regard to the biologist's interpretation of the phenomena of nature the author concludes that as concerns the distinctions between parasitism and symbiosis "Science has as yet attained no clarity of thought."

W. R. C.

2. *Die Mneme als erhaltendes Prinzip im Wechsel des organischen Geschehens;* von RICHARD SEMON. Pp. xviii, 420. Leipzig, 1920 (Wilhelm Engelmann).—This is the fourth and fifth unchanged printing of the third (1911) edition of this book, which contains a full exposition of the author's theory that organic memory is the maintaining principle in evolution. By this theory the effects of external stimuli on the organism result in a permanently altered protoplasmic constitution, thereby modifying to some extent the future responses of the organism. Such organic memory is conceived as underlying and directing the course of regeneration, of regulation, of the successively following morphological and physiological changes in the developing embryo, and in the later life of the organism as well as ultimately affecting the germ cells in such a way as to modify the hereditary phenomena and thus lead to the evolution of species.

W. R. C.

3. *Bibliotheca Chemica-Mathematica. Catalogue of works in many tongues, on exact and applied science, with a subject index;* by H. Z. and H. C. S. In two volumes. Pp. 964, with 127

plates, containing 247 portraits and facsimiles. London, 1921 (Henry Sotheran & Co.). Volume I, pp. 428, volume II, pp. 429-964.—The very comprehensive character of this work will be appreciated from the fact that the total number of titles included runs up to about 17,400. The subject index, in addition, covers nearly one hundred pages; this embraces some titles not included in the body of the volumes. The work was begun in 1906, and the catalogue has grown very largely since that time. It fairly claims to be the first Historical Catalogue of Science published in any country, giving bibliographical particulars, and many biographical and historical references; the current prices are also added. The credit for initiating the work is given to Dr. Heinrich Zeitlinger, of Linz on the Danube. . It is, in fact, a remarkable catalogue embracing, as it does, the subjects of mathematics, astronomy, physics, chemistry and allied fields and nearly all the standard works and most of the earlier works of historical importance. The interest of the volumes is much increased by the large number of plates, 127 in all, which are reproduced from the works themselves by a photographic process, and hence have a peculiar quaint historic interest; many are given here for the first time.

4. *Bibliotheca Zoologica II. Verzeichnis der Schriften ueber Zoologie welche in den periodischen Werken enthalten und vom Jahre 1861-1880 selbständig erschienen sind;* bearbeitet von Dr. O. Taschenberg. Lieferung 20. Leipzig (Wilhelm Engelmann).—Since the notice (vol. **1**, p. 519) of parts 21 to 23 of this important work, No. 20 has been received. It bears the date of 1913 and includes signatures 745 to 754. pp. 5993 to 6072. It is announced that only some 450 pages, including the Index, remain to complete the whole. In view of the very high present cost of publication it is to be hoped that all the subscribers to this unique and exhaustive work will do their part in full.

5. *Annual Report of the Field Museum of Natural History for the year* 1920; D. C. Davies, Acting Director. Pp. 371-440, with numerous plates. Chicago, 1921.—This report has a peculiar and indeed melancholy interest from the fact that Dr. Skiff, the able and energetic director since 1894, died on February 24, 1921 (this Journal, **1**, 380.) The work here recorded, however, came under his supervision and is most important since it marks the completion of the new building and the transfer to it of all the collections. The magnitude of this work will be appreciated from the fact that 354 loads were transported by motor trucks in addition to the transfer by rail, which last was accomplished in 34 working days.

OBITUARY.

Dr. Edward Bennett Rosa, chief physicist of the Bureau of Standards, died on May 17th in his sixtieth year.

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[FIFTH SERIES.]

Art. V.—*Llanoria, the Paleozoic Land Area in Louisiana and Eastern Texas**; by Hugh D. Miser.

Contents.

Introduction.

Evidence for a Paleozoic land area that occupied at least a part of Louisiana and eastern Texas has been published from time to time within the last 30 years by different geologists. The most important paper on the subject is one by J. C. Branner,[1] published in 1897. In

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* Published by permission of the Director of the U. S. Geological Survey.

[1] Branner, J. C., The former extension of the Appalachians across Mississippi, Louisiana, and Texas, this Journal, (4), vol. 4, pp. 357-371, 1897. Abstract, Brit. Assoc. Adv. Sci., Rept. 1897, pp. 643-644, 1898. Abstract Annales de Géographie, 7-me Année, No. 35, pp. 345-346, Sept. 15, 1898. Abstract, Nature, vol. 56, p. 70, Nov. 18, 1897. Review by A. H. Purdue, Jour. Geology, vol. 5, pp. 759-760, 1897.

Am. Jour. Sci.—Fifth Series, Vol. II, No. 8.—August, 1921.

this paper he brought together and presented many facts in support of his hypothesis that the Appalachians formerly extended across the lower Mississippi Valley to central Texas. Considerable information on the subject was obtained by the late Dr. A. H. Purdue and the writer during several years of study of the rock formations in the Ouachita Mountains and Arkansas Valley, in Arkansas, beginning in 1907. Not only is this presented here by the writer, but an attempt is made to bring together and state briefly all the data that have been published by other geologists. The writer is indebted to E. O. Ulrich, G. H. Girty, C. E. Siebenthal, Chas. Schuchert, and L. W. Stephenson, who have kindly read this paper and offered valuable suggestions.

This paper consists largely of the presentation of evidence for the existence of the old land area; it does not discuss more than the most striking events in its history. Discussion of the complete history, which would be based on the character and distribution of the rocks of the Gulf Coastal Plain and the adjoining regions and on the stratigraphic breaks presented by them, would be largely hypothetical.

The name Llano was applied to this old land area by Bailey Willis[2] and has been used by Charles Schuchert[3] and E. O. Ulrich,[4] but the name Llanoria has been used by E. T. Dumble[5] and Sidney Powers.[6] Of these two names Llanoria is the more appropriate because Llano is very frequently applied to the Central Mineral, or Llano-Burnett, region of Texas, which was an outlier of the main land area to the east, or which formed only a small part of it if the two were connected.

Since most of the present paper is a discussion of numerous features found in the Ouachita Mountains and Arkansas Valley, a brief summary of the geology of these regions is given.

---

[2] Willis, Bailey, A theory of continental structure applied to North America: Geol. Soc. America, Bull., vol. **18**, pp. 394-395, 398, 1907. Discoidal structure of the lithosphere, Geol. Soc. America, Bull., vol. **31**, Plate 11 opposite p. 301, 1920.

[3] Schuchert, Charles, Paleogeography of North America, Geol. Soc. America, Bull., vol. **20**, pp. 448, 457, 458, 470, pl. 49, 1910.

The nature of Paleozoic crustal instability in eastern North America, this Journal, (4), vol. **50**, pp. 403, 404, 407, 413, 1920.

[4] Ulrich, E. O., Revision of the Paleozoic systems, Geol. Soc. America, Bull., vol. **22**, pp. 435, 476, 1911.

[5] Dumble, E. T., The geology of east Texas, Univ. of Texas Bull., No. 1869, pp. 11-13, Feb., 1920.

[6] Powers, Sidney, The Sabine Uplift, Louisiana, Amer. Assoc. Petroleum Geologists, Bull., vol. **4**, no. 2, p. 125, 1920.

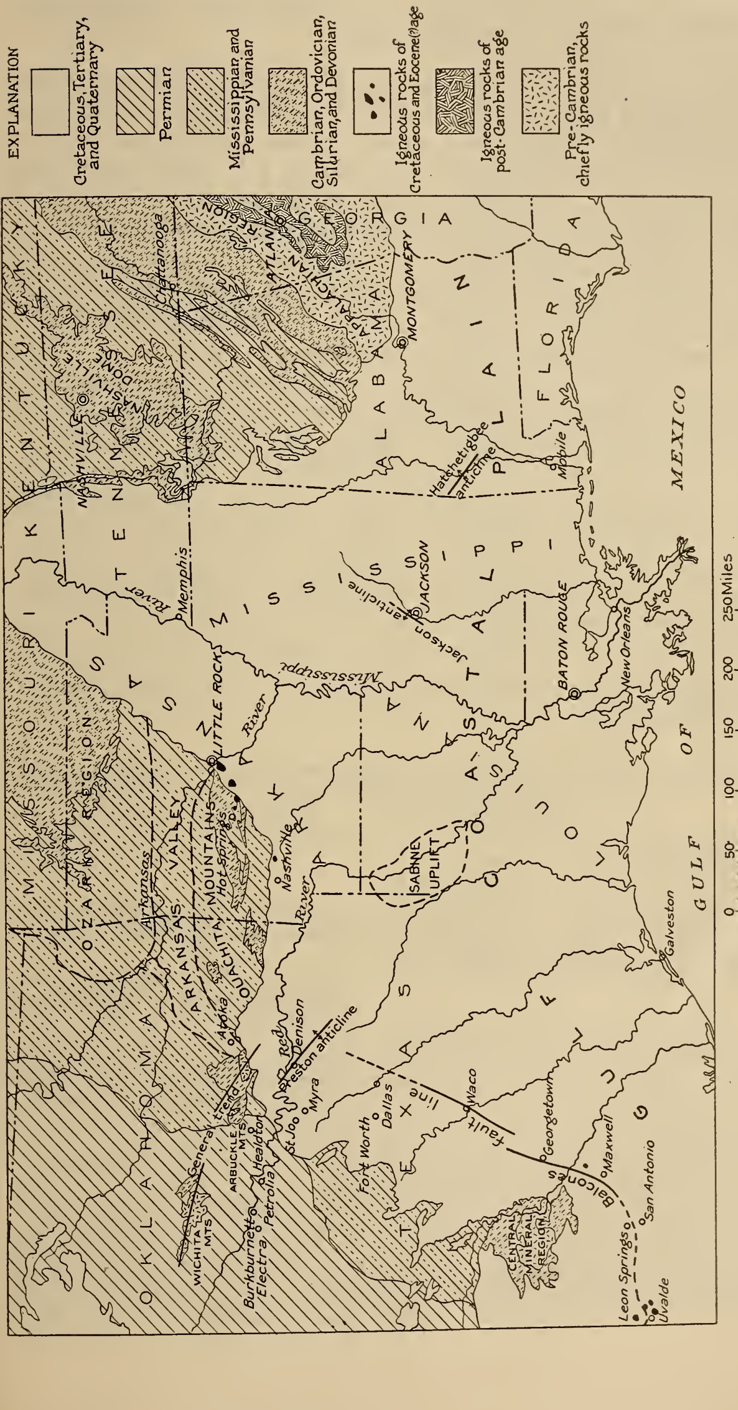

Fig. 1.—Geologic map of the Gulf Coastal Plain and adjoining areas. Geology taken largely from geologic map of North America, U. S. Geol. Survey, 1912.

GENERAL GEOLOGY OF THE OUACHITA MOUNTAINS AND ARKANSAS VALLEY.

The Ouachita Mountains are 50 to 60 miles wide and extend from Little Rock, Ark., to Atoka, Okla., a distance of 200 miles. They are joined on the south and east by the Gulf Coastal Plain. (See figure 1.) The Arkansas Valley just north of the Ouachita Mountains is 30 to 40 miles wide and extends westward from near Little Rock, Ark., to near Lehigh, Okla., a distance of about 220 miles. The rocks exposed in these regions are all of sedimentary origin except two small areas of igneous rocks and their related dikes, of Cretaceous age, in Arkansas. They range in age from Cambrian to Pennsylvanian and present the accompanying composite section. They were formed in a geosyncline to which the name "Ouachita" has been appropriately applied by E. O. Ulrich,[7] and they were compressed into numerous nearly east-west folds late in the Pennsylvanian epoch. The maximum thicknesses of the formations, as given in the section, aggregate 37,000 feet, but as the formations vary considerably in thickness from place to place the total thickness in any particular part of these regions would be less than the total just given, though, as pointed out on a later page, it would be great.

Composite section of exposed rocks of Paleozoic age in the Ouachita Mountains and Arkansas Valley.

	Thickness in feet	*Remarks on occurrence*
Carboniferous:		
Pennsylvanian		
Boggy shale	2,000[a]-3,000[b]	
Savanna sandstone	750[c]-1,500[d]	Present in Arkansas Valley in Arkansas and Oklahoma.
McAlester shale	1,150[c]-2,500[e]	
Hartshorne sandstone	100[f][g]-300[g]	
Atoka formation	3,000[h]-7,800[i]	Present in Arkansas Valley and Ouachita region in Arkansas and Oklahoma.
Wapanucka limestone	0[l]-800[j]	Exposed near boundary between Arkansas Valley and Ouachita region in Oklahoma; absent in Arkansas.

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[7] Ulrich, E. O., Revision of the Paleozoic systems, Geol. Soc. America, Bull., vol. 22, pp. 293, 358, 435, 469, 476, 1911.

[a] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Coalgate folio (No. 74), columnar section sheet, 1901. [b] Taff, J. A., and Adams, G. I., Geology of the eastern Choctaw coal field, Indian Territory: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, 278, 1900. [c] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), columnar section sheet 1, 1902. [d] Taff, J. A., and Adams, G. I., op. cit., p. 277. [e] Taff, J. A., and Adams, G. I., op. cit., p.

Mississippian		
Caney shale	0[k]-1,500[c]	Exposed in Ouachita region in Oklahoma; absent in Arkansas.
Jackfork sandstone	0[l]-6,600[m]	Exposed in Ouachita region in Oklahoma and in Arkansas Valley and Ouachita region in Arkansas; absent at one locality in Oklahoma.
Stanley shale	0[l]-6,100[n]	Exposed in Ouachita region in Oklahoma and Arkansas; absent at one locality in Oklahoma.
Hot Springs sandstone	0[o]-200[o]	Exposed in places at and near Hot Springs, Ark., but absent at most places in Arkansas; not present in Oklahoma.
Devonian:		
Arkansas novaculite (upper part may possibly be Carboniferous)	0[o]-950[o]	Exposed in Ouachita region in Oklahoma and Arkansas; absent at few places in Arkansas.
Silurian:		
Missouri Mountain slate	0[o]-300[o]	Exposed in Ouachita region in Oklahoma and Arkansas.
Blaylock sandstone	0[o]-1,500[o]	Exposed in southern part of the Ouachita region in Oklahoma and Arkansas; absent in northern part of this region in both States.
Ordovician:		
Polk Creek shale	0[o]-400[p]	Exposed in Ouachita region in Oklahoma and Arkansas; absent at few localities.
Bigfork chert	700[o]	Exposed in Ouachita region in Oklahoma and Arkansas.
Womble shale	250[o]-1,000[o]	Exposed in Ouachita region in Arkansas; also present in Ouachita region in Oklahoma.[q]
Blakely sandstone	0[o]-500[o]	Exposed in Ouachita region in Arkansas; present in Ouachita region in McCurtain Co., Okla.[q]

275. [f] Taff, J A., and Adams, G. I., op. cit., p. 274. [g] Collier, A. J., The Arkansas coal field, U. S. Geol. Survey, Bull. 326, p. 12, 1907. [h] Taff, J. A., Grahamite deposits of southeastern Oklahoma, U. S. Geol. Survey, Bull. 380, p. 289, 1909. [i] Measured by writer in Yell County, Arkansas. [j] Wallis, B. F., The geology and economic value of the Wapanucka limestone of Oklahoma, Oklahoma Geol. Survey, Bull. 23, pp. 30, 42, 67, 1915. [k] Wallis, B. F., op. cit., p. 67. [l] Girty, G. H., The fauna of the Caney shale of Oklahoma, U. S. Geol. Survey, Bull. 377, p. 6, 1909; Wallis, B. F., op. cit., p. 27. [m] Purdue, A. H., The slates of Arkansas, Arkansas Geol. Survey, p. 48, 1909. [n] Taff, J. A., U. S. Geol. Survey, Geol. Atlas, Atoka folio (No. 79), columnar section sheet 2, 1902. [o] Measured by A. H. Purdue and writer in Arkansas. [p] Ulrich, E. O., Revision of the Paleozoic systems, Geol. Soc. Amer. Bull., vol. 22, p. 677, 1911. [q] C. W. Honess, structural features of the southern Ouachita Mountains, Oklahoma (abstract): Geol. Soc. America, Bull., vol. 31, No. 1, p. 121, March, 1920.

Mazarn shale	1,000[o]	Exposed in Ouachita region in Arkansas; also present in this region in Oklahoma.[q]
Ordovician (?):		
Crystal Mountain sandstone	850[o]	Exposed in Ouachita region in Arkansas; also present in this region in McCurtain Co., Okla.[q]
Cambrian:		
Collier shale (observed thickness)	200[o]	

The Caney shale and the underlying formations—the Jackfork sandstone, Stanley shale and Hot Springs sandstone of the Ouachita Mountains—have been placed in the Pennsylvanian series by some geologists but other geologists and the accepted usage of the U. S. Geological Survey place them in the Mississippian series. As the proper correlation of these formations has an important bearing on several features to be discussed below, brief summaries of E. O. Ulrich's opinion and of the evidence supplied by their fossils are presented. The Stanley and the Jackfork have yielded a few plants and the Jackfork has yielded a few indeterminable invertebrate fossils, but the Caney shale has yielded a rather large invertebrate fauna and a few fish remains. No fossils have been found in the Hot Springs sandstone.

In summarizing the evidence furnished by the plant collections obtained prior to 1915 by the writer and others from the Stanley shale and Jackfork sandstone David White[8] says:

> "The discovery of better material will doubtless necessitate revision of some of the tentative [specific] identifications. Possibly they will show that the beds are Pennsylvanian, but the aspect of the plant fragments and the apparent relations of the beds strongly suggest that they are Mississippian. Accordingly, I am inclined to regard them as Mississippian, and to suggest that they are of Chester age, but the paleobotanical data available is insufficient to justify their conclusive reference to the Mississippian."

C. S. Prosser, who collected some fragments of fossil plants from the Stanley shale in the city of Hot Springs, Ark., made the following statement concerning them:[9] "On one of the olive pieces of shale is a fern pinnule, which is similar to those of *Sphenopteris*. It resembles

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[8] Statement for use in the Hot Springs and DeQueen-Caddo Gap folios (in preparation).

[9] Prosser, C. S., Notes on Lower Carboniferous plants from the Ouachita uplift, Arkansas Geol. Survey Ann. Rept. for 1890, vol. 3, pp. 423-424, 1892.

somewhat the pinnules of *Sphenopteris decomposita* Kidston, from the Calciferous sandstone (Lower Carboniferous) of Scotland; but nothing could be stated positively of such a fragment. Other fragments resemble *Cordaites.*''

C. R. Eastman,[10] who studied fish remains from the Caney shale, stated that their character tends to support the upper Mississippian age of the Caney.

A part of a recent summary by George H. Girty[11] on the invertebrate fauna of the Caney shale follows:

> ''When the formation [Caney] was first mapped and when its fauna was first described the Caney shale was referred, as it is now, to the upper part of the Mississippian series. * * *
>
> ''Since this conclusion was formed much evidence has accumulated, and it tends strongly to corroborate the opinion that the Caney shale is of Mississippian age. Hundreds of collections of invertebrate fossils have been made in Oklahoma and Arkansas in areas adjacent to those in which the Caney shale occurs. In these collections a pronounced faunal change is shown between the Morrow group, which is of Pottsville age, and the formations that underlie it, whose faunas, though differing more or less profoundly from the typical Mississippian faunas farther north, are nevertheless undoubtedly Mississippian. Wherever faunas of the Mississippian type occur they occur below faunas of the Morrow type, and the strata that contain them can be traced to other sections in which the same relation of rocks and faunas is maintained. The same relations are shown by the Caney shale and the formation that lies next above it, the Wapanucka limestone. The Caney fauna has conspicuously the facies of the Mississippian faunas of the adjacent areas in Oklahoma and Arkansas. This fact admits of no doubt. Furthermore, the fauna of the Wapanucka limestone is closely allied to that of the Morrow, which overlies the Mississippian rocks in nearby areas and without much doubt represents the same geologic epoch.
>
> ''It is true that as the Morrow is believed to be of upper Pottsville age other rocks may occur below it and still be Pottsville, but in that case their faunas might justly be expected to have the Pottsville rather than the Mississippian facies. It may be well to recall that the Caney fauna, so far as it is known, comes from the lower half of the formation, but so long as collections continue to show the facies of the Mississippian faunas that occur below the Morrow the Caney shale can logically be placed only in the Mississippian.''

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[10] Eastman, C. R., Brain structures of fossil fishes from the Caney shales; Geol. Soc. America, Bull., vol. 24, pp. 119-120, 1913.

[11] Statement for use in the Hot Springs folio (in preparation).

E. O. Ulrich,[12] who has made field studies of the formations under discussion, holds: (1) that the Hot Springs sandstone and Stanley shale are equivalent to the Chester group and to beds that bridge the Chester-Pottsville interval, (2) that the Jackfork sandstone is of lower Pottsville age, and (3) that the Caney shale is of upper Pottsville age. The reasons for these opinions can not be discussed here for lack of space.

Evidence for a Paleozoic land area in Louisiana and eastern Texas, and its features.

Any land area that may have existed in Louisiana and eastern Texas during the Paleozoic era is now largely if not entirely concealed by Cretaceous and younger sediments of the Gulf Coastal Plain. Evidence regarding it must therefore be obtained from (1) the Paleozoic and older rocks that are exposed in the regions bordering the Gulf Plain, (2) the structure of the sediments of the Gulf Plain, and (3) wells that have passed through the Cretaceous and younger rocks of the Gulf Plain and penetrated the underlying Paleozoic and pre-Cambrian rocks. This evidence follows.

General character of Ordovician and Silurian rocks in Ouachita Mountains.

The rocks of Ordovician and Silurian age exposed in the Ouachita Mountains consist mainly of shale and sandstone, whereas the rocks of these ages in the Arbuckle Mountains, in the Ozark region, and in the Nashville dome in middle Tennessee consist predominantly of limestones. This strongly suggests that the present Ouachita region was near an old land area undergoing vigorous erosion during these two periods, and if this is true it is necessary to assume that the old land area existed south of the present Ouachita Mountains.

Blakely sandstone of Ouachita Mountains.

The Blakely sandstone, of Ordovician age, thins out to the north in Montgomery County, Ark. This formation is 500 feet or less thick and is composed largely of shale but partly of sandstone, though the sandstone is

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[12] Oral communication.

the more prominent surface feature of the two. The sandstone beds are lenticular and thin out to the north, whereas the intervening beds of shale do not appear to thin out in this direction. The absence of the sandstone to the north therefore can not be explained by the hypothesis that it extended farther north and that it was subsequently eroded.

Blaylock sandstone of Ouachita Mountains.

Although the Blaylock sandstone, which at places reaches a thickness of 1,500 feet and is of Silurian age, is of wide extent from east to west, its outcrops stretching from a point near Malvern, Ark., nearly to Bismarck, Okla., it is present in the Ouachita Mountains only on their south side. The northward thinning of the sandstone may be due partly to erosion, as is indicated by the local occurrence of a conglomerate at the base of the overlapping Missouri Mountain slate. If the thinning out of the sandstone is due entirely to erosion this would mean that at least 1,500 feet of material has been removed from the northern part of the present Ouachita region, and it would be expected that the underlying Polk Creek shale would also have been removed from large areas at the same time the Blaylock was being removed. But the Polk Creek shale is generally present in the region north of that in which the Blaylock sandstone occurs, and its thickness there is much the same as it is in places where it underlies the Blaylock. The conclusions regarding the Blaylock are that it was deposited in a minor east-west trough on the south side of the Ouachita geosyncline, that the northward thinning of the formation can be attributed in only a very small part to erosion, and that the land-derived sediments for it came from the south.

Stanley shale and Jackfork sandstone of Ouachita Mountains.

The Stanley shale, 5,000 to 6,000 feet thick, and the Jackfork sandstone, 5,000 to 6,600 feet thick, both of Mississippian age, are exposed through the entire length of the Ouachita region, and the Jackfork sandstone is exposed at places in the Arkansas Valley in Arkansas but both formations thin out to the north and west. They are absent in the Arbuckle Mountains, and at a locality on the north border of the Ouachita region near McAlester, Okla.,[13] and also in the Ozark region, though in that region they may be represented by comparatively thin limestones, sandstones, and shales of Mississippian age. It may be suggested that these two formations formerly extended much farther west and north and that their absence is due to erosion, but there is no evidence to indicate that any considerable thickness of strata was removed by erosion from the Arbuckle and Ozark regions during the Mississippian epoch. Not only do the formations themselves become thinner toward the north, but sandstone beds that form about one-fourth of the Stanley shale along the southern border of the Ouachita region become thinner or thin out completely before they reach the north side of the region, and the Jackfork sandstone changes toward the north from a formation composed almost entirely of sandstone with very little shale to a formation composed largely of shale. This northward thinning of the sandstone beds of the Stanley shale and the dovetailing of thick beds of shale in the Jackfork sandstone to the north imply a southern source for the sand and mud that later formed these formations. Many small quartz pebbles, one-fourth of an inch or less in diameter, occur in the Jackfork sandstone, particularly in its lower part, on the southern border of the Ouachita Mountains. They become less abundant toward the north. The enormous thickness and comparatively large areal extent of the Stanley and Jackfork indicate that the land mass to the south suffered great erosion. From the evidence now at hand the Arbuckle and Ozark regions could not have supplied so vast a quantity of sediment during the Mississippian epoch.

The northward thinning of the sandstones in the formation to which the name Stanley shale is applied was noted by L. S. Griswold,[14] who says, "The existence of sandstone beds overlying the novaculites on the south side of

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[13] Girty, G. H., The fauna of the Caney shale of Oklahoma, U. S. Geol. Survey, Bull. 377, p. 6, 1909. Wallis, B. F., The geology and economic value of the Wapanucka limestone of Oklahoma, Oklahoma Geol. Survey, Bull. 23, p. 27, 1915.

[14] Griswold, L. S., Whetstones and the novaculites of Arkansas, Arkansas Geol. Survey, Ann. Rept. for 1890, vol. 3, pp. 193, 213, 1892.

the Ouachita uplift, with shale beds occupying the corresponding position on the north side, indicates that the land whence these sediments were derived lay to the south, just as in the case of the Appalachians it lay to the east.'' G. H. Ashley,[15] who studied a large area of Carboniferous rocks underlain by the Stanley, Jackfork, and Atoka formations south of the area examined by Griswold, says that they apparently confirm Griswold's conclusion regarding the southern source of the Carboniferous sediments.

Concerning the source of the clastic sediments of not only the Stanley and Jackfork but of the Caney and Atoka formations, David White[16] says:

> ''Toward the northeast [of north-central Texas], somewhere in the region of the Red River Valley, a Mississippian-Pennsylvanian land barrier existed which is now bridged by later Pennsylvanian ''Red Beds'' or Cretaceous strata. The existence of such a land mass is predicated by the sediments (clastics) of the Jackfork, Stanley, Caney, and Atoka formations as well as by the fossils. The sediments of these formations could hardly have been derived from the Ozark uplift, nor does it seem probable that they could have originated in the areas now marked by the Arbuckle-Wichita uplift.''

Tuffs of Mississippian age in the Ouachita Mountains.

Tuffs occur near the base of the Stanley shale in Polk County, Ark., and McCurtain County, Okal., in three and possibly four or five beds, which range in thickness from 6 to 85 feet, the lowest bed being the thickest and the most widely distributed. According to E. S. Larsen, who has studied them in thin sections, these tuffs are composed in large part of devitrified and silicified volcanic glass and of feldspar and other minerals. A study of the tuffs in Arkansas has been begun by the writer but has not yet been completed. However, as they occur only on the south side of the Ouachita Mountains, and thin out toward the north, and as the size of grains of their component materials apparently decreases toward the north, it would seem that the volcanic materials they contain were ejected

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[15] Ashley, G. H., Geology of the Paleozoic area of Arkansas south of the novaculite region, Am. Philos. Soc., Proc. vol. 36, p. 248, 1897.

[16] White, David, Discussion of paper by F. B. Plummer on the stratigraphy of the Pennsylvanian formations of north-central Texas, Assoc. Amer. Petroleum Geologists, Bull., vol. 3, p. 149, 1919.

from some vent or vents on or near the old land area to the south.

The Stanley shale, near whose base the tuffs occur, is underlain, where the tuffs are found, by the Arkansas novaculite and is overlain by the Jackfork sandstone and other Carboniferous rocks. The novaculite is of Devonian age with the exception of its upper part, which may be of early Mississippian age. The facts that this formation is generally free from coarse-grained sediments and that it consists mainly of novaculite, a fine-grained rock which is generally regarded as being a variety of chert, indicate that while it was being deposited the sea in the Ouachita geosyncline was comparatively clear. If so, any land area that may have existed at this time in Louisiana and eastern Texas had a low relief and was subject to little erosion. On the other hand, in Mississippian rocks that overlie the Arkansas novaculite, except the tuffs, are all shales and sandstones, and occur in very thick formations in most parts of the Ouachita Mountains, the thickest being the Stanley shale, 5,000 to 6,000 feet thick and the Jackfork sandstone, 5,000 to 6,600 feet thick. Any old land area to the south that could have supplied so much sediment in so short a time must have been extensive and must have been rapidly eroded and therefore probably included mountains. As the southern land area was low, and was eroded very little during Devonian and possibly during early Mississippian time, the diastrophic movements that produced the mountains must have taken place in late Devonian or early Mississippian time. The occurrence of the tuffs near the base of the Mississippian beds and the probability that the fragmental materials composing the tuffs had a southern source strongly suggest that the mountain-making movements were accompanied by volcanic activity during which the fragmental materials for the tuffs were ejected.

Pennsylvanian rocks in Arkansas and Oklahoma.

The Pennsylvanian rock, mainly shales and sandstones, become thinner to the north, particularly the Atoka formation which is 7,800 feet thick in the Arkansas Valley in Arkansas, 6,000 to 7,000 feet thick in this valley in Oklahoma, and 6,000 feet thick in Pike County, Ark., on the south border of the Ouachita region. In Pike County it was originally more than 6,000 feet thick; its upper part has been removed by erosion. The rocks that are equivalent to the Atoka along the southern border of the Boston Mountains which adjoin the north side of the Arkansas Valley, probably comprise the lower 1,500 feet or more of the Winslow formation in the Winslow quadrangle,[17] the lower 600 to 800 feet of the Winslow formation in the Tahlequah quadrangle,[18] and 200 to 400 feet of the Winslow in the Muskogee quadrangle.[18]

N. F. Drake,[19] in a discussion of the origin of the sediments of the "Coal Measures" of Oklahoma, which, as defined by him, include not only the Pennsylvanian but also the Mississippian rocks of the Ouachita Mountains, says:

> "Throughout the Coal Measures the thickness of the sediments gradually decreases northward and westward. The most rapid decrease is toward the north, and the lower beds decrease more rapidly than the higher ones. * * * The relative proportion * * * of shales and limestones to sandstones and conglomerates gradually increases westward and especially northward. Because of these conditions the sediments are considered to have come from a land area lying to the southeast."

A recent study of the Pennsylvanian sandstones and shales in the Bristow quadrangle, in Creek County, Okla., by A. E. Fath[20] has led him to believe that the sediments for them come from a land area to the south-southwest.

Ice-borne bowlders in Caney shale in Oklahoma.

J. A. Taff[21] has described the occurrence of erratic ice-borne bowlders, up to 60 feet in length, in the Caney shale (Mississippian) in the Ouachita Mountains in southeastern Oklahoma. They have also been described

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[17] Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (No. 202), p. 16, 1916.

[18] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 5, 1905; Muskogee folio (No. 132), p. 4, 1906.

[19] Drake, N. F., A geological reconnaissance of the coal fields of the Indian Territory, Am. Philos. Soc. Proc., vol. 36, p. 380, 1898.

[20] Oral communication.

[21] Taff, J. A., Some erratic bowlders in middle Carboniferous shale in Indian Territory (abstract), Science, new ser., vol. 21, p. 225, 1905. Ice-borne bowlder deposits in mid-Carboniferous marine shales: Geol. Soc. America, Bull., vol. 20, pp. 701-702, 1910.

by E. O. Ulrich[22] and J. B. Woodworth.[23] The area of bowlder-bearing beds in the Caney shale, according to Taff, who carefully studied their character and distribution, extends from the vicinity of Atoka to within a few miles of the Oklahoma-Arkansas line. The identity, lithological and paleontological, of the bowlders with a large part of the Ordovician and Silurian strata in the Arbuckle Mountains, and the local relations of the Arbuckle and Ouachita mountains, according to Mr. Taff, "press toward the conclusion that the erratics had their sources in a range or group of mountains in the region now occupied by southern Indian Territory and northern Texas."[24] These mountains he considered a part of a supposed southeastward extension of the present Arbuckle uplift.

Veatch on source of Paleozoic sediments in Ouachita Mountains.

A. C. Veatch,[25] in a brief discussion of the Paleozoic rocks of the Ouachita Mountains, expresses the opinion that the land area that furnished the material for these immensely thick series of rocks lay to the south and southeast. He continues, "The relative position of the continental and oceanic areas was therefore at this time [Paleozoic era] somewhat reversed—the ocean occupying the greater part of what is now the central and western United States and the land the Coastal Plain of the eastern and southern United States and portions of the Atlantic Ocean and Gulf of Mexico."

Pennsylvanian rocks of north-central Texas.

According to N. F. Drake[26] most of the clastic material that forms the Pennsylvanian rocks of the Colorado coal field in north-central Texas appears to have been derived from an extensive old land area to the east and northeast,

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[22] Ulrich, E. O., Revision of the Paleozoic systems, Geol. Soc. America, Bull., vol. 22, p. 352 footnote, 1911.

[23] Woodworth, J. B., Bowlder beds of the Caney shale at Talihina, Oklahoma, Geol. Soc. America, Bull., vol. 23, pp. 457-462, 1912. Abstract, Science, new ser., vol. 35, p. 319, 1912.

[24] Taff, J. A., op. cit., Science, new ser., vol. 21, p. 225.

[25] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas, U. S. Geol. Survey Prof. Paper 46, p. 17, 1906.

[26] Drake, N. F., Report on the Colorado coal field of Texas, Texas Geol. Survey, Fourth Ann. Rept., pp. 373-374, 1893. (Reprint), University of Texas, Bull. No. 1755, pp. 15-16, 1917.

now covered by later formations, and only a very small part of it from the older rocks of the Central Mineral region. His reasons for this conclusion may be briefly summarized as follows:

1. The outcrop or strike of the beds is almost at right angles to the northern border of the Central Mineral region.
2. The beds indicate deeper water and slower deposition near the Central Mineral region than farther north.
3. Each bed at or near the border of the Central Mineral region dips westward and overlaps in this direction the underlying beds, in much the same way that the younger foreset beds of delta deposits overlap the older beds.
4. Conglomerates extend almost to Red River, and the pebbles composing them remain remarkably uniform in character; they include no pebbles of limestone and marble such as would be derived from the rocks in the Central Mineral region.
5. The beds indicate that the sea was deeper to the west than to the east.

The same view regarding the source of the land-derived sediments of the Pennsylvanian rocks of north-central Texas has been expressed by C. L. Baker,[27] R. T. Hill,[28] E. T. Dumble,[29] and F. B. Plummer,[30] but Hill at the same time expressed the view that an old land mass in eastern Texas also supplied the sediments for the Carboniferous rocks in southeastern Oklahoma and western Arkansas.

Carbon ratios of Pennsylvanian coals in northern Texas.

M. L. Fuller in a recent paper on the relation of oil to

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[27] Udden, J. A., Baker, C. L., Böse, Emil, Review of the geology of Texas, Texas Univ., Bull. No. 44, pp. 106-107, 1916.

[28] Hill, R. T., Geography and geology of the Black and Grand prairies, Texas: U. S. Geol. Survey, Twenty-first Ann. Rept., pt. 7, pp. 91-92, 103-104, 1901.

[29] Dumble, E. T., The individuality of Texas geology, The Rice Institute pamphlet, vol. 3, No. 2, pp. 155-156, April, 1916. Origin of the Texas domes, Am. Inst. Min. Eng., Bull. 142, p. 1634, Oct., 1918. The Geology of East Texas, Univ. of Texas Bull. No. 1869, pp. 11-13, 1920. Discussion of paper by E. DeGolyer on the theory of the volcanic origin of salt domes, Am. Inst. Min. and Met. Eng., Trans., vol. 61, p. 476, 1920.

[30] Plummer, F. B., Preliminary paper on the stratigraphy of the Pennsylvanian formations of north-central Texas (unpublished manuscript).

carbon ratios of Pennsylvanian coals in northern Texas[31] says:

> "The high carbon ratio east of the Carboniferous area, apparently higher than that around the Wichita Mountains on the north or the Central Texas Uplift on the south, is very suggestive and apparently points to an area of high disturbance beneath the Cretaceous immediately east of the margin of the latter. Whether there is an old land mass of pre-Pennsylvanian rocks, an arch of older Pennsylvanian (Bend, etc.) or a series of troughs of the latter between arches of older rocks, is not yet established."

Similar conclusions have also been expressed by Fuller in the references cited below.[32]

Thickness and extent of sediments derived from Llanoria.

Llanoria was greatly eroded and was of vast size, as shown by the large areal extent and enormous aggregate thickness of the Paleozoic rocks in the Arkansas Valley and Ouachita Mountains and of the Pennsylvanian rocks of north-central Texas.

The maximum thicknesses of the rock formations in the Ouachita Mountains and Arkansas Valley as given on page 64 aggregate 37,000 feet, but as their thicknesses differ considerably from place to place the total thickness in any particular part of these regions would be less than the aggregate given. Nevertheless the following estimates by several geologists of the aggregate thicknesses in different parts of the regions indicate that between 20,000 and 25,000 feet of rocks, of which fully 90 per cent are clastic, were laid down in the greater part of the Ouachita geosyncline comprising the present Ouachita Mountains and Arkansas Valley.

The total of the minimum and maximum thicknesses of the rocks in the Atoka and Coalgate quadrangles of Oklahoma, as given by J. A. Taff,[33] are 21,400 and 22,400

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[31] Fuller, M. L., Relation of oil to carbon ratios of Pennsylvanian coals in north Texas, Econ. Geol., vol. 14, no. 7, p. 541, Nov. 1919.

[32] Fuller, M. L., Carbon ratios in Carboniferous coals of Oklahoma, and their relation to petroleum, Econ. Geol., vol. 15, No. 3, p. 234, April-May, 1920. Discussion of paper by F. B. Plummer on the stratigraphy of the Pennsylvanian formations of North-Central Texas, Assoc. Amer. Petroleum Geologists, Bull., vol. 3, pp. 149-150, 1919.

[33] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Coalgate folio (No. 74), 1901, and Atoka folio (No. 79), 1902.

feet, respectively. J. C. Branner[34] has estimated that the Carboniferous rocks in the Arkansas Valley in Arkansas are 23,780 feet thick; N. F. Drake[35] has estimated that the "Coal Measures deposits" in Oklahoma are 24,500 feet thick; and the thickness of the rock formations of Cambrian to Carboniferous age in the Ouachita Mountains in west-central Arkansas, as given by A. H. Purdue,[36] aggregate 24,000 feet.

The combined width of the two regions here mentioned is 80 to 100 miles, and their length is about 200 miles. As the rocks were compressed into east-west folds and considerably faulted about the close of the Pennsylvanian epoch, they now occupy a smaller area than they did when they were horizontal or nearly so. The compression, as calculated for a large part of the Ouachita Mountains in Arkansas, has reduced this horizontal extent almost one-half. Furthermore, the rock formations of the Arkansas Valley and Ouachita Mountains extend an unknown though probably considerable distance both eastward and southward beneath the Gulf Coastal Plain.

The Pennsylvanian rocks of north-central Texas extend from the Central Mineral region northward to the State line and aggregate more than 5,000 feet in thickness, but only part of the Pennsylvanian sediments were laid down over all the area in which these rocks are now exposed, as is shown by the thinning of the strata to the west and their overlapping in this direction upon the Bend series of the Texas Geological Survey.[37]

Age and thickness of the exposed rocks of the Gulf Coastal Plain.

The exposed rocks of the Coastal Plain are of Lower Cretaceous, Upper Cretaceous, Eocene, Oligocene, Miocene, Pliocene and Quaternary ages. E. W. Shaw[38] has

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[34] Branner, J. C., Thickness of Paleozoic sediments in Arkansas, this Journal, (4), vol. 2, pp. 229-236, 1896.

[35] Drake, N. F., A geological reconnaissance of the coal fields of the Indian Territory, Am. Phil. Soc. Proc., vol. 36, p. 388, 1898.

[36] Purdee, A. H., The slates of Arkansas, Arkansas Geol. Survey, pp. 30, 48, 1909.

[37] Drake, N. F., Report on the Colorado coal field of Texas, Texas Geol. Survey, Fourth Ann. Rept., pp. 374 et seq., 1893; (Reprint), University of Texas Bull. No. 1755, pp. 16 et seq., 1917.

[38] Shaw, E. W., Stratigraphy of the Gulf Coastal Plain as related to salt domes, Washington Acad. Sci., Jour., vol. 9, No. 10, p. 289, May 19, 1919.

summarized as follows the thicknesses of the sediments of these ages in Louisiana and eastern Texas:

> "The aggregate thickness of the Cenozoic is commonly between 5,000 and 7,000 feet, the Eocene being 2,500 to 3,000, Oligocene and Miocene 2,000 to 2,500, and the Pliocene and Quaternary from 1,000 to 3,000. The upper Cretaceous seems to have the thickness ranging from 1,500 to 2,500 and the lower Cretaceous, where present, from a feather edge to about a thousand feet. Over a large area in coastal Louisiana and Texas the aggregate thickness of the various Cretaceous, Tertiary, and Quaternary formations probably ranges between 8,000 and 12,000 feet and may average about 10,000 feet.
>
> "Apparently most of the formations thicken somewhat toward the coast but the average or aggregate amount of thickening is unknown. To the east there is a notable thinning and rise of certain formations at least; beds lying at a depth of 2,000 feet near Mobile lie at far greater depths two hundred miles to the west and a similar distance from the coast."

Structure of the Gulf Coastal Plain.

The Cretaceous and later sediments under the Coastal Plain have a general dip of 100 feet or less to the mile toward the Gulf, but those in the Mississippi embayment of the Gulf Plain lie in a downwarped trough of older rocks, where their general dip is toward the Mississippi, which runs through the middle of the embayment. The general dip just indicated is however broken by many small salt domes in Texas and Louisiana, by some faults and by several large domes and anticlines, among which are the Sabine uplift and Preston, Jackson, and Hatchetigbee anticlines. (See figure 1.)

The Preston anticline,[39] in northeastern Texas and southeastern Oklahoma, extends southeastward as far as Gober, Fannin County, Tex., and is in line or nearly in line with the trend of the Criner Hills uplift,[40] a subsidiary uplift in the Paleozoic rocks that lies south of and roughly parallel with the Arbuckle uplift of southern Oklahoma, which involves not only Paleozoic but pre-Cambrian rocks. As the southeast end of the Arbuckle uplift is concealed by rocks of Cretaceous age its extent

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[39] Stephenson, L. W., A contribution to the geology of northeastern Texas and southern Oklahoma, U. S. Geol. Survey, Prof. Paper **120**, pp. 133, 159-160 and Plate 17, 1919.

[40] Taff, J. A., Preliminary report on the geology of the Arbuckle and Wichita mountains in Indian Territory and Oklahoma, U. S. Geol. Survey, Prof. Paper **31**, Plate I and pp. 47-50, 1904.

in this direction is not known, but L. W. Stephenson[41] has expressed the opinion that the Preston anticline is probably directly related to it and that the folding of the Cretaceous strata in the anticline was merely incidental to the upbowing of the underlying basement rocks.

The Sabine uplift,[42] also called the Sabine peninsula,[43] lies in northwestern Louisiana and northeastern Texas. It is in line with the general southeastward trend of the Preston anticline and is not far south of a straight line projected S. 60° E. from the Arbuckle uplift, whose general trend is in this direction. Although the Sabine uplift and Preston anticline are structural features involving Tertiary, Cretaceous, and probably Paleozoic or older rocks and are thus of Cretaceous or later age, they perhaps occupy the site of one or more pre-Cretaceous anticlines and represent merely an accentuation of the earlier anticlines.

The view that there is a relation between the structure of the Cretaceous and Tertiary sediments of the Gulf Coastal Plain and the structure of the underlying Paleozoic or older rocks has been expressed by other geologists, especially those who have studied the problems presented by the salt domes of the coastal plain. The generally accepted opinion regarding these domes are that they lie along lines of fracture in the Paleozoic or older rocks. These lines of fracture, as well as the Sabine uplift and other folds here mentioned, may have been first produced in the Paleozoic or pre-Paleozoic rocks prior to the Cretaceous period and further movement may have taken place during Cretaceous or later time.[44]

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[41] Stephenson, L. W., op. cit., p. 160.

[42] Harris, G. D., Oil and gas in northwestern Louisiana with special reference to the Caddo field, Louisiana Geol. Survey, Rept. for 1909, Bull. 8, Plate 1 and pp. 5-8, 1908. Oil and gas in Louisiana with a brief summary of their occurrence in adjacent States, U. S. Geol. Survey, Bull. 429, Plate 1, figure 1 and p. 9, 1910.

Matson, G. C., and Hopkins, O. B., The DeSoto-Red River oil and gas field, Louisiana, U. S. Geol. Survey, Bull. 661, pp. 117-118, and Plate 7, 1918.

Powers, Sidney, The Sabine uplift, Louisiana: Amer. Assoc. Petroleum Geologists, Bull., vol. 4, no. 2, pp. 117-136, 1920.

[43] Harris, G. D., Rock salt—its origin, geological occurrences and economic importance in the State of Louisiana, Louisiana Geol. Survey, Rept. for 1907, Bull. 7, Plate 24, and pp. 79-80, 1908.

[44] Since the transmittal of the present paper for publication a paper by Powers (Amer. Assoc. Petroleum Geologists, Bull., vol. 4, no. 2, pp. 117-136, 1920) has been published in which he expresses a similar view regarding the Sabine uplift.

Concealed rocks of the Gulf Coastal Plain.

The relations of the rocks along the borders of the Gulf Coastal Plain show that the pre-Cambrian, Cambrian, Ordovician, Silurian, Devonian, Carboniferous (including Mississippian, Pennsylvanian and Permian) rocks are overlain by Cretaceous and younger beds. Rocks of these ages underlie the entire Gulf Plain, but their age and character at any particular place can be determined only by deep wells that penetrate the basement rocks, though their general character may be inferred at some places with a fair degree of certainty for a short distance from their outcrops. For example, the pre-Cambrian crystalline rocks that are exposed in the Appalachian region of Alabama doubtless extend many miles southwestward beneath Lower and Upper Cretaceous beds, and similar rocks that are exposed in the Arbuckle Mountains of southern Oklahoma doubtless extend at least several miles southeastward beneath Lower Cretaceous beds.

Rocks belonging to the Pennsylvanian series are, so far as known, the youngest Paleozoic rocks that lie beneath the Gulf Plain except those in a small area along Red River in northern Texas and southern Oklahoma, where the underlying rocks are Permian. No Triassic and Jurassic rocks are known to underlie any part of the Gulf Plain, but some geologists postulate the occurrence there of Permian or Triassic rocks in order to explain the source of the enormous quantities of salt and other minerals of the numerous salt domes of Texas and Louisiana.

E. T. Dumble[45] says:

> "In all the region east of Llano [Central Mineral region of Texas] * * * the latest Paleozoic rocks are those of the Bend formation, which is basal Pennsylvanian, and these are only known contiguous to the Llano border.
>
> "Along the southeastern border of the Llano region the Cretaceous in places overlaps the Bend and lies upon the older Paleozoics. Along the southern line the Bend seems to be entirely absent. The evidence of further westward extension of the underlying Bend is found in its exposures along the western border of the Llano area and is obtained from well drilling. A well

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[45] Dumble, E. T., The geology of east Texas, University of Texas Bull. No. 1869, pp. 11-13, Feb., 1920.

southwest of Uvalde passed entirely through the Cretaceous into black shale which is believed to represent the Bend. Wells north and west of Uvalde have encountered similar materials below the Cretaceous. The Bend is also well developed in the Paleozoic area west of the Pecos. This would indicate that during the Bend the Llano area was a peninsula extending northward from the Llanoria land mass.''

The extent of the rocks of Pennsylvanian age underneath the Coastal Plain in eastern Texas is not known, but, as pointed out by Dumble,[46] they are probably confined to the extreme western and northern borders of the Coastal Plain in that State. Sidney Powers,[47] who has collected much information on deep wells in eastern Texas, says:

> ''Recent borings, * * * starting in one instance in the Tertiary and in the other instances in the Cretaceous, at Waco, Georgetown, Maxwell, San Antonio, and Leon Springs, find pre-Cambrian schist beneath the Cretaceous at depths of 3,700, 1,100, 3,000, 1,800 and 1,100 feet, respectively.''

Wells at and near Fort Worth, Tex., have penetrated sandstone and shale of Pennsylvanian age,[48] and a well at Dallas, Texas, has penetrated rocks of apparently the same age.[49] Wells on the Preston anticline have revealed the presence of the Caney shale, of Mississippian age, and the Glenn formation, of Pennsylvanian age, directly underneath the strata of Lower Cretaceous age, as far southeast as Denison, Texas.[50]

In Arkansas no wells have passed through the Cretaceous rocks south of Nashville. A well at that place penetrated rocks of apparent Carboniferous age.[51]

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[46] Idem.

[47] Powers, Sidney, The Butler salt dome, Freestone County, Texas, this Journal, (4), vol. 49, p. 141, 1920.

[48] Winton, W. M., and Adkins, W. S., The geology of Tarrant County, Univ. of Texas Bull. No. **1931**, pp. 25, 107-114, March, 1920.

[49] Fuller, M. L., Relation of oil to carbon ratios of Pennsylvanian coals in north Texas, Economic Geology, vol. **14**, no. 7, p. 541, Nov., 1919.

[50] Hopkins, O. B., Powers, S., and Robinson, H M., Structure of the Madill-Denison area, Oklahoma and Texas, with notes on the oil and gas development in that and adjoining areas, U. S. Geol. Survey, Bull. (in press.)

[51] Miser, H. D., and Purdue, A. H., Asphalt deposits and oil conditions in southwestern Arkansas, U. S. Geol. Survey, Bull. **691**-J, p. 290, 1918.

Deformation of rocks in the Arbuckle and Wichita mountains.

Although several unconformities[52] separate the Paleozoic formations in the Arbuckle Mountains, the beds were folded and faulted mainly during two periods.[53] The first of these periods occurred near the close of the Mississippian epoch or near the beginning of the Pennsylvanian epoch, when the western part of the region was probably elevated high enough to form mountains. The land formed by this uplift remained above sea level during a large part of the Pennsylvanian epoch, but before the close of the epoch it was submerged, in part at least, and the Franks conglomerate of Pennsylvanian age was deposited across it on the eroded edges of the older strata. The second period of folding and faulting occurred near the close of the Pennsylvanian epoch and prior to the deposition of the nearly flat-lying "Red Beds," the oldest of which are of very late Pennsylvanian or early Permian age. At this time also the rocks in the Arkansas Valley and the Ouachita Mountains were closely compressed into numerous east-west folds and were faulted at many places.

The history of the Wichita Mountains was regarded by J. A. Taff as similar to that of the Arbuckle Mountains.[54] The Arbuckle and Wichita areas, being land during much of the Pennsylvanian epoch, were outliers of the main Pennsylvanian land mass to the southeast or formed a part of it.[54a]

[52] Taff, J. A. Preliminary report on the geology of the Arbuckle and Wichita mountains in Indian Territory and Oklahoma, U. S. Geol. Survey, Prof. Paper 31, 1904.

Reeds, C. A. A report on the geological and mineral resources of the Arbuckle Mountains, Oklahoma, Oklahoma Geol. Survey, Bull. 3, 1910.

——The Hunton formation of Oklahoma, this Journal (4), vol. 32, pp. 256-268, 1911.

[53] Taff, J. A. Op. cit., pp. 15, 33-35, 37-38, 1904. U. S. Geol. Survey Geol. Atlas, Tishomingo folio (No. 98) pp. 5, 7, 1903.

[54] Taff, J. A., U. S. Geol. Survey, Prof. Paper 31, p. 80.

[54a] Since this paper was written R. C. Moore gave a paper before the Chicago meeting of the Geological Society of America, in December, 1920, in which he presented the conclusion that there was only one main period of folding and faulting in the Arbuckle Mountains. This period, which was accompanied by orogenic movements in the Ouachita Mountains and Arkansas Valley, he places in the late Pennsylvanian. One of the principal features of his evidence for this conclusion is that the Franks conglomerate is not equivalent to the Wapanucka limestone, as was held by Taff, but is in general the equivalent of the Seminole conglomerate which is regarded as being late Pennsylvanian in age and which is thus much younger than the Wapanucka limestone.

Buried Pennsylvanian hills in northern Texas and southern Oklahoma.

Sidney Powers[55] says:

> "Information concerning the extent of this former land area [Pennsylvanian land area in east-central Texas] * * * is being secured by the subsurface discoveries at Healdton, Oklahoma, and at Electra, Burkburnett, and Petrolia, Texas, and in the area south and east of these fields. Granite of pre-Cambrian age has been found beneath the Petrolia field, in Clay County, at a depth of 4,240 feet in the Texas Company Byers No. 41 and in a well 7 miles north of St. Jo, Montague County, at 3,007 feet. Limestone, which has been identified as probably of Ordovician age, occurs above the granite in the Byers well below 3,750 feet and in Ball No. 1, 5 miles north of Myra, Cooke County, below 2,195 feet (identified by Dr. J. A. Udden). However, most of the massive limestone found in the deep wells in the Red River section is supposed to be of Pennsylvanian age, unconformable with the overlying Cisco beds [of Pennsylvanian age]. These buried hills are interpreted as outliers of the main land area to the southeast."

The buried hills just mentioned lie not far south of the Arbuckle and Wichita mountains and doubtless stood above sea level during much of the time in the Pennsylvanian epoch that these two regions were land. The occurrence of limestone of supposed Pennsylvanian age beneath the unconformity in the buried hills region and the occurrence of the Cisco [Pennsylvanian] beds above it indicate that the folding and uplift in this region, which has been described by Powers and others,[56] took place during the Pennsylanian epoch.

Trans-Mississippian extension of Appalachian land area.

J. C. Branner has presented much evidence in support of the theory that the "old Appalachian land area crossed

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[55] Powers, Sidney, The Butler salt dome, Freestone County, Texas, this Journal, (4), vol. 49, p. 142, Feb., 1920.

[56] Powers, Sidney, Idem.

——Ordovician strata beneath the Healdton oil field, Oklahoma (Abstract), Geol. Soc. America, Bull., vol. 28, p. 159, 1917.

——The Healdton oil field, Oklahoma, Econ. Geology, vol 12, pp. 594-606, 1917.

Hager, Lee, Red River uplift has another angle, Oil and Gas Jour., pp. 64-65, Oct. 17, 1919.

Merritt, J. W., Pennsylvanian sedimentation around Healdton Island, Amer. Assoc. Petroleum Geologists, Bull., vol. 4, No. 1, pp. 47-52, 1920.

what is now the lower Mississippi Valley from northern Alabama to the pre-Cambrian area northwest of Austin, Texas.''[57] His conclusions are so important that practically all his summary is here quoted.

''I. The Ouachita anticline [uplift] is the structural equivalent of the Cincinnati-Nashville arch * * * .

II. The Coal Measures drainage of the Illinois-Indiana-Kentucky basin flowed westward through the Arkansas valley into a Carboniferous mediterranean sea.

III. The drainage of the Coal Measures region south of the Ouachita anticline [uplift] flowed westward and entered this sea north of the Texas pre-Cambrian area.

IV. The drainage of both the Arkansas and Texas Carboniferous areas was reversed about the end of Jurassic times, when orographic movements over southeast Arkansas, eastern Texas, Louisiana, and Mississippi submerged the former extension of the Appalachian watershed and admitted the early Cretaceous sea across the Paleozoic land as far north as southern Illinois.

V. This depression was not a deep one (Hilgard)[58] and did not all occur at one time, for there have been subsequent disturbances of a more or less similar nature in the same region.

VI. The evidences of these depressions are:

1. The reversed drainage of the Arkansas valley.
2. The reversed drainage over the Carboniferous area of central Texas.
3. The submerged eastern end of the Ouachita uplift.
4. The eastward slope of the peneplain of the Ouachita region.
5. The direction of the faults and folds near the eastern exposure of the Lower Coal Measures in Arkansas.
6. The great [Balcones] fault through Texas near the Tertiary border, having a downthrow of 1,000 to 1,500 feet on the south and east sides.
7. Eruptive rocks accompanying the Texas [Balcones] fault and the Tertiary border through that State and Arkansas to the Arkansas river.
8. Hot springs near the same line.
9. Faults in Alabama with a downthrow of 10,000 feet or more on the northwest side.
10. The thickness of the Cretaceous and Tertiary sediments over the depressed area: from 4,000 to 10,000 feet.

VII. The southwestern or central Texas end of the Appalachian land area was formerly covered by Cretaceous sediments,

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[57] Branner, J. C., The former extension of the Appalachians across Mississippi, Louisiana, and Texas, this Journal, (4), vol. 4, pp. 357-371, 1897.

[58] Hilgard, E. W., On the geological history of the Gulf of Mexico, this Journal, (3), vol. 2, p. 394, 1871.

but it has since been uncovered by erosion; farther east it is still concealed.

VIII. The Carboniferous beds uncovered in Texas all belong to the Upper Coal Measures; it is inferred that a greater thickness is still covered.

IX. The character of both the Silurian [Cambrian, Ordovician, Silurian, and Devonian] and Lower Coal Measures [Mississippian and Pennsylvanian] sediments of the Ouachita uplift show that they came from the south, so that the land area must have been in that direction during Paleozoic times.

X. The sea occasionally invaded both the Arkansas and Texas synclinal troughs during Coal Measures times, but coal-forming conditions obtained in the Texas syncline later than in the Arkansas basin.

XI. The Tertiary depression was probably more marked on the Arkansas than on the Tennessee side of the embayment; this is shown by the Cretaceous border being concealed by the Tertiary deposits in Arkansas, while in Tennessee, Mississippi and Alabama they are exposed in a broad belt.''

Arthur Winslow, who studied the Carboniferous rocks in the Arkansas Valley in Arkansas about 30 years ago, expressed the opinion that ''the similarity between the structure of this area and that of the Carboniferous area in Pennsylvania is not a mere accident, but is due to a trans-Mississippian extension of the same cause.''[59] He thus appears to to have believed in the extension of the Appalachian land area across the lower Mississippi Valley.

The opinion that the Appalachians extended westward across the lower Mississippi Valley into Texas has also been expressed by other geologists, though they have held that there were times when the lower part of this valley was submerged, so that the Paleozoic land area to the west was disconnected during such times from the main part of the Appalachian land area to the east. The opinions of different paleogeographers on this matter as they are expressed on their maps are given below for the Paleozoic era, and for the Triassic and Jurassic periods.

Stuart Weller,[60] who published two paleogeographic maps in 1898, held that the southern end of the Appalachian land area extended westward across the lower

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[59] Winslow, Arthur, The geotectonic and physiographic geology of western Arkansas, Geol. Soc. America, Bull., vol. 2, p. 231, 1890.

[60] Weller, Stuart, Classification of the Mississippian series, Jour. Geology, vol. 6, pp. 306-308, 1898.

Mississippi Valley just before the beginning of Mississippian time and during Osage time.

T. C. Chamberlin and R. D. Salisbury,[61] on several maps published in 1906, show land extending from the Appalachians westward across the lower Mississippi Valley to and beyond Texas during early, middle, and late Cambrian, middle Ordovician, Niagaran, Onondagan, Upper Devonian, Mississippian, and Pennsylvanian times; they show embayments occupying the lower Mississippi Valley during Helderberg and Hamilton times, and do not show any submergence in this part of the valley during Triassic and Jurassic times.

W. B. Scott,[62] on his paleogeographic maps of North America published in 1907, showed the lower Mississippi Valley to be ''land or unknown'' during Ordovician, Silurian, and Upper Carboniferous times, showed that it was submerged during Devonian and Lower Carboniferous times, and that it was land during Triassic and Jurassic times.

Bailey Willis, on his paleogeographic maps published in 1909[63] and 1910,[64] designates the lower Mississippi Valley as ''Land or sea; more likely sea'' during early Cambrian, Middle Ordovician, Silurian, Middle Devonian, Mississippian, Pennsylvanian, latest Paleozoic, and Triassic times. He designates it as ''Land or sea; more likely land'' during late Jurassic time, and holds that it was submerged by epicontinental marine waters during ''Late Middle and Upper Cambrian'' times.

A. W. Grabau[65] has published maps showing the paleogeography of North America (1) at the end of ''Upper Cambric'' time, (2) in early ''Beekmantownian'' time, (3) at the end of ''Beekmantownian'' time, (4) at the end of Chazy time, and (5) at the end of Trenton time, and in

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[61] Chamberlin, T. C., and Salisbury, R. D., Geology, vols. 2 and 3, Henry Holt & Co., New York, 1906.

[62] Scott, W. B., An introduction to geology, The Macmillan Co., 1917.

[63] Willis, Bailey, Paleogeographic maps of North America, Jour. Geology, vol. 17, 1909.

[64] Willis, Bailey and Salisbury, R. D., Outlines of Geologic history with especial reference to North America, The University of Chicago Press, 1910.

[65] Grabau, A. W., Physical and faunal evolution of North America during Ordovicic, Siluric, and early Devonic time, Jour. Geology, vol. 17, pp. 209-252, 1909.

Willis, Bailey, and Salisbury, R. D., Outlines of Geologic history with especial reference to North America, pp. 44-88, University of Chicago Press, 1910.

none of them does he show a westward extension of the Appalachians across the lower Mississippi Valley.

Charles Schuchert[66] holds that there was a land connection between Texas and the Appalachians during the "Upper Acadic" (Middle Cambrian) and "Upper Siluric," but he[67] and E. O. Ulrich[67] hold that the Appalachian land area was separated by epicontinental seas from the land area in Louisiana and eastern Texas at all other times during the Paleozoic era. Schuchert[68] also holds that no part of the present Gulf Coastal Plain was submerged during the Triassic and Jurassic periods, except southern Texas, which he thinks was submerged during late Upper Jurassic time.

Llanoria as a positive element and its location by paleogeographers.

All paleogeographers agree that Llanoria was one of the positive elements of North America during the Paleozoic era, and was thus undergoing erosion during most of the era, but although they agree as to its general location they differ as to its boundaries. This disagreement, however, is not surprising, as the outlines of Llanoria changed from time to time, and as our knowledge of these changes is very scant.

Willis states as follows:[69] "It is bounded by the Gulf of Mexico on the southeast; on the north it probably extends to the folded zone of Paleozoics in Indian Territory [Oklahoma]; and on the west it appears to be separated by the zone of folding in central New Mexico from the similar [positive] elements in Colorado and Arizona." On a recent map he[70] shows that the land area under discussion was connected with Ozarkia to the north and

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[66] Schuchert, Charles, Paleogeography of North America, Geol. Soc. America, Bull., vol. 20, maps, 1910.

[67] Ulrich, E. O., and Charles Schuchert in Chas. Schuchert, Paleogeography of North America, Geol. Soc. America, Bull. vol. 20, maps, 1910.

Ulrich, E. O., Revision of the Paleozoic systems, Geol. Soc. America, Bull., vol. 22, fig. 7, 1911.

Ulrich, E. O., The Ordovician-Silurian boundary, Int. Geol. Cong. XII, Canada, 1913, C. R., pp. 660-667, 1914.

[68] Schuchert, Charles, op. cit.

[69] Willis, Bailey, A theory of continental structure applied to North America, Geol. Soc. America, Bull., vol. 18, pp. 394-395, 1909.

[70] Willis, Bailey, Discoidal structure of the lithosphere, Geol. Soc. America, Bull., vol. 31, Plate 11, 1920.

was disconnected from Appalachia to the east, from Mexia (a new name for the positive area in Mexico) to the southwest, and from Colorado Land to the northwest. Schuchert[71] considered that it extended from Columbia (old name for positive element in Mexico) northeastward across eastern Texas into Louisiana and into southern Arkansas. The Llano (Central Mineral) region he placed on its northwest border. Ulrich[72] agrees with Schuchert's location of the Paleozoic land area in Louisiana and eastern Texas except that he says it was disconnected from Columbia by an embayment running northeastward from Mexico across Texas, passing just east of the Central Mineral region, and then connecting with the west end of the embayment in the Ouachita geosyncline.

CONCLUSIONS.

Conclusions regarding the Paleozoic land area under discussion can not be very definite, as the rocks that formed it have been entirely concealed by Cretaceous and later rocks, but the conclusions presented below appear to be justified by the evidence at hand.

A land area, which has been called Llano by Willis, Schuchert, and Ulrich and Llanoria by Dumble and Powers, existed in Louisiana and eastern Texas during much if not most of the Paleozoic era and during the Triassic and Jurassic periods of the Mesozoic era. It varied in outline from time to time. It may have occupied a part of the area of the present Gulf of Mexico; at times it was doubtless connected with large land areas that occupied at least much of central and northern Texas, southern Oklahoma, and southern Arkansas, and for short periods it may have extended eastward across the lower Mississippi Valley and joined the southwest end of the Appalachian area. It furnished most of the sediments that formed the clastic rocks of Pennsylvanian age in north-central Texas and those of Ordovician, Silurian, Mississippian, and Pennsylvanian age in the Ouachita Mountains and Arkansas Valley of Arkansas and Oklahoma. At times, as during the Devonian period, it had

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[71] Schuchert, Chas., op. cit., p. 470, and plate 49.

[72] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America, Bull, vol. 22, fig. 7 on page 368, 1911.

very little relief but at other times, as during the Ordovician and Silurian periods and the Mississippian and Pennsylvanian epochs, it was mountainous. It was depressed and entirely submerged during Lower Cretaceous time, and later depressions carried the sea across it during Upper Cretaceous and Tertiary times, so that its rocks are now covered and concealed by deposits of these ages. The discovery of pre-Cambrian schists directly beneath Cretaceous strata at Waco, Georgetown, Maxwell, San Antonio, and Leon Springs, Tex., suggests that the rocks of this buried land area were similar to the crystal-line rocks that are now exposed in the Piedmont Plateau of the eastern United States. If so such rocks underlie the Cretaceous strata over much of Louisiana, eastern Texas, and perhaps adjoining areas to the south and east. Prominent structural features of the Gulf Coastal Plain, including the Preston anticline and Sabine uplift, may mark the location of some of the folds that were produced in the rocks on the old land area but that have undergone further movement since they were buried by Cretaceous and later sediments. The increase in the intensity of the folding of the rocks in the Ouachita Mountains and Arkansas Valley toward the south suggests that the deformation of the basement rock of the Gulf Plain south of these regions was still greater.

The results of future deep drilling in the Gulf Coastal Plain and further study of the Paleozoic and older rocks that are exposed around the borders of the Gulf Plain will add greatly to our imperfect knowledge of the old land area considered in this paper.

ART. VI.—*A Fossil Flora from the Puente Formation of the Monterey Group*; by RALPH W. CHANEY.

The Puente formation as described by Eldridge[1] is a series made up largely of diatomaceous shales which appears to represent the middle or lower middle portion of the Miocene of southern California, and is therefore included in the Monterey group. The fossil fishes of the formation have recently been described by Jordan and Gilbert,[2] and a single species of Pecten has been noted by Eldridge.[1] These faunas indicate the accumulation of the shales in small bays or in an archipelago of small islands, and are made up of marine species.

The only previously known flora from the Puente formation is made up of marine algæ. Recently a small collection of terrestrial plants has been received from Mr. E. E. Hadley of Alhambra, California, which he collected from two localities, near Alhambra and El Modena. This collection is of interest, both from its relation to other Tertiary floras, and from its occurrence in a marine formation.

Some eighteen species are included in the collection, of which two appear to be referable to modern genera of marine algæ, Desmerestia and Lessonia. The remainder, all land plants, have been determined as shown in the accompanying table, which shows also the horizon at which certain species have been previously recorded. Several of the identifications are doubtful due to the limited amount of material.

Table of Species indicating their distribution.

Species	*Horizon*	*Locality*
Aralia whitneyi	Eocene	Chalk Bluffs, Calif.
Bumelia florissanti (?)	Miocene	Florissant, Colo.
Crataegus (?) sp.		
Fagopsis longifolia	Miocene	Florissant, Colo.
Ficus arenaceæformis	Miocene	Florissant, Colo.
Ficus cf. *puryearensis*	Eocene	Southeastern United States
Fraxinus mespilifolia	Miocene	Florissant, Colo.

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[1] Eldridge, G. H., The Puente Hills Oils District, Southern California, U. S. G. S., Bull. 309, pp. 104-105.

[2] Jordan, David Starr, and Gilbert, James Z., Fossil Fishes of the Monterey Formations of Southern California, Leland Stanford Junior University Publications, University Series, 1919.

Fraxinus ungeri (?)	Miocene	Florissant, Colo.
Laurus saliciformis	Miocene	Corral Hollow, Calif.
Nelumbo (?) sp.		
Planera myricæfolia	Miocene	Florissant, Colo.
Populus crassa	Miocene	Florissant, Colo.
Salix n. sp.		
Sapindus n. sp.		
Sterculea cf. *engleri*	Miocene	Florissant, Colo.
Zizyphus piperoides (?)	Eocene	Chalk Bluffs, Calif.

The Miocene age of the flora is indicated by its relation to the flora of the Florissant beds, with which it has eight species (three doubtfully determined) in common, and to the Miocene deposits of Corral Hollow, a total of nine Miocene species. Two species (one of which is doubtfully recorded) are found at Chalk Bluffs, California where the deposits are commonly listed as of Miocene age, though they will doubtless be found to be older, and are here designated as of Eocene age. One of these, *Aralia whitneyi,* has been doubtfully recorded from the Miocene of the John Day Basin in Oregon. The resemblance noted of one of the species of Ficus to *Ficus puryearensis* of the Wilcox is probably nothing more than superficial, as indicated by several incomplete and poorly preserved specimens in the Puente flora. The age of the flora may be tentatively established as Miocene, which is in accord with the indications of the faunas.

With the exception of Ficus, Laurus, and Sapindus, which occupy shores and coastal swamps, the genera included in the flora are commonly found on stream borders and in moist woods. Nelumbo, doubtfully determined, is a fresh-water aquatic form. Thus there is evidence that most of the leaves have been transported seaward, probably by streams, and mingled with marine deposits along the shores. The coriaceous character of the majority of the leaves would allow this mode of transportation without their destruction.

The climatic implications of the flora and its means of transportation to the sea are not in accord with the conclusions of Jordan and Gilbert.[3] Describing the conditions under which a relatively pure deposit of diatomaceous shale would be accumulated, they state:—"The region must have been arid, else sand would have been washed in and mixed with the diatom deposits." This assump-

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[3] Jordan and Gilbert, op. cit. p. 13.

tion of aridity based on a lack of clastic sediments is open to question, for it appears to be clearly established that coarse clastic sediments will be deposited along the shore of an arid tract by the runoff of the occasional rainfall. Further, the moisture requirements of the land plants show conclusively that the climate was not arid, for the majority of the genera represented are found in moist woods and thickets. The mixture of inland types with marine deposits has been suggested to have been brought about by stream transportation, though it is possible they were transported seaward by the wind. The general lack of clastic sediment in the diatomaceous shales may rather be attributed to the low relief of the land mass than to the lack of running water. For even though the streams flowed seaward at so low a gradient that they could transport little clastic sediment, the leaves of land plants might readily be floated seaward by them. The temperature conditions indicated by the flora are in accord with those suggested by Jordan and Gilbert, as being like those now existing in the region.

The occurrence of terrestrial plant fossils in a marine formation is unusual, as pointed out by White,[4] and in the case of specimens as perfectly preserved as those here noted, indicates their deposition close to the shore. Factors which may be supposed to have contributed to this unusual preservation may be mentioned as follows:—first, the lack of sediment in the water of the streams which transported the leaves out to the sea, an absence evidenced by the purity of the diatomaceous deposits, would reduce the chances of the leaves being macerated during their journey; second, the conditions under which the diatoms were trapped and impounded in bays[5] would favor rapid accumulation of the diatomaceous shale, which in turn would favor the preservation of the leaves; and third, the fine texture of the diatomaceous shale offers a matrix suitable for the formation of perfect impressions of leaves enclosed in it. This combination of circumstances, while unusual, should be the rule for marine diatomaceous deposits and it may be hoped that a careful search in such deposits in other localities will result in the finding of other inclusions of terrestrial plants in marine formations.

[4] White, David, Value of Floral Evidence in Marine Strata as Indication of Nearness to Shores. Bull. Geol. Soc. Amer. 22, pp. 221-227.

[5] Jordan and Gilbert, op. cit. p. 14.

ART. VII.—*John Day Eporeodons, with Descriptions of New Genera and Species;* by MALCOLM RUTHERFORD THORPE.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

TABLE OF CONTENTS.

INTRODUCTION.

In 1875 Marsh founded the genus *Eporeodon* on a skull collected about 1870 by Rev. Thomas Condon in the John Day basin, Oregon. By some students, this genus may be considered synonymous with *Eucrotaphus* Leidy; the present author, however, regards *Eucrotaphus* as a synonym of *Agriochœrus,* for reasons to be stated in a subsequent paper.

In determining the geologic horizon of the specimens, the same criterion has been employed as that used by the West Coast paleontologists, i. e. specimens showing any green coloration in the matrix should be considered as middle John Day, and those with light colored matrix, grey to buff, as belonging to the upper series. Using this datum, it is found that of 218 specimens in the Marsh Collection at Yale, 184 show unmistakable green coloration in the matrix, and 34, grey or buff colors. In other words, 84 per cent of the specimens of *Eporeodon* in the John Day basin are found in the middle John Day, and the remainder, 16 per cent, in the upper. The genus *Promerycochœrus* overlaps downward into the middle John Day in about the same proportion.

Geologically, the John Day formation is divided into lower, middle, and upper. Paleontologically, the lower

John Day has no designation, as it has so far yielded extremely scanty and ill-preserved vertebrate remains. The middle is termed the Diceratherium zone (Wortman), and the upper, the Promerycochœrus zone (formerly Merycochœrus). It is the writer's opinion that the term Diceratherium zone should be replaced by Eporeodon zone, for the following reasons:

(1) *Diceratherium* is known to occur in both the middle and upper series in considerable abundance; (2) it is quite difficult to identify *Diceratherium* in the field, owing to the general lack of skull and tooth material, and due to the fragmentary condition of the skeletal elements as usually found; (3) the *Eporeodon* material in the Marsh and other collections shows conclusively that representatives of this genus are the most common fossil vertebrates in the middle John Day. As a result of studies carried on at the University of California, the fact is brought out that

> "The middle John Day is characterized by abundant remains of *Eporeodon,* especially of the two smaller species *occidentalis* and *pacificus,* and by a great number of rodents, which have been obtained principally at two horizons, one at about the middle and the other at the top of the Diceratherium beds. Both horizons contain practically the same fauna. Next to *Eporeodon* in abundance the most common form is a *Hypertragulus,* fragmentary specimens of which occur at almost every exposure. Rhinoceros material is fairly abundant but usually fragmentary and possibly represents other genera in addition to *Diceratherium.*" (Merriam and Sinclair 1907, p. 190.)

(4) The Oreodontidæ are such a wide-spread family and bear so great a similarity to each other in skeletal and tooth structure that their identification would be much easier to all field men, except expert paleontologists, than would that of *Diceratherium,* especially when only bone fragments of the latter are present. (5) There would be no confusion in distinction between *Eporeodon* of the middle and *Promerycochœrus* of the upper series, as the two genera have certain invariable distinctions clearly defined.

The study of specimens of this genus from the North Fork of the John Day River is unsatisfactory at best, due to inadequate geologic data concerning that area. It seems advisable at present to assume that these beds are of later origin than the typical John Day formation, and that assumption offers an explanation of why the forms from this area are different from those in the rest of the basin. One of the future problems, and one which is indeed critical, is a detailed geologic and paleontologic study of the North Fork area.

The number of skulls[1] of John Day Eporeodons represented in the Marsh Collection is approximately 300, while fragmentary materials indicate at least 50 more individuals. On a basis of 218 well preserved skulls, a quantitative study was made, some of the results of which are briefly stated below.

In determining the relative age of the individuals at death, the computations were made on a basis of 10, as follows: 0-3, milk dentition; 4-6, average medium age with 5 considered as mid-life, or fully adult; 7-8, those with the tooth pattern of M^1 obliterated and that of M^2 much worn; and 8-10, those having the tooth pattern of true molars very much worn or completely obliterated.

Of 204 individuals in which the age was determined, 27 or 13.2 per cent died between 1 and 3; 134 or 65.6 per cent between 4 and 6; 25 or 12.2 per cent between 7 and 8; and 18 or 8.8 per cent between 8 and 10. This summary for all species is typical for the individual species with but few exceptions. *Eporeodon occidentalis* shows 23.8 per cent that died having milk dentition and no individuals that reached an age between 8 and 10. *Eporeodon pacificus* shows 18 per cent reaching a very old age, 8 and above. In *E. leptacanthus,* 6.1 per cent died with deciduous dentition and only 1.5 per cent reached the age of 8, while the majority died in their prime, between 4 and 6. Half the specimens of *E. trigonocephalus* are 3 or below.

The majority of the specimens were collected at or near Turtle Cove. The other areas, named in order of their importance in yielding remains of this genus, are as follows: Bridge Creek, Haystack Valley, 5 or 6 miles below Cottonwood, Clarno Bottom, the North Fork, and Big Bottom.

I am deeply appreciative of the privilege, afforded me by Messrs. Matthew and Granger, of measuring and studying the Cope types of this genus in the American

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[1] The present study is based wholly on skulls and jaws; the Marsh Collection, however, contains an abundance of skeletal material as well.

Museum of Natural History. I wish also to express my thanks to Professors Schuchert and Lull for their helpful criticism and suggestions, as well as to Miss LeVene for her very careful and efficient aid in editing this and other papers. The illustrations have been made by Mr. Rudolf Weber.

Description of Species.

Eporeodon occidentalis (Marsh) 1873.

(Figs. 1-3.)

Holotype, Cat. No. 10142, Y. P. M. Upper Oligocene (middle John Day), Bridge Creek?, John Day River, Oregon. Plesiotype, Cat. No. 12345, Y. P. M., from Turtle Cove, John Day River, Oregon.

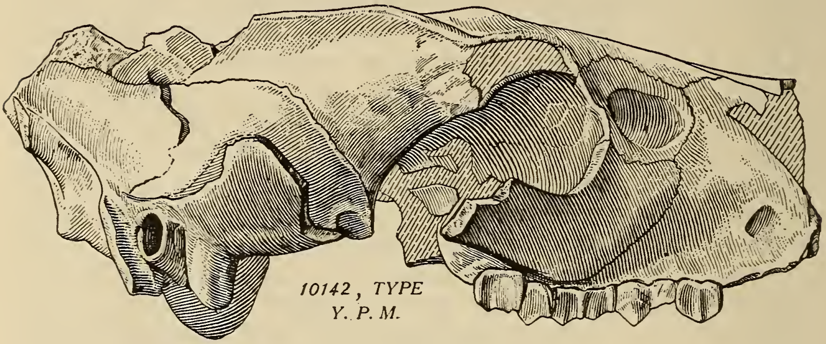
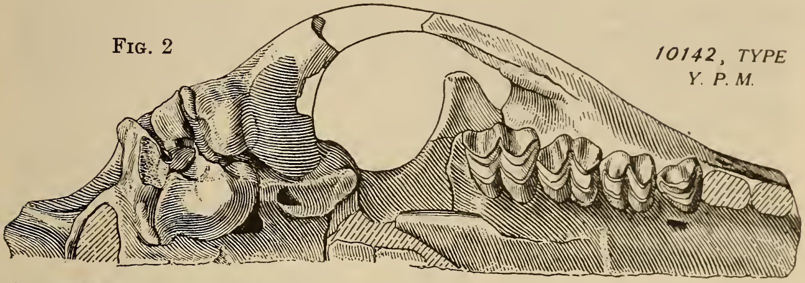


Fig. 1.—*Eporeodon occidentalis* (Marsh). Holotype. Right lateral view. × 3/5.

Specific characters.—Bullæ large and laterally compressed; skull mesocephalic and about the same length as that of *Merycoidodon* (*Oreodon*) *culbertsonii;* lacrymal fossa large and deep, but confined to lacrymal bone; postorbital constriction of medium diameter; bizygomatic diameter large; sagittal crest low and short; infraorbital foramen above middle of P^3; masseteric fossa deep and nearly horizontal; coronoid process thin and much higher than the condyle; paramastoids slender; posterior nares V-shaped; palate not produced beyond M^3.

Specimen No. 12316, Y. P. M., possesses natural casts of the bullæ which are divided into anterior and posterior hemispheres. In this collection there are about 50 individuals, chiefly from Turtle Cove, Haystack Valley, and Bridge Creek. The species is abundant in the middle John Day.

FIG. 2



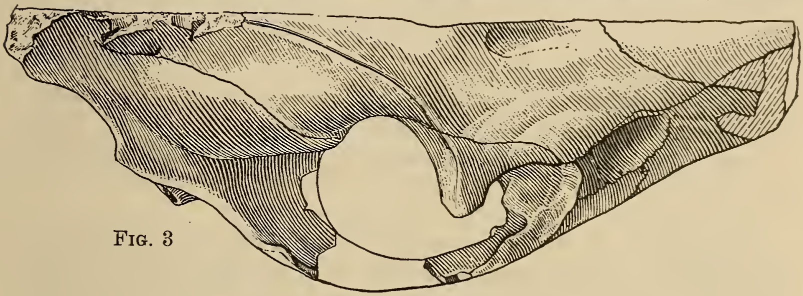


FIG. 3

FIG. 2.—*Eporeodon occidentalis* (Marsh). Holotype. Right half, palatal view. × 3/5.
FIG. 3.—*Eporeodon occidentalis* (Marsh). Holotype. Right half, superior view. × 3/5.

Measurements.

	Holotype mm.	Plesiotype mm.
Total skull length	188*	192
Bizygomatic diameter	127*	136
Superior molar series, length	43	44
Superior premolar series, length	39.5	39.5
Diameter, postorbital constriction	41	37

* Approximate.

Eporeodon leptacanthus leptacanthus (Cope) 1884.

Holotype, No. 7695, Cope Coll., A. M. N. H. Upper Oligocene (middle John Day), John Day River, Oregon.

Specific characters.—Skull large and dolichocephalic; paroccipital process strongly compressed; nasal bones pointed posteriorly, and projecting to a point nearly above the prosthion; infra-orbital foramen above middle of P^3; lacrymal fossa large and deep; maximum bizygomatic diameter anterior to glenoid process; long high sagittal crest; bullæ large, laterally compressed; rami shallow below tooth-row; masseteric fossa shallow and much more vertical than in *E. occidentalis;* palate produced but slightly beyond M^3; posterior narial opening shaped like a shallow V.

In this collection, the species is represented by 60 or more specimens, collected at Turtle Cove, Bridge Creek, Haystack Valley, and at the fossil horse beds on Cottonwood Creek.

*Measurements of Holotype.**

	mm.
Total length of skull	247
Superior molar series, length	52.3
Superior premolar series, length	45.8

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* This holotype is laterally crushed, and transverse measurements have been omitted, since, even at best, they would be only approximate.

No. 10145, Y. P. M., is considered a male on account of the longer dental series, much heavier and more robust canines, wider palate and frontals, larger cranium, square muzzle, and, in general, the more pronounced robustness of this skull in comparison with some others of the same species. The paramastoid processes are very heavy, but the postglenoid tubercles are abnormally small and the position of P^1 and P^2 is oblique. This specimen was collected by William Day in 1875 at Turtle Cove.

Skull No. 12408, Y. P. M., from the North Fork of John Day River, is referred to this species, but shows certain differences, as follows: length of molar-premolar series, 91 mm., the same as in *E. pacificus*, but the skull length is that of *E. leptacanthus;* total length of dentition less by 3 mm.; paroccipital processes turned obliquely outward; sagittal crest shorter; origin of zygoma heavier and face more prominently divided by the forward prolongation of the zygoma; nasals wedge-shaped, becoming progressively wider as they advance; postglenoid tubercles smaller; molar and premolar series of nearly equal length; lacrymal fossæ more shallow. Specimens numbered 12409, 12410, and 12414 exhibit the same characteristics as No. 12408.

Eporeodon leptacanthus pacificus (Cope) 1884.

Holotype, No. 7502, Cope Coll., A. M. N. H. Upper Oligocene (middle John Day), John Day and Crooked rivers, Oregon.

Specific characters.—Skull long and narrow; lacrymal fossa large and deep; infra-orbital foramen above posterior part of P^3; long sagittal crest; postorbital constriction moderately wide; palate moderately produced posteriorly; bulla large and laterally compressed, with a small forward prolongation not seen in any other species of this genus; bulla separated from postglenoid tubercles, which are oblong and small; paroccipital process slender and greater diameter transverse to sagittal plane; posterior nares shaped like a shallow open V; posterior part of nasal bones pointed and extending to anterior margin of orbit.

At least 50 individuals are present in this collection from Turtle Cove, Haystack Valley, Bridge Creek, Clarno Bottom, and from 5 or 6 miles below Cottonwood.

Measurements of Holotype.

	mm.
Total length of skull	241
Bizygomatic diameter	137
Superior molar series, length	47
Superior premolar series, length	44.7
Diameter, postorbital constriction	41

Cat. No. 10143, Y. P. M., is tentatively referred to *E. pacificus*. This specimen, collected at Turtle Cove in 1875 by L. S. Davis, is that of an old individual, probably a male. The major differences from the type of *E. pacificus* are: pterygoid process of the maxilla strongly developed, extending posteriorly and ending in a blunt point; posterior nares semicircular; glenoid articular surface wide and heavy; bullæ smaller; mastoid heavy and rugose and paramastoid thickened, with its greater diameter oblique to sagittal plane, instead of transverse; mesocephalic instead of dolichocephalic; length of molar series 44 mm., premolar, 49, but total length of dental series including canine is the same as that of *E. pacificus;* anterior zygomatic pedicle heavy, including malar.

It is probable that both old age and sex have produced these variations from the type. Just what proportion of influence each has had it is impossible to say, but the differences in the bone, i. e., maxilla, palate, glenoid, mastoid, and paramastoid, as well as zygoma, are probably due to sex; the others, such as length of molar and premolar series and mesocephaly, may well occur in old age. Skull No. 10147, Y. P. M., is that of an extremely old individual and exhibits some of the characters noted above.

Three specimens, Nos. 12402, 12403, and 12404, Y. P. M., collected by L. S. Davis in 1875 on the North Fork of the John Day River, 15 miles from its junction with the main stream, are apparently the forms of *E. pacificus* in that locality. Their horizon is, however, both middle and upper John Day. Specific characters are as follows: approximately same length as *E. pacificus;* total length of tooth row less by 5 mm.; molar series shorter, equalling or slightly less than length of premolar series; postglenoid tubercles less robust; paroccipital processes extending strongly outward and downward, and in contact with the bullæ only at base; palate much wider and less uparched; palate less produced posteriorly; incisive foramina wider and less ovate; face broader and width at zygoma greater; supra-orbital foramina closer together; nasals more slender and elongate; cranium about the same width but postorbital constriction less; orbits more nearly round, with much less vertical diameter; anterior prolongation of zygoma much more prominent, dividing the face more sharply; skull more robust; origin of zygoma heavier and more offset from alveolar parapet; basicranial axis less steep.

Still another specimen, No. 12401, Y. P. M., consists of a skull only, certain characters of which refer it to *E. pacificus.* It was found by Davis in the North Fork area, but its matrix is light chocolate in color and the horizon probably upper John Day. This color is not shown in the matrix of any specimens in the collection outside of the North Fork area. The specific characters are: skull length a little less than that of *E. occidentalis,* or 182 mm. from occipital condyles to prosthion inclusive; markedly dolichocephalic; total length of dentition, 100.5 mm., length of molar series, 48 mm., and of premolars, 44 mm.; bullæ small; short sagittal crest; lacrymal fossæ small and very shallow; infra-orbital foramen above anterior portion of P^3; nasals extending approximately to a point above incisor border. The right P^4 has two accessory pillars on the external face of the cone; the left is normal.

It is possible that this may represent a new subspecies, but in view of the fact that the specimen has suffered marked lateral compression, it seems best for the present to leave it under *E. pacificus.*

Eporeodon trigonocephalus (Cope) 1884.

Holotype, No. 7505, Cope Coll., A. M. N. H. Upper Oligocene (upper John Day), North Fork of John Day River, Oregon.

Specific characters.—Palatonarial border produced posterior to maxillary bones; posterior nares shaped like a shallow V; small infra-orbital foramen above front of P^3; muzzle short; paroccipital process not separated from bulla by a groove; high, thin sagittal crest; bullæ small and ovoidal, with external ridge enclosing a groove continuous with stylohyoid fossa, the long diameter directed forward and inward; lacrymal fossa well marked, but shallow and confined to lacrymal bone; nasal bones blunt posteriorly; skull flat and broad.

The holotype is an old individual and nearly all of the teeth are broken away. The matrix is light grey. In the Marsh Collection, this species is represented by a comparatively small number of skulls, all from either Turtle Cove or Bridge Creek. These specimens, however, differ from the type to a certain degree, but not enough to invalidate the identification.

Measurements of Holotype.

	mm.
Total length of skull	201
Bizygomatic diameter	145.6
Superior molar series, length	36*
Superior premolar series, length	41*
Diameter, postorbital constriction	31.5

* Approximate.

Eporeodon trigonocephalus parvus, subsp. nov.

(Figs. 4, 5.)

Holotype, Cat. No. 12425, Y. P. M. Upper Oligocene (middle John Day), Haystack Valley, John Day River, Oregon. Collected by L. S. Davis in 1875.

Specific characters.—In comparison with *E. trigonocephalus,* this subspecies shows the following differences:

skull smaller and about 20 mm. shorter in total length (this difference is not due to age, as the holotype is fully adult); very short sagittal crest; tooth-row shorter, individually and totally; muzzle more depressed and highest part of skull above postorbital bridge; postorbital constriction of greater diameter; bullæ large and triangular; anterior portion of bullæ extends forward as far as middle of glenoid articulation; paroccipitals extend outward; M^2 is square instead of being wider than long.

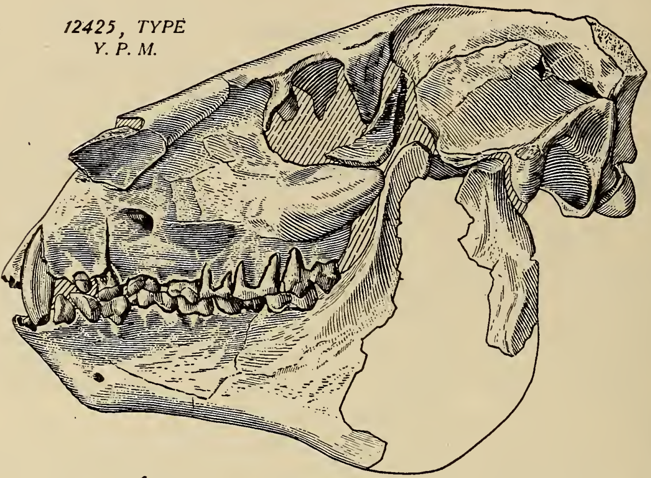


Fig. 4.—*Eporeodon trigonocephalus parvus,* subsp. nov. Holotype. Left lateral view. × 1/2.

The type locality of *E. trigonocephalus* is the North Fork of the John Day River, and the subspecies is probably the basin representative. However, the new form is middle John Day, and the other, upper.

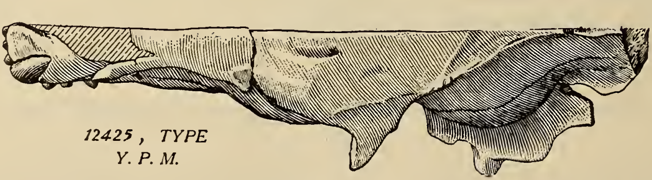


Fig. 5.—*Eporeodon trigonocephalus parvus,* subsp. nov. Holotype. Left half, superior view. × 1/2.

The paratype of the subspecies, found at Turtle Cove by William Day in 1876, is Cat. No. 12426, Y. P. M., and was enclosed in the typical green matrix of the middle John Day. The superior premolars in both holo- and paratype are crowded, and the nasals extend to a point above the incisor border.

Measurements of Holotype.

	mm.
Length, occip. condyles to prosthion, inc.	169
Superior molar series, length	38
Superior premolar series, length	34.5
Max. diameter, postorbital constriction	35

Eporeodon longifrons (Cope) 1884.

Holotype, No. 7504, Cope Coll., A. M. N. H. Upper Oligocene (upper John Day), North Fork, John Day River, Oregon.

Specific characters.—Skull large and robust; lacrymal fossa moderately deep and well defined; short sagittal crest; cranium and postorbital constriction wide; infraorbital foramen above posterior part of P^3; greatest bizygomatic diameter anterior to glenoid process; posterior part of nasal bones pointed and extending to anterior margin of orbits; posterior nares round, and palate moderately produced beyond M^3.

This species was not common, if we may judge from the number in the Marsh Collection. Specimens were collected under the direction of Professor Marsh on the North Fork of John Day River (type locality), at Haystack Valley, 5 or 6 miles below Cottonwood, and at Turtle Cove.

Measurements of Holotype.

	mm.
Total length of skull	255
Superior molar series, length	47
Superior premolar series, length	47
Superior dental series, with canine, length	118
Diameter, postorbital constriction	47

Eporeodon major (Leidy) 1854.

A fragmentary muzzle with complete and well preserved molar series, together with P^4 and P^3, Cat. No. 12400, Y. P. M., is referred to *E. major*. It coincides with Leidy's description of the type in so far as it is possible to determine. The Yale specimen, the only one of this species in the Marsh Collection from the John Day basin, was found at Turtle Cove on the John Day River by William Day in 1875. It is of middle John Day age.

Eporeodon bullatus (Leidy) 1869.

Three skulls, Nos. 10146, 11056, and 12299, Y. P. M., the two former from Turtle Cove and the third from Bridge Creek, are tentatively referred to this species. In tooth measurements they correspond to the type, but the scarcity of other measurements of the type and the lack of drawings make it impossible to be sure of the identification.

Leidy compared the type with *Oreodon culbertsonii,* which he said it closely resembled, except for the presence of large auditory bullæ. These three skulls from the John Day basin are much more robust than the White River *O. culbertsonii,* and possess a much greater bizygomatic diameter. No. 11056 is more robust than No. 12299, and may be a male. It is also individually older.

These skulls tend toward brachycephaly, as in *E. occidentalis,* and, with the exception of the latter species and *E. trigonocephalus,* they exhibit this trend more distinctly than any other species from the basin. The lacrymal fossæ are relatively small and shallow, the nasal bones wide, the postorbital constriction narrow, the sagittal crest moderately long, the bulla about the size of that in *E. occidentalis,* the palate moderately produced posteriorly beyond M^3, the palate wide, the canines heavy and more robust than in the other species of this locality. In No. 10146 the premolars are crowded so that both P^2 are set obliquely; this is true also in No. 12299, but not to so great a degree.

Eporeodon condoni, sp. nov.

(FIGS. 6-8.)

Holotype, Cat. No. 11016, Y. P. M. Upper Oligocene (middle John Day), Bridge Creek, John Day Valley, Oregon. Collected by L. S. Davis in 1874. Paratypes, Cat. Nos. 11029 and 12294, Y. P. M., from Haystack Valley and Turtle Cove respectively.

Specific characters:—Somewhat smaller than *E. pacificus* and more brachycephalic; length of molar and premolar series approximately equal; bullæ small and less compressed, about the same size as in *E. occidentalis;*

lacrymal fossæ shallower and smaller; paroccipital processes compressed and turned obliquely outward, whereas in *E. pacificus* they are obliquely inward; palate moderately produced and much more round at the posterior nares than even in *E. leptacanthus;* canines less robust than in *E. pacificus;* postglenoids and bullæ in contact.

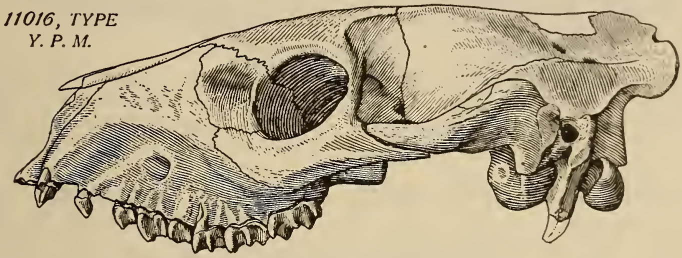


FIG. 6.—*Eporeodon condoni,* sp. nov. Holotype. Left lateral view. × 2/5.

This species is named in honor of Rev. Thomas Condon, to whom is due the distinction of first bringing to the attention of scientists knowledge of the great fossil deposits of the John Day basin. Specimens were collected at Clarno Bottom, Turtle Cove, Big Bottom, and Bridge Creek.

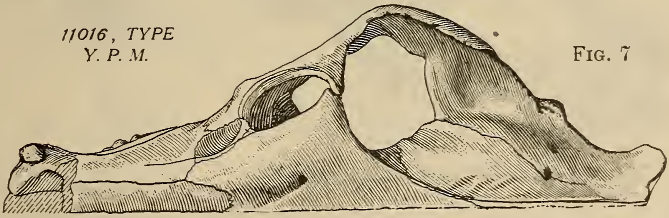


FIG. 7

FIG. 8

FIG. 7.—*Eporeodon condoni,* sp. nov. Holotype. Right half, superior view. × 2/5.
FIG. 8.—*Eporeodon condoni,* sp. nov. Holotype. Right half, palatal view. × 2/5.

Measurements of Holotype.

	mm.
Total length of skull	208
Bizygomatic diameter	121.6
Superior molar series, length	42.3
Superior premolar series, length	40
Diameter, postorbital constriction	36.5

Eporeodon perbullatus, sp. nov.

(FIGS. 9, 10.)

Holotype, Cat. No. 11011, Y. P. M. Upper Oligocene (upper John Day), Bridge Creek, John Day River, Oregon. Collected by S. H. Snook in 1874. Paratypes, Cat. Nos. 12319 and 12320, Y. P. M., Upper Oligocene (middle John Day), also from Bridge Creek. Collected by L. S. Davis in 1874.

Specific characters.—Bullæ relatively enormous, full and ovate and nearly twice the size of those in *E. leptacanthus,* which is the largest species of this genus in the John Day basin; lacrymal fossæ deep and large; paramastoids transversely compressed, ending inferiorly in a thin tip and they extend downward and well outward from the median line of the bullæ; postglenoid tubercles relatively small; length of superior dental series intermediate between *E. pacificus* and *E. leptacanthus;* nasal bones wide; cranium wider than in *E. leptacanthus;* palate produced but a very short distance beyond last molar; masseteric fossa relatively deep.

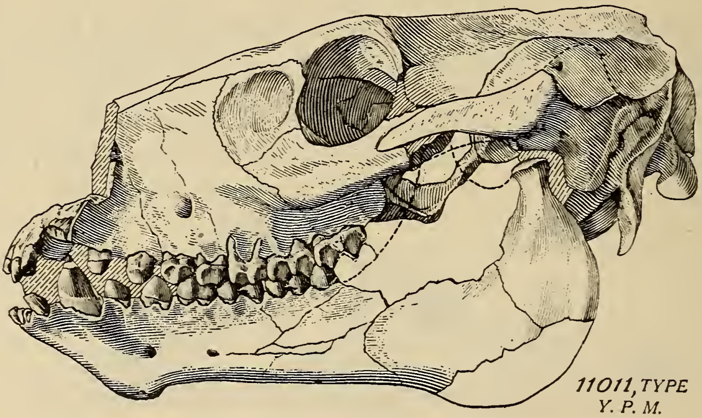


FIG. 9.—*Eporeodon perbullatus,* sp. nov. Holotype. Left lateral view. × 2/5.

Nos. 11011 and 12320 are probably males, while No. 12319 is more delicately proportioned and may be a female. In the latter, the nasal bones are much more narrow, the orbits smaller, and the whole skull and jaws less robust, than in the other two.

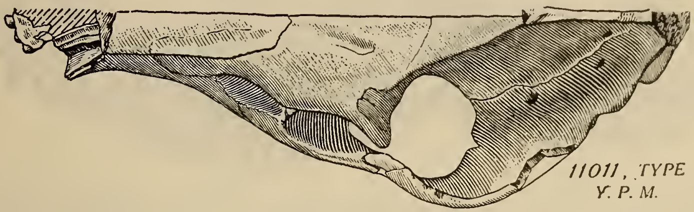


FIG. 10.—*Eporeodon perbullatus,* sp. nov. Holotype. Left half, superior view. × 2/5.

Measurements of Holotype.

	mm.
Total length of skull	227
Bizygomatic diameter	138
Superior molar-premolar series, length	95
Superior premolar series, length	47
Diameter, postorbital constriction	37.5
Ramus, max. length	186
Inferior molar series, length	52
Inferior dental series, with P_1, length	102
Bulla, ant.-post. diameter	31.3
Transverse diameter	25
Vertical diameter	27

Oreodontoides oregonensis, subgen. et sp. nov.

(FIGS. 11-13.)

Holotype, Cat. No. 12329, Y. P. M. Upper Oligocene (upper John Day), Turtle Cove, John Day River, Oregon. Collected by William Day in 1875.

Distinctive characters.—Size small, length less than that of *E. trigonocephalus;* muzzle pointed; face narrow; orbits nearly round, looking chiefly outward, but somewhat upward and forward; cranium very full; no sagittal crest, as frontal ridges do not unite; postorbital constriction very wide; skull depressed at each extremity; lacrymal fossæ well marked, but small; mesocephalic. The sides of the meso- and metastyle of M^3 are straight, giving the metacone a square outline, instead of rounding at the base as in other species. This may or may not be a specific character.

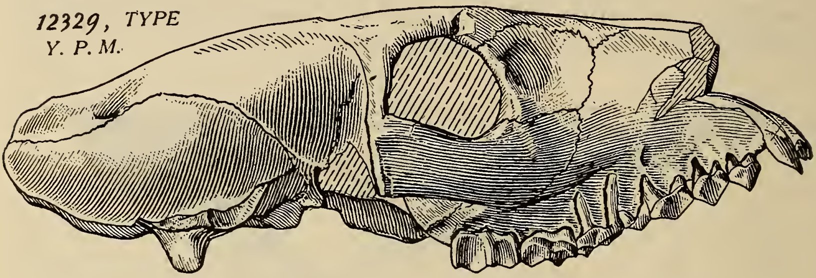
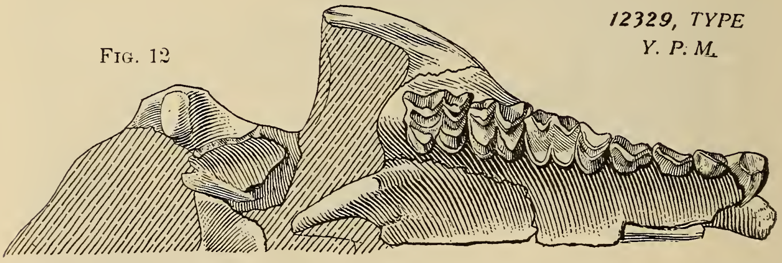


Fig. 11.—*Oreodontoides oregonensis,* subgen. et sp. nov. Holotype. Right lateral view. × 2/3.

Great size of brain chamber, lack of any sagittal crest, unusual diameter of postorbital constriction, and a marked tendency toward brachycephaly are the most marked characteristics of this form.

Fig. 12



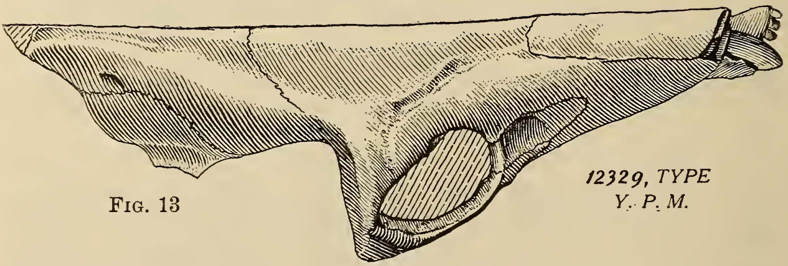


Fig. 13

Fig. 12.—*Oreodontoides oregonensis,* subgen. et sp. nov. Holotype. Right half, palatal view. × 2/3.

Fig. 13.—*Oreodontoides oregonensis,* subgen. et sp. nov. Holotype. Right half, superior view. × 2/3.

Measurements of Holotype.

	mm.
Total length of skull	160*
Superior molar series, length	31.7
Superior premolar series, length	30
Cranium, max. width	52.5
Diameter, postorbital constriction	42

* Approximate.

Paroreodon marshi, gen. et sp. nov.

(FIGS. 14-16.)

Holotype, Cat. No. 12415, Y. P. M. Upper Oligocene (middle John Day), Haystack Valley-Turtle Cove area, John Day River, Oregon. Collected by L. S. Davis in 1875.

Distinctive characters.—Size small; brachycephalic; facial vacuities in advance of orbits, bounded by lacrymal, frontal, and maxillary bones; enormous brain chamber; extremely short sagittal crest; face short and muzzle narrow; steep basicranial axis; bulla very large and robust, ending inferiorly in a sharp ridge; paroccipital process triangular, with greatest diameter transverse, abutting against bulla for two-thirds its length, and descending outward, forward, and downward; very small diastema between C and P^1; palate produced posterior to M^3; palatal vault uparched; three very small incisors crowded against each other and the canine; lacrymal fossa shallow and open, maximum diameter vertical;

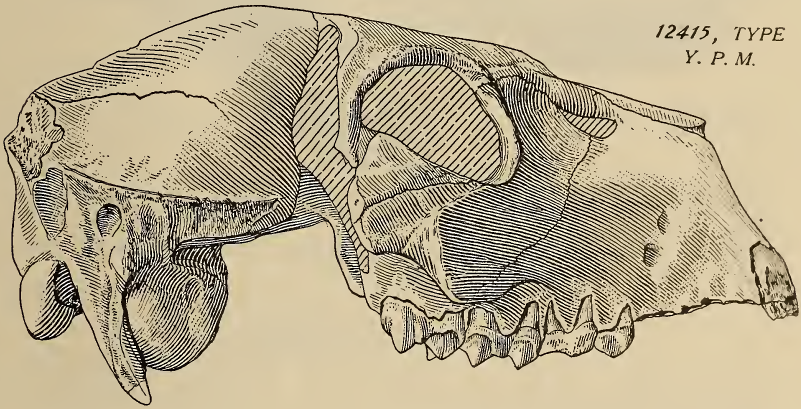


FIG. 14.—*Paroreodon marshi*, gen. et sp. nov. Holotype. Right lateral view. × 2/3.

infraorbital foramen above posterior portion of P^3, this foramen double, with a smaller one above and in advance of the larger. Both sides possess this double foramen, but it is possibly due to individual variation.

Fig. 15

Fig. 16

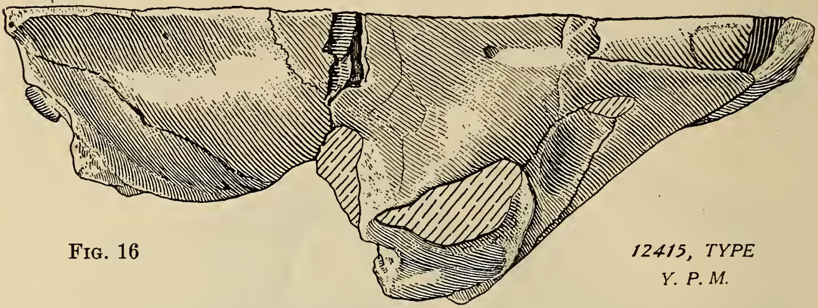


Fig. 15.—*Paroreodon marshi,* gen. et sp. nov. Holotype. Right half, palatal view. × 2/3.

Fig. 16.—*Paroreodon marshi,* gen. et sp. nov. Holotype. Right half, superior view. × 2/3.

Measurements of Holotype.

	mm.
Axial length, basion to prosthion	141.2
Superior molar series, length	38
Superior premolar series, length	33
Cranium, max. width	57.3
Diameter, postorbital constriction	43
Bulla, ant.-post. diameter	23.3
Transverse diameter	21
Vertical diameter	24

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ART. VIII.—*Two New Forms of Agriochœrus*; by MALCOLM RUTHERFORD THORPE.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

TABLE OF CONTENTS.

INTRODUCTION.

The genus *Agriochœrus* has approximately as many synonyms as have the Chalicotheres. In 1850, Leidy described the first form as *A. antiquus* from the badlands of Nebraska. Other genera proposed since that time and now regarded as synonymous are: *Eucrotaphus* Leidy 1852, *Coloreodon* Cope 1879, *Merycopater* Cope 1879, *Artionyx* Osborn and Wortman 1893, and *Agriomeryx* Marsh 1894.

Coloreodon and *Agriomeryx* were based on the presence of three instead of four superior premolars, while *Artionyx* was established on a pes and a portion of hind leg. *Artionyx* was the basis for a new suborder, Artionychia. Skeletal elements have been referred to no fewer than three mammalian orders, and the peculiarities of structure exhibited by this genus have given rise to much speculation in regard to its taxonomy and life habits.

The writer's reasons for placing *Eucrotaphus* in the genus now under consideration will be more fully set forth in a subsequent paper, based chiefly upon Leidy's descriptions and the work of contemporaneous and subsequent students.

The former method of classification of the species on a basis of the possession of either three or four superior premolars has proved unreliable. However, the later forms usually have but three superior premolars. The osteology of this genus and its affinities have been very ably described and discussed in the papers cited in the list of references. The illustrations for the present paper were made by Mr. Rudolf Weber.

WHITE RIVER SPECIES.

Agriochœrus antiquus antiquus Leidy 1850.

Middle Oligocene (lower Brule), bad lands, Nebraska.

Specific characters.—Skull approximately the size of *Oreodon culbertsonii;* orbits subrotund; infra-orbital foramen above interval between P^3 and P^4; anterior part of palate strongly uparched; external buttresses of molars hemispherical; no internal cingulum on M^3; postero-internal lobe of P^4 very small; P^3 right triangular; P^4 molariform but with anterior internal wall incomplete; muzzle long and narrow; bullæ moderately large; superior premolars always four; inferior incisors three, but very small.

Several specimens in the Marsh Collection have served for amplification of this type, especially Nos. 12657 and 12666, Y. P. M.

Measurements.

	mm.
Breadth of forehead at postorbital processes (holotype) . . .	59.2
Superior molar series, length (No. 12657, Y. P. M.)	47

Inferior dental series with P_1, length (No. 12666, Y. P. M.)	104
Inferior molar series, length (No. 12666, Y. P. M.)	53
Inferior premolar series, length (No. 12666, Y. P. M.)	27
Depth of ramus below middle of M_3 (No. 12666, Y. P. M.) ..	44.5
Depth of ramus below middle of P_3 (No. 12666, Y. P. M.) ..	32

Agriochœrus antiquus dakotensis, subsp. nov.

(Fig. 1.)

Holotype (skull), Cat. No. 10106, Y. P. M.; paratype (jaws), Cat. No. 12665, Y. P. M. Middle Oligocene (lower Brule), South Dakota.

Specific characters.—Skull approximately the size of *A. antiquus antiquus;* palate more steeply uparched, especially between the premolars; P^4 rotated forward and set obliquely in maxilla; P^3 almost an equilateral triangle in basal outline; infra-orbital foramen above interval between P^2 and P^3; four superior premolars. The bullæ extend forward to the glenoid surface and but slightly below it. They are in contact with the postglenoid tubercle and paramastoid process as well as the glenoid articular surface. Superior contour of skull nearly straight, the muzzle being of the same depth as the cranium; orbits small and round; an osseous ridge, depending from the squamosal and parietal bones, and extending from the glenoid articular surfaces to the pterygoid processes, encloses a basicranial depression. This peculiarity I have not seen in any other species. The sagittal crest is moderately long.

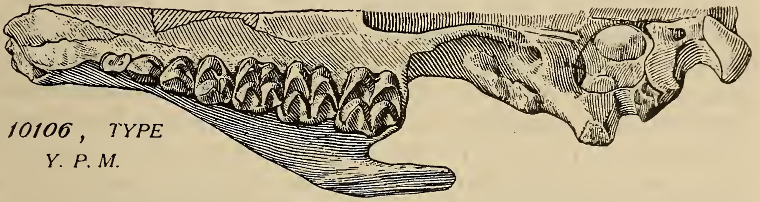

Fig. 1.—*Agriochœrus antiquus dakotensis,* subsp. nov. Holotype. Right half, palatal view. Basal outline of bulla drawn from opposite side. × 1/2.

Measurements of Holotype.

	mm.
Skull, length, occip. condyles to incisors, inc.	197*
Bizygomatic diameter	103*
Brain-case, max. width	61
Superior dental series, with C, length	106
Superior molar series, length	43
Inferior molar series, length (No. 12665, Y. P. M.)	47.2
Inferior premolar series, length (No. 12665, Y. P. M.)	38.7

* Approximate.

Agriochœrus migrans (Marsh) 1894.

Holotype, Cat. No. 10102, Y. P. M. Upper Oligocene (Protoceras beds), South Dakota.

Specific characters.—Skull somewhat longer than *A. latifrons;* deep frontal fossæ immediately anterior to the junction of the temporal ridges; the latter are very short and originate about midway between their junction and the postorbital processes; palate gently concave; three superior premolars; muzzle moderately short; infraorbital foramen over posterior part of P^3; marked concavity above and below canine convexity; anterior zygoma massive, with a prominent ridge, trending outward and downward above M^3; orbits look upward and outward; forehead flat; nasal bones flat and extend to a line above the anterior margin of the canines; prominent sagittal crest; palatonarial border pointed, the apex being opposite the middle of M^3; pterygoid processes robust; prominent convexity near nasion on a line between the anterior margins of the orbits.

The above description is much more detailed than the original one by Marsh in 1894, and is the only amplification of this well marked species since that date.

Measurements of Holotype.

	mm.
Skull, estimated length, occip. condyles to incisors, inc.	235
Bizygomatic diameter	128
Superior dental series, with C, length	110
Superior dental series, without C, length	70.8
Superior molar series, length	45
Diastema between C and P^2, length	31

JOHN DAY BASIN SPECIES.

Agriochœrus bullatus, sp. nov.

(FIGS. 2-4.)

Holotype, Cat. No. 12424, Y. P. M. Upper Oligocene (upper John Day), Turtle Cove, John Day River, Oregon.

The type material consists of the skull only, with the portion anterior to P^2 carried away. It is a submature individual, but with permanent dentition.

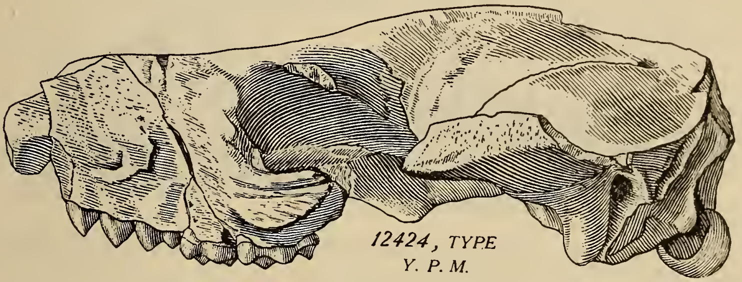

FIG. 2.—*Agriochœrus bullatus*, sp. nov. Holotype. Left lateral view. × 3/5.

Specific characters.—Skull mesocephalic; infra-orbital foramen above middle of P^3; nasal bones wide, flat, and obtuse posteriorly, as in *Oreodon gracilis;* orbits proportionally smaller than in any other species; sagittal crest low and relatively short; shallow concavity between temporal ridges anterior to their junction; temporal ridges short, beginning well posterior to orbits; palate steeply inclined to sagittal suture, with a cross-section like an inverted V; palatonarial border opposite posterior lobe of

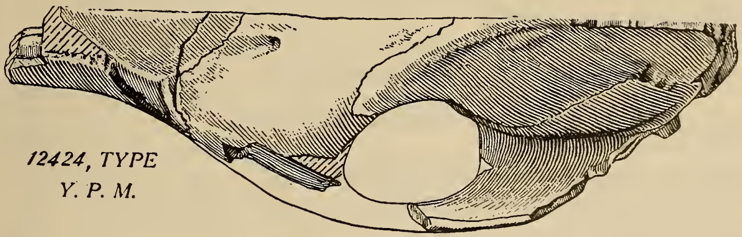

FIG. 3.—*Agriochœrus bullatus*, sp. nov. Holotype. Left half, superior view. × 3/5.

M² (in adult this would probably be farther back); basicranial axis shallow; paroccipitals plate-like and standing at an angle of about 45° to the sagittal plane; postglenoid robust; basisphenoid nearly flat between bullæ; infero-anterior termination of occipital condyles extends forward below basisphenoid in the shape of a shelf; bulla has a flat, nearly vertical surface facing inward and backward, joining the paroccipital process; antero-externally a ridge runs forward and inward beyond the middle of the glenoid articular surface; inferior surface of bulla keeled, the keel running transversely from the postglenoid tubercle, with which it is in contact, to the lower border of the internal plane face; long axis of bulla lies at about a 35-degree angle from the sagittal plane, the anterior portion approaching the pterygoid process, a form of bulla which does not occur in any other species of this genus.

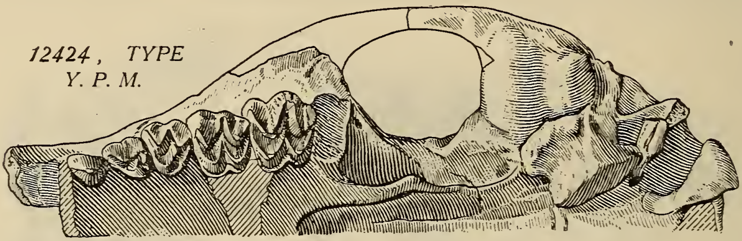

FIG. 4.—*Agriochœrus bullatus,* sp. nov. Holotype. Left half, palatal view. × 3/5.

Measurements.

	mm.
Skull, total length, occip. condyles to C, inc.	175*
Bizygomatic diameter	102
Diameter of postorbital constriction	39
Dentition, P² to M², inc., length	57
M² + M¹, length	29
Brain-case, max. diameter	58

* Approximate.

SYNOPSIS OF SPECIES.

1. Infraorbital foramen above interval between P² and P³. Size about that of *Oreodon culbertsonii;* bullæ small; palate very steeply uparched; palatonarial border oppo-

site anterior lobe of M^3; nasals pointed posteriorly; four superior premolars. Middle Oligocene (lower Brule) ....*A. antiquus dakotensis,* subsp. nov.

About same size as above; bullæ large; palate gently concave; palatonarial border opposite anterior part of M^3; nasals acute posteriorly; four superior premolars. Upper Oligocene (middle and upper John Day). *A. trifrons* Cope.

Skull size of second above; bullæ small; palate gently concave; palatonarial border opposite posterior lobe of M^2; nasals blunt posteriorly; three superior premolars. Upper Oligocene (middle and upper John Day). *A. ferox* (Cope).

2. Infraorbital foramen above anterior lobe of P^3.

Skull about size of *Eporeodon major;* bullæ large and medially constricted; palate strongly concave; palatonarial border acute and opposite middle of M^3; nasals broadly rounded posteriorly; four superior premolars. Upper Oligocene (middle John Day). *A. ryderanus* Cope.

3. Infraorbital foramen above middle of P^3.

Somewhat larger than *O. culbertsonii;* bullæ large; palate flat; internal wall of P^4 complete; either three or four superior premolars. Middle Oligocene (lower Brule) ....*A. latifrons* Leidy.

Skull about size of that of *Eporeodon major;* bullæ unknown; palate nearly flat; palatonarial border opposite posterior part of M^3,; nasals rounded posteriorly; three superior premolars. Upper Oligocene (middle and upper John Day).......*A. macrocephalus* (Cope).

Size about that of *O. culbertsonii;* bullæ moderately large and inferiorly keeled in transverse plane; palate steeply inclined; palatonarial border opposite anterior part of M^3; nasals obtuse posteriorly; three superior premolars. Upper Oligocene (upper John Day). *A. bullatus,* sp. nov.

4. Infraorbital foramen above posterior part of P^3.

Skull about size of second above; bullæ unknown; palate gently concave; palatonarial border opposite middle of M^3; nasals rounded posteriorly; three superior premolars. Upper Oligocene (Protoceras beds). *A. migrans* (Marsh).

5. Infraorbital foramen above interval between P^3 and P^4.

Size slightly greater than *O. culbertsonii;* bullæ moderately inflated; palate strongly uparched anteriorly; internal wall of P_4 incomplete; four superior premolars; palatonarial border opposite anterior lobe of M^3;

nasals pointed posteriorly. Middle Oligocene (lower Brule) .... *A. antiquus antiquus* Leidy.

Size about equal to that of *Eporeodon major;* bullæ small; palate nearly flat; palatonarial border opposite posterior edge of M^3; nasals pointed posteriorly; four superior premolars. Upper Oligocene (middle John Day). *A. guyotianus* Cope.

6. Infraorbital foramen unknown.

Size largest of this genus; four premolars; sagittal crest low and broad; brachyodont; P^1 two-rooted; antero-posterior diameter of molars greater than transverse. Lower Oligocene (Pipestone Creek). *A. maximus* Douglass.

Size smallest of the genus; P^3 right triangular; P^4 equilaterally triangular in cross-section; molars broader than long; M^2 and M^3 possess internal cingula. Lower Oligocene .... *A. minimus* Douglass.

Species large; bullæ large; nasals narrow and pointed posteriorly (Wortman); palatonarial border opposite anterior cusp of M^3; three superior premolars. Upper Oligocene (Protoceras beds) .... *A. auritus* Leidy.

Species about size of *A. latifrons;* (known from single molar tooth). Middle Miocene (lower Manchhars). *A.* sp. Lydekker.

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Art. IX.—*The Crystalline Characters of Calcium Carbide;* by C. H. Warren.

Something over ten years ago the crystalline characters of calcium carbide were the subject of a thorough study in connection with litigation relative to certain patent claims.

The first crystallographers to study the crystalline properties of carbide in detail were the late Professor A. J. Moses and the writer, and they began their observations probably at about the same time. In 1912 Professor Moses proposed, that, at a later date, he and the writer should cooperate in publishing the results of their study.

Unfortunately the carrying out of this joint work was delayed, and he who would have been senior author has, to the deep sorrow of all who knew him, ceased forever his scientific work.

The crystalline properties of this substance are in many ways so interesting, perhaps unique, that the writer feels it desirable to put them on record, realizing, however, that they will doubtless lack many observations of interest that Professor Moses would have contributed.

In the course of the litigation above referred to, Professors J. P. Iddings and L. V. Pirsson, E. H. Kraus and Doctors F. E. Wright and H. P. Whitlock also studied the carbide.

Megascopic characters.—Calcium carbide as made in the electric furnace is for the most part a granular or columnar crystalline aggregate of a prevailing black, reddish-black, or reddish-brown, less commonly, yellowish-red or brown color. Natural surfaces sometimes show a bluish or purplish iridescence. The crystalline structure is usually revealed on broken surfaces by the presence of a great number of brilliantly reflecting cleavage surfaces. The cleavages are nearly equal and parallel to three directions at right angles to one another. The granularity of carbide varies widely. In quickly chilled material from the margins of ingots the grain is very fine to invisible. Material taken from the inner parts of slowly cooled ingots, or from carbide cooled in the furnace, may be coarse grained, the individual dimensions of grains being several millimeters or even a centimeter or more.

Freshly broken cleavage surfaces when examined with a pocket lens show on their surface a series of minute lines or ridges, which run parallel or at 45° to the intersections of the rectangular cleavages. If a cleavage fragment be viewed in a good light, it may be seen, particularly near the edges where some light penetrates the fragment, that there are within the substance series of exceedingly thin lamellæ, distinguished by reason of slight differences of color or transparency, which are either parallel, or inclined at approximately 45° to the cleavage edges. The rectangular lines on the cleavage face mark the boundaries of individual lamellæ where these emerge on the cleavage surface. The individual grains of carbide appear, therefore, at the outset to be in no sense simple individuals but highly composite in character, being made up of a series of thin plates united in a definite but complex manner. The accompanying sketch will serve to illustrate the structures described (Fig. 1).

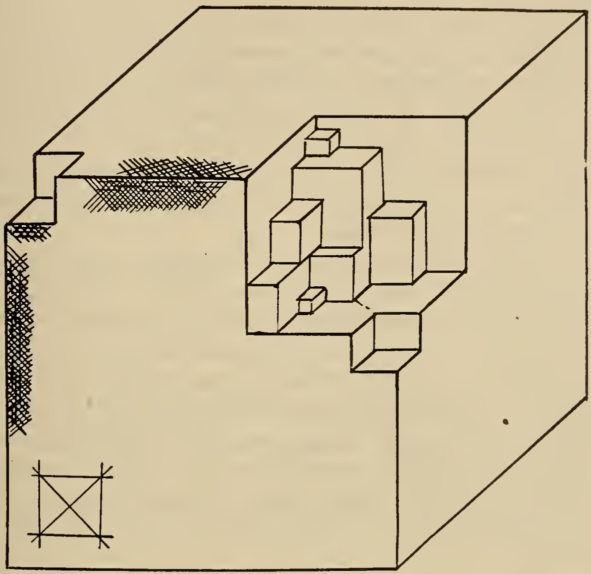

Fig. 1.—Sketch of a calcium carbide cleavage fragment. Cleavage is parallel to the three pinacoids and pseudo-cubic in character. The carbide is polysynthetically twinned; the twinning directions make with the pinacoidal edges angles of approximately 45°, the twinning is therefore pseudo-dodecahedral. The twinning lamellæ may often be seen in freshly broken fragments near the translucent edges. An attempt to illustrate this is made in the figure. The directions followed by the lamellæ on any one cleavage face are shown by the figure in the lower corner.

Columnar structures (groups of parallel elongate columns) are common, particularly in the coarser varieties. The direction of elongation of the columns makes an angle of 45° with the rectangular cleavages. The contact surfaces between individual columns is wavy and irregular.

Microscopic character of electric furnace carbide.—Small fragments of carbide were ground down on two parallel sides with fine carborundum or rouge and dry kerosene oil until sufficiently thin to transmit light. Owing to the tendency of the carbide to break and cleave when any considerable degree of thinness is reached, these sections, in general, were not as satisfactory for study as crushed material.

Most of the preparations for study were prepared either by crushing small fragments in a mortar under some liquid which decomposes carbide slowly or not at all (dry kerosene oil, *a*-monobrom-naphthalene or methylene-iodide), and then transferring some of the powder with the liquid to a glass slide and covering the whole with a cover-glass; or a small fragment was carefully crushed and the powder quickly passed through a fine screen (100-150-200 mesh) on to a glass slide on which was a drop of one of the liquids used, and the whole covered with a thin cover-glass.

Color.—The color in transmitted light is purplish-red or lilac-yellow, and less commonly a slightly greenish yellow. Exceedingly thin fragments appear nearly or quite colorless.

Pleochroism.—Slight differences of color (pleochroism) for light vibrating in different crystallographic directions may be seen, but only in relatively thick fragments.

Transparency.—The transparency is good in thin fragment (0.01 to 0.02). Thicker and larger fragments are subtransparent to translucent. Many fragments are only feebly translucent owing to deep color, inclusions and twinning.

Cleavage.—The cleavage is easy and perfect in three directions at right angles to each other, as nearly as can be determined under the microscope. The true rectangularity of this cleavage was established by Professor E. H. Kraus by measurements on the reflection goniometer.

Twinning.—The twinning is highly polysythetic. Individual cleavage plates, ground very thin, show, particularly between crossed nicols, that the grains are entirely made up of groups of lamellæ, which run either parallel or perpendicular to, or at an angle of approximately 45°, to the cleavages. The lamellæ often wedge out parallel to their elongation, or may end against members of another set. Different sets are commonly arranged so as to form rectangular patterns. A single plate examined after successive grindings showed different sets of lamellæ for different degrees of thickness. Changes of focus show the same. The greatest width observed by the author for any single lamellæ was 0.045 m. The larger groups of broader lamellæ appeared often to enclose rectangular areas of finer lamellæ.

There appears also to be a well-defined tendency in carbide to separate or *part* in a direction parallel to the twinning plane. It has also been observed that the twinning structures are as a rule more finely complex, carbide having a yellow color.

The whole structure is most complex. The observations made macroscopically and microscopically show that the twinning and composition plane have a direction approximately 45° to the cleavage direction, that is parallel to any one of the six diagonals of the cleavage angles. With three rectangular directions of apparently almost equal cleavage value and a twinning parallel to the diagonals, we have a crystalline structure that simulates geometrically that of crystals of the isometric system, viz., cubical cleavage and a dedocahedral twinning. Its optical properties show that it is not isometric, but it seems appropriate to describe it as geometrically pseudo-cubic.

Indices of refraction.—The indices of refraction as determined by comparison with that of methylene iodide (index 1.75) by the Becke & Schroeder v. der Kolk method are always higher than 1.75.

The *double-refraction* is strong and may be expressed numerically as at least 0.050.

In almost every fragment, with the possible exception of very small ones, evidently portions of single lamellæ, the distribution of the interference colors furnishes, as has been noted, proof of the polysynthetic character of the grains. Single grains of uniform thickness may show all variations of colors from a very dull gray to bright colors of 2d and 3d orders. Thicker portions of grains may show low colors while higher colors appear in thinner portions. These anomalies are observed in grains from a *single* rectangular cleavage piece and in ones which show no indication of distortion incident to crushing the sample; and such distortion is easily deteced by the bending and disturbance of the twinning line and lamellæ.

Extinction.—The extinction in calcium carbide is in general parallel to the rectangular cleavages. For the calcium carbide which has a yellowish color, and contains probably some substance in solid solution, the extinction, when definite, is in general inclined to rectangular cleavages. The angle of inclination observed ranges from a few degrees up to 22° or 24°. The common values observed are from 12° to 22°. Rarely a yellowish fragment has been observed with an approximately parallel extinction, but in the great majority of cases in inclined extinction is associated with a yellow color.

Nearly isotropic sections.—In preparations made from the carbide, cleavage fragments may be frequently found containing square or rectangular areas, characterized by a series of rectangular markings (parallel or perpendicular to the cleavages) on the surface, which remain for the most part almost completely dark (nearly isotropic) upon rotation of the grain between crossed nicols in parallel light. These dark areas are never quite homogeneous in appearance and are frequently crossed or penetrated by lamellæ which do not remain dark. This lack of crystalline uniformity is most clearly seen when the areas are tested with sensitive plate. Two or even three of these dark areas have been observed in a single fragment measuring approximately 0.1 mm. by 0.07 mm. In fact they vary considerably in size from very minute squares up to ones at least 0.05 mm. on a side. It has been frequently observed that these areas are surrounded by series of lamellæ parallel to the sides showing interference colors which rise regularly in order in a direction away from the area.

The facts above set forth indicate that these dark areas are of complex structure, like carbide in general, and that the apparently isotropic character is brought about by a crossing (through twinning) of a number of doubly refracting lamellæ of such thickness, and such a manner, that the individual plates have a compensating effect (optically) on each other, the integrated effect being almost zero.

Interference figures.—If the dark areas last described are examined in convergent polarized light, interference figures are obtained which resemble the so-called uniaxial figures in character, viz., a dark cross surrounded (in white light) by colored curves, in appearance, approximately circles, which as the preparation is rotated, either remains stationary, or rotates with the preparation about the axis of the instrument. The figure is positive in optical character. In a great number of the figures, rotation of the section causes a slight opening of the dark cross. A fading of the dark bars is characteristic, and in certain cases may cause them to wholly disappear. Furthermore, it was found necessary, in order to get a definite figure, to have the pin-hole diaphragm, through which the objective image of the figure is viewed, in a certain position in each case. A slight movement of the cap sideways or back and forth in general cause distortion of the figure or breaks it up altogether. Professor Moses obtained interference figures from certain specially prepared sections of very coarsely crystalline material, which in his opinion were truly uniaxial, and his opinion was shared by certain of the other observers.

In figures where a distinct opening of the cross is to be seen, it has been noted that one arm of the cross is heavier than the other and that the direction of the line joining the center of the hyperbolæ is parallel to the twinning striæ. This feature was especially emphasized by Professor Kraus.

From other fragments showing distinct double refraction and parallel extinction, interference figures have been obtained which appear to be normally biaxial in character, and the axial angle as judged by the distance between the dark hyperbolæ, is very variable for different fragments; in some instances it has been observed as high as 30°. The dispersion of the optic axes is red < violet. Here also the line joining the centers of the hyperbolæ is parallel to twinning striæ which are parallel or at right angles to the cleavages, viz. the axial plane is parallel to striæ.

From thicker grains of obviously very composite character, interference figures are obtained which in parallel position appear biaxial in character with one bar strikingly heavier than the other. On rotation of the fragment, the cross appears to rotate somewhat about its own axis, splits open into hyperbolæ, as with normal biaxial figures, but fades rapidly to white as the 45° position is approached. Various gradations between these last described figures and those which so far as can be told are normally biaxial have been observed.

On account of the fact that the yellow carbide very rarely yields fragments exhibiting a uniform optical structure throughout a sufficiently large portion of the grain to permit of satisfactory study with convergent light, it has not been found possible to establish the position of the principal optical elements. Portions of interference figures have, however, been obtained which showed in white light highly colored curves lying unsymmetrically in the field (the fragment lying on one cleavage face) and upon rotation a dark brush moving across the field, the direction of its movement being opposite to that of the rotation of the fragment. This indicates that, as would be expected from the oblique extinction of the grains, the position of the optical elements is unsymmetrical to the cleavages.

System of Crystallization.—The double-refraction, the rectangular cleavage and parallel extinction of calcium carbide lead to the conclusion that the system is either tetragonal or orthorhombic. There was a difference of opinion among the various observers as to which one of the two systems the carbide really belonged to. The curiously anomalous behavior of the interference figures is puzzling and difficult of explanation, but in general it might be produced by a complex twinning, be the system of crystallization either tetragonal or orthorhombic. The writer has always been, and still is of the opinion, that without definite proof, it is more in keeping with crystallographic philosophy to consider the carbide as of orthorhombic symmetry, with a polysynthetic twinning parallel to the diagonals approximately at 45° to the pinacoids: pseudo-duodecahedral). This twinning is mimetic, causing the carbide to appear pseudo-cubic geometrically and pseudo-tetragonal optically.

The yellow and less pure carbide, which, as has been indicated earlier, is probably a solid solution with other substances, is apparently triclinic. Geometrically (viz. in cleavage) it appears not to differ noticeably from the purplish or purer carbide.

Reaction with water.—The effect of slow decomposition of the carbide by water, as seen under the microscope, is curious and worthy of note. This effect is best observed if a few thin rectangular cleavage fragments are immersed in glycerine containing a very little water so as to cause the decomposition of the carbide into acetylene and calcium hydroxide to proceed very slowly and without effervescence enough to disturb the position of the grains. Viewed between crossed-nicols the margin of the grains may be seen to gradually lose the strong interference colors due to the birefringence of the carbide, and a rim of feebly birefringent material begins to develop. The corners naturally change more rapidly than the sides so that the unchanged carbide within assumes a circular or elliptical outline, which constantly diminishes in size until the entire grain has changed to the feebly doubly-refracting (about 0.008) material, which is calcium-hydroxide. During this change the structural appearance of the grain does not alter, cleavage cracks and twinning lines remaining. After a lapse of a little longer time the substance breaks up, separating along the directions of the cleavages, and finally dissolves in the liquid if there is sufficient water present. The change appears to involve the passage of one crystalline substance to another without the immediate breaking down of the essential crystal structure.

In the reaction given by the equation

$$CaC_2 + 2HOH = Ca(OH)_2 + C_2H_2$$

we might suppose that perhaps the OH group simply takes the place of carbon atoms, the crystal structure being preserved intact by the network of calcium atoms, or at least some such mechanism is conceivable. This phenomenon recalls to mind the preservation of crystalline structure in certain zeolites when slowly dehydrated. It also occurs to the writer, that the change of biotite to chlorite, so frequently seen in rocks, where the chlorite seems to simply replace the original biotite, the brown color and strong birefringence of the latter changing to the green color and low birefringence of the former, is also a substitution of certain atoms or atomic groups in the crystal structure, the main features of which remain intact throughout the change.

An X-ray study of calcium carbide and its decomposition product, could it be carried out, would be interesting in this connection.

It may be remarked that the phenomena above described constitute an excellent micro-test for calcium carbide.

Calcium cyanamide.—This substance is formed directly from calcium carbide when it is heated in contact with air (nitrogen) at 900°C. and is usually present in commercial carbide. Its crystalline and optical properties were first worked out, we believe, by Professor Moses and are briefly as follows:

System rhombohedral. Cleavage rhombohedral, perfect, angle 74°, calculated from an apparent angle as measured under the microscope of 68°. There is a poor cleavage or parting parallel to the base; rarely shows a twinning, probably parallel to the cleavage rhombohedron.

Colorless, index of refraction of ordinary ray 1.60; of extraordinary very high but undetermined.

Double-refraction exceedingly strong, at least twice that of calcite, or above 0.35. Optically positive.

The chief point of interest is the enormous double-refraction of this substance.

Other substances.—In commercial carbide beside cyanamide, unconverted carbon, crystallized oxide of alumina (corundum), and lime occur as accessories in variable amounts.

Massachusetts Institute of Technology,
Cambridge, Mass., April, 1921.

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[FIFTH SERIES.]

ART. X.—*Some Mechanical Curiosities connected with the Earth's Field of Force;*[1] by WALTER D. LAMBERT, U. S. Coast and Geodetic Survey.

By the earth's field of force is meant the field due to the attraction of the earth according to the law of inverse squares combined with the apparent forces due to the movement of our frame of reference resulting from the rotation of the earth. In general we shall consider the field of force for statical purposes only and then the apparent forces due to the motion of our frame of reference reduce to the ordinary centrifugal force; we thus avoid the complications arising from the presence of the compound centrifugal acceleration or accleration of Coriolis,[2] which enters into problems of motion relative to the earth.

It is convenient to distinguish between *gravity* and *gravitation.* By *gravitation* is meant the force of mass-attraction only according to the law of inverse squares; by *gravity* is meant the force of mass-attraction combined with the centrifugal force of rotation. This paper deals exclusively with gravity.

As a first approximation, corresponding to the assumption that within the region considered the surface of the earth may be treated as a plane, we may consider gravity as constant in amount and as acting in parallel lines. The equipotential or level surfaces will be parallel planes

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[1] Read at the meeting of the Maryland-Virginia-District of Columbia Section of the Mathematical Association of America held at Annapolis, Maryland, December 11, 1920.

[2] The compound centrifugal acceleration of a particle referred to a set of rotating axes is equal to twice the vector product of the angular velocity of rotation of the axes themselves by the linear velocity of the particle relative to the axes. The compound centrifugal acceleration governs the easterly deflection of a falling body, the rotation of the plane of oscillation of the Foucault pendulum, the direction of the trade winds, etc.

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9

spaced at equal distances apart for equal differences of the gravity potential. As a second approximation, we may consider the lines along which gravity acts as straight and as all meeting at a common center, that is, the center of the earth. On this assumption the earth is a sphere and the level surfaces of the gravity potential are spheres concentric with it. So many of our ideas about gravity are based, more or less unconsciously, on the conception of parallel planes or concentric spheres that the consequences of the fact that these conceptions are only approximations to the truth often seem like paradoxes.[3] Much of this paper will be devoted to these apparent paradoxes.

The next step in the series of approximations would be to take the level surfaces as spheroids of revolution having a common axis, the polar axis of the earth. Now *spheroid* is a rather indefinite term, more general than *ellipsoid*. All ellipsoids of revolution that have their axes nearly equal are spheroids of revolution, but not all such spheroids are ellipsoids. This fact is illustrated by the extreme case of the level surface marking the outermost limit of the atmosphere.[4] This case was treated by Laplace.[5] The equatorial radius of this surface is 6.6 times the radius of the earth, this distance being such that the centrifugal force of rotation just balances the earth's attraction at the equator of the surface; the polar radius is two-thirds of the equatorial radius. The most curious feature of the surface (see fig. 1) is at the equator where instead of continuous curvature, as on an ordinary spheroid, there is found what seems to be a sharp ridge but is really the intersection of two nappes of the surface at an angle of 120°; the portions

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[3] The familiar paradox that the Mississippi river runs uphill, because its mouth is farther from the center of the earth than its source, may be said to arise from overlooking the fact that the sea level surface and other level surfaces are spheroids and not spheres. The misconception is based on a too literal acceptance of the statement that bodies tend to fall towards the center of the earth. It would be just as logical to say that the ocean lies on a slope, or rather on two slopes, because at the equator it is 13 miles farther from the earth's center than it is at the poles, as it is to say that the Mississippi runs uphill.

[4] The limit meant is one derived from the classical mechanics of masses. No account is taken of the motion of the molecules of the atmosphere according to the kinetic theory of gases nor of other questions of molecular dynamics.

[5] Mécanique Céleste, Book III, Chap. VII, Sect. 47, or in Bowditch's translation, Vol. II, p. 519. See also Resal, Mécanique Céleste, 2d ed., p. 322, and Helmert, Höhere Geodäsie, Vol. II, p. 100.

FIG. 1.

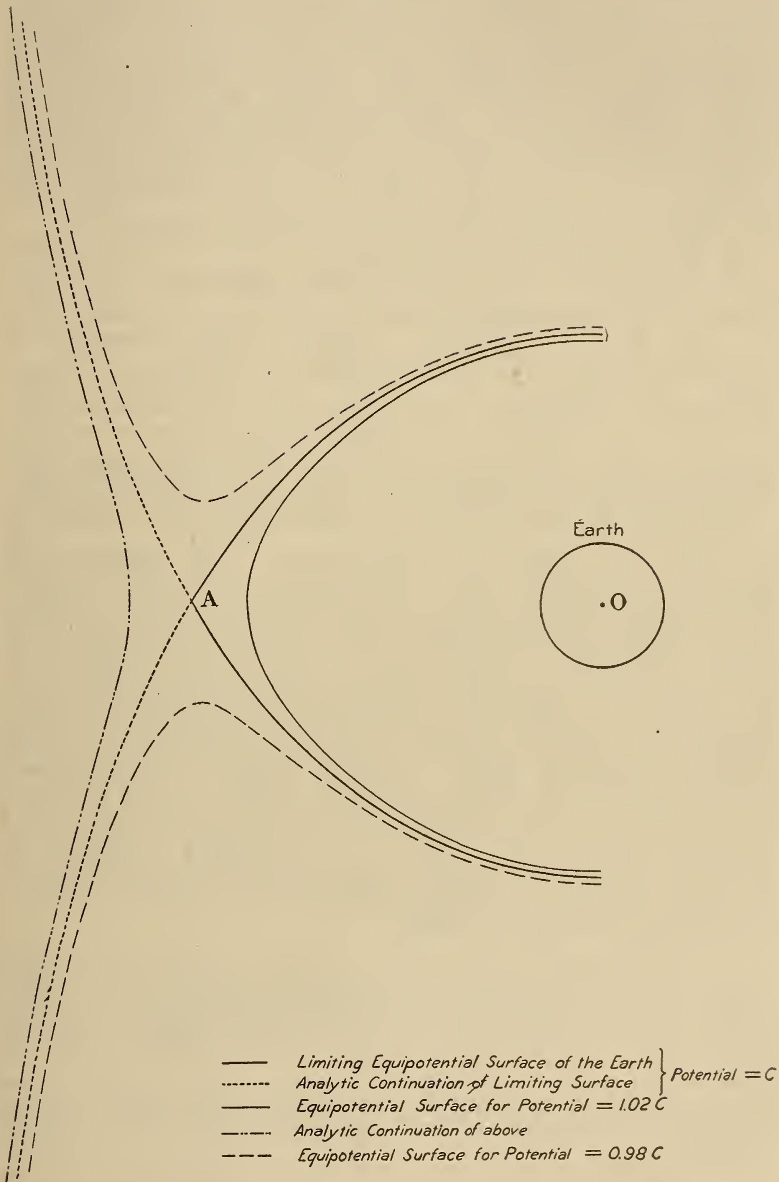

FIG. 1.—Limiting surface of the atmosphere and adjacent level surfaces; note the difference in the manner in which the level surfaces around the point A connect with one another in passing from one side of the limiting surface to the other.

beyond the nodal line are inapplicable to the problem for physical reasons.[6] The equipotential surfaces just within the limiting surface show a tendency to "sharp-edgedness," a tendency that rapidly decreases as we move inwards. The limiting surface is a spheroid by courtesy only, but the surfaces with radii up to 3 or 4 times that of the earth are very passable spheroids, although not exact ellipsoids; in middle latitudes they are depressed below ellipsoids having the same axes.

In the problem just discussed the effect of the earth's deviation from a spherical form was neglected. By introducing just the right distribution of mass we may make one of the equipotential surfaces lying outside of attracting matter an exact ellipsoid; the other surfaces will not be absolutely exact ellipsoids but transcendental surfaces very closely resembling ellipsoids, particularly those not far from the exact ellipsoid.[7] The important thing to notice, however, is not so much the question whether the level surfaces are exact ellipsoids, but rather the fact that these level surfaces are not similar; the flattening increases with the distance from the center. Any two given surfaces are farther apart at the equator than at the poles. (See fig. 2.) This corresponds to the fact that gravity is less at the equator than at the poles, the force at a point in a direction perpendicular to two consecutive surfaces being inversely proportional to the distance between them. For the earth a level surface that is 1000 meters above sea level at the equator is about 995 meters above sea level at the poles, a variation of 5 parts in a thousand or one in two hundred. Gravity at the pole is therefore greater than gravity at the equator by about 1/200 part of itself.[8]

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[6] A study of the mathematical equation giving the form of these equipotential surfaces will explain the existence of the nodal line. The mathematical equation defines surfaces not applicable to the problem in hand for physical reasons. These surfaces are shown by dotted or dashed lines in the figure.

[7] This refers to the surfaces outside of attracting matter. Within a homogeneous ellipsoid the equipotential surfaces, whether due to mass-attraction alone or to mass-attraction combined with the centrifugal force, are exact ellipsoids.

On the subject of ellipsoidal and approximately ellipsoid level surfaces see the author's *Report on Stokes' Theorem and related methods of determining the Figure of the Earth,* probably soon to be issued as a U. S. Coast and Geodetic Survey special publication; also Helmert, Höhere Geodäsie, Vol. II, p. 92.

[8] More exactly $1/189 = 0.00529$.

For an example on a smaller scale let us take Lake Michigan, which extends from latitude 41°20′ to 46°00′, and let us suppose the level of its surface to be undisturbed by conditions of wind, current or temperature. We should then be apt to say that such a surface would surely be level, and so it would be in the proper sense of the word.

FIG. 2.

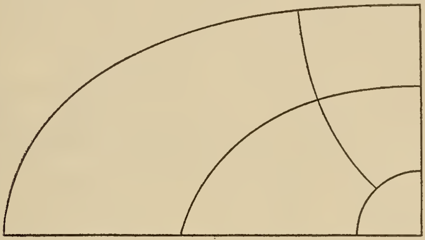

FIG. 2.—Showing the increase in the ellipticity of a level surface with its dimensions and the convexity of the vertical towards the equator.

Nevertheless the northern end is 8 centimeters nearer sea level than the southern end.[9] The elevation of a point above sea level has only a geometrical significance, not a dynamical one, until we know where it is located. That is, suppose two points nearly at the same elevation; we cannot tell whether water would flow from the one that is at the greater distance above sea level to the one that is at the smaller distance above sea level or *vice versa* until we know in what latitudes the points are. For the point that seemed higher may lie on a level surface situated *inside* the surface containing the point that seemed lower. It is convenient in dynamical problems to devise some system of numbering the successive level surfaces and, instead of dealing with the distance of a point above sea level, to deal with the number of the level surface on which it lies. Meteorologists now do something of the sort,[10] but the ordinary surveyor finds the idea of numbered level surfaces, or dynamic heights as they have been called, rather abstract, and in many cases an unnecessary refinement. For his benefit the Coast and Geodetic Survey gives the result of its precise leveling in terms of

[9] This figure is based on an average elevation of the lake surface of 177 meters. If this were greater, the difference between the two ends would be greater also.

[10] For example Bjerknes' Dynamic Meteorology and Hydrography (Washington, Carnegie Institution, 1910) p. 13.

elevations at the particular latitudes where the bench marks are situated. This has the disadvantage, illustrated above, of giving different elevations to two ends of a level lake. To allow for this lowering of the level surfaces as the pole is approached and to obtain the actual distances above sea level a correction must be introduced into the direct result of spirit leveling. This is called the *orthometric correction*.[11] On one line of levels from San Diego to Seattle, which runs much of the way over high ground, the correction amounts to 1¼ meters, a quantity far from negligible.

The direction of gravity which defines the vertical is always perpendicular to a level surface; that is, a line whose tangent at any point takes the direction of gravity at that point is an orthogonal trajectory of the family of level surfaces. Such an orthogonal trajectory is clearly not a straight line but, in the normal case here considered, is convex toward the equator. (See fig. 2.) The astronomic latitude of a place is defined as the angle which the vertical at that place makes with the plane of the equator. Evidently then the latitude at the top of high tower is greater than the latitude of its base. The reduction of astronomic latitude to sea level is part of the ordinary routine of geodetic computations.[12]

Let us now consider what appears to be a highly artificial problem. Suppose the earth smoothed off so that its physical surface shall coincide exactly with a level surface. A particle placed on such a surface is in relative equilibrium even without the presence of friction. But suppose a huge sphere to stand on this level surface. (See fig. 3.) The vector representing the reaction of the surface is perpendicular to it at the point of contact, coinciding in direction with gravity at the point of contact. But gravity acts on the sphere as if the latter were concentrated at its center, and thus the line of action of gravity is not quite coincident with the direction in which the earth's surface reacts. Gravity and the reaction are the

[11] See for example Bowie and Avers, Fourth General Adjustment of the Precise Level Net of the United States and the resulting Standard Elevations; U. S. Coast and Geodetic Survey, Special Publication No. 18, p. 49, or Hosmer, Geodesy (New York, 1919), p. 254.

[12] Bowie, Determination of Time, Longitude, Latitude and Azimuth (5th Ed.), U. S. Coast and Geodetic Survey, Special Publication No. 14, p. 130. Clarke, Geodesy (Oxford, 1880), p. 101. Helmert, Höhere Geodäsie, Vol. II, p. 98.

only forces and therefore there is no equilibrium but a tendency to move towards the equator. To avoid some of the difficulties suggested at the beginning of this paper that arise in problems of motion relative to axes that are themselves moving, we suppose a constraint applied in the form of a track along the meridian to which the sphere is thus confined. The resultant force along the meridian is indeed small—of the order of magnitude of one one-millionth of the force of gravity—but a few figures on the effects produced may seem somewhat surprising until we remember that even a small force can accomplish much by long-continued action.[13] Suppose the radius of the sphere to be one kilometer and that the latitudes from which it starts are successively 30°, 45° and 60°. The little table shows the journey to the equator divided into thirds and gives the time (in days and hours) taken to cover one, two and three-thirds of the journey and the velocity attained in meters per second.

FIG. 3.

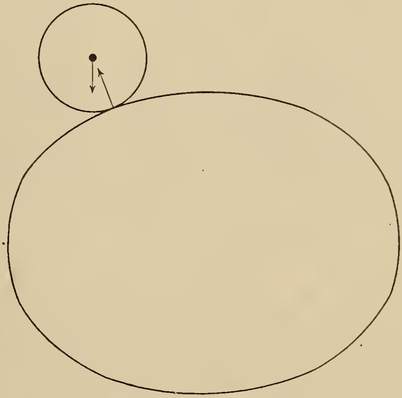

FIG. 3.—Showing the difference in direction between the force of gravity acting on a sphere and the reaction of the level surface on which the sphere rests.

Initial latitude 30°

Reaches lat.	after	Velocity m. per sec.
20°	9^d 11^h	3.1
10	11 9	4.0
0	14 11	4.3

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[13] See Appendix A to this paper for the mathematical developments.

Initial latitude 45°

Reaches lat.	after	Velocity m. per sec.
30°	8^{d} 19^{h}	4.3
15	12 15	5.7
0	15 21	6.1

Initial latitude 60°

Reaches lat.	after	Velocity m. per sec.
40°	10^{d} 15^{h}	5.0
20	14 23	6.8
0	18 11	7.5

The table is calculated on the supposition that the sphere rolls without slipping; then about 2/7 of the work done goes into the kinetic energy of rotation, thereby diminishing the amount of energy available to produce velocity of translation. If we imagine a constraint such that the sphere is obliged to slide without friction, it would travel somewhat faster.

The matter may be looked at from a slightly different point of view. The sphere really falls in going towards the equator and what body will not fall when it has the chance? What do we mean by *falling*? Suppose the successive level surfaces are numbered in any manner so that any surface bears a higher number than the one immediately inside of it. A particle falls when it passes from any surface to another surface bearing a smaller number. The original level surface that passed through the center of the sphere at latitude 60° passes above the center of the sphere when the latter has come to the equator, so the sphere has fallen through a distance equal to the distance from its center to that level surface which in latitude 60° passed through its center, or as a simple calculation shows, through 4.0 meters. Perhaps with this way of looking at the problem the velocities at the equator will not seem so surprising.

If you will pardon a bit of personal reminiscence, I will tell you what suggested the apparently fantastic problem of the huge rolling sphere. A well-known geologist told me that he had been convinced by geologic evidence that a part or a whole of each continental block has shifted its position in past time by moving towards the equator and in so doing has probably twisted in direction with reference to the meridian. He had been led to think along these lines by two articles[14] published quite independently of each other, in which the authors evolved the hypothesis of continental creep in explanation of mountain building. If we accept this idea, the inevitable question is: what forces caused this motion of the continental masses?[15]

Now the continents are certainly not huge spheres rolling on the earth's surface. If we adopt the floating-crust theory, they would be comparable to bodies floating almost submerged in a liquid magma. If the floating bodies were of almost the same density as the magma, they would float almost exactly level with its surface and could be considered as solidified portions of it, so that, according to a well-known principle of hydrostatics, they would be in equilibrium if the liquid containing them were. But if the floating bodies were lighter and projected above the level surface of the sustaining liquid, there would be forces acting of just the same nature as those that draw the sphere toward the equator.[16] The problem of the sphere was given in some detail merely because it was easier to reduce it to a concrete numerical example. The forces acting are in a general way proportional to the average elevation of the continental mass above sea level and to the sine of twice the mean latitude of the continent, and so would be greatest for a mean latitude of 45°. It is not difficult, moreover, to make out, if we are dealing with a floating continental mass longer than it is wide and lying with its greatest length neither along the meridian nor perpendicular to it, that there will be twisting forces called into play that would tend to set the axis of greatest length at right angles to the meridian when the mean latitude of the continent is less than 45° or that would tend to set the axis of greatest length along the meridian when the mean latitude is greater than 45°.

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[14] Taylor, Bulletin of the Geological Society of America, vol. 20, p. 625, 1910. Wegener, Petermann's Geographische Mitteilungen, 1912, pp. 185, 253, 305. Much the same matter was later issued in book form under the title: Die Entstehung der Kontinente und Ozeane (Brunswick, 1915).

[15] An attempt to see whether the supposed shifting of continents continues and is large enough to be perceptible in the course of a few decades was interrupted by the outbreak of the war. The plan was to redetermine transatlantic differences of longitude and to compare the results with earlier ones.

[16] For the mathematical developments see appendix B to this paper.

We may, if we like, consider that the floating continent has fallen in moving toward the equator. In calculating the difference of potential between one position and another, we must take account of the mass of the liquid displaced.

All this is quite speculative of course; it is based on the hypothesis of floating continental masses and on the assumption of a sustaining magma that would, of course, be a viscous liquid, but viscous in the sense of the classical theory of viscosity. According to the classical theory a liquid, no matter how viscous, will give way before a force, no matter how small, provided sufficient time be allowed for the latter to act in. The peculiarities of the field of force of gravity will give us minute forces, as we have seen, and the geologists will doubtless allow us aeons of time for the action of the forces, but the viscosity of the liquid may be of a different nature from that postulated by the classical theory, so that the force acting might have to exceed a certain limiting amount before the liquid would give way before it, no matter how long the small force in question might act. The question of viscosity is a troublesome one, for the classical theory does not adequately explain observed facts[17] and our present knowledge does not allow us to be very dogmatic. The equatorward force is present, but whether it has had in geologic history an appreciable influence on the position and configuration of our continents is a question for geologists to determine. At any rate it may be considered as one of the mechanical curiosities with which this paper deals.

We do not, however, need to deal with hypothetical rolling spheres or floating continents in order to find room for the manifestation of peculiarities of the earth's field of force. We can set up in the laboratory or in the field a comparatively small instrument that will give not merely qualitative evidence of these peculiarities but accurate measurements of them.

Let us consider a rod suspended at its middle by a delicate fiber. The rod is loaded at both ends so that as

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[17] Jeffreys, The Viscosity of the Earth, Monthly Notices of the Royal Astronomical Society, vol. 75 (1915), p. 648, and vol. 76 (1915), p. 84. Michelson, The Laws of Elastico-Viscous Flow, Journal of Geology, vol. 25, p. 405, 1917, and vol. 28, p. 18, 1920.

much as possible of its weight may be concentrated there; for simplicity of explanation we shall suppose an ideal case in which the entire weight is divided equally between the two ends and concentrated there. This simple affair, rod and fiber, is the schematic form of the Eötvös torsion balance of the first type (see fig. 4).[18] Now suppose the earth's field of force to be normal and the suspended rod to hang in a vertical plane coinciding neither with the meridian nor with the prime vertical. Let us disregard

FIG. 4.

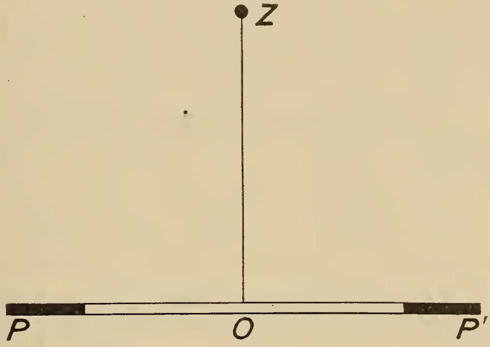

FIG. 4.—Schematic form of the Eötvös balance, first type.

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[18] For the description and use of the Eötvös balance and the numerical results obtained with it the following articles may be consulted. Each article in the list is given a letter by which—to save space—it is hereinafter referred to as needed.

A. Eötvös, Untersuchungen über Gravitation und Erdmagnetismus; Wiedemann's Annalen der Physik und Chemie, Vol. 295, new Ser. 59 (1896), p. 354.

Also the following articles by Eötvös in the Proceedings of the Conferences of the International Geodetic Association:

B. Budapest meeting (1906), Vol. I, p. 337.
C. Cambridge meeting (1909), Vol. I, p. 319.
D. Hamburg meeting (1912), Vol. I, p. 427.
E. Brillouin, Sur l'ellipticité du géoide dans le tunnel de Simplon; mémoires présentés par divers savants à l'Académie des Sciences de l'Institut National, Vol. 33, No. 3.
F. Soler, Primi Esperimenti con la bilancia di Eötvös; Memorie del Reale Istituto Veneto di Scienze, Lettere ed Arti, Vol. 28, No. 8 (Venice, 1913).
G. Soler, Prima Campagna con la bilancia di Eötvös nei dintorni di Padova; Reale Commissione Geodetica Italiana (Venice, 1914).
H. Soler, Seconda Campagna con la bilancia di Eötvös, Reale Commissione Geodetica Italiana (Padua, 1916).
I. For a good brief account see Bouasse; Géographie Mathématique, Paris, 1919, p. 351.

for the moment the torsion of the suspending fiber. Under the influence of the earth's field of force the rod tends to turn into the plane of the prime vertical, because in so doing it falls. How may it be said to fall when the height at which the center is suspended remains unchanged? Let us consider the curvature of the sections of the level surfaces in the meridian and in the prime vertical. It is easy to calculate that (in the normal case) the curvature of the meridian section is a maximum and the curvature of the prime vertical section a minimum. The two sets of traces of the level surfaces on the planes of meridian and prime vertical are shown in fig. 5, the prime-vertical traces being represented by full lines. The level surfaces are arbitrarily numbered with the numbers increasing outward, which corresponds to values of the potential increasing with height. The line PP′ represents the suspended rod of the Eötvös balance. We see that its ends (where the weight is concentrated) are in the surface numbered "3" when the rod is in the meridian but are in the lower-lying surface marked "1" when the rod is in the prime vertical. Thus there must be a force tending to swing the rod from high to low, or towards the prime vertical.

The same thing may be seen from a direct consideration of the forces acting. The moment of these forces comes out

$$m\, l^2 \sin 2\theta\, f \left(\frac{1}{R} - \frac{1}{N}\right)$$

In this expression $2m$ is the mass of the rod, $2l$ its length, θ the angle between the plane of the rod and the meridian, f the intensity of gravity, which acts vertically at the center of the rod, and R and N are the radii of curvature of the meridian and prime vertical sections respectively. If we substitute for R and N their values in latitude ϕ, there results for the turning moment very nearly[19]

$$\frac{2\, m\, l^2}{a}\, \epsilon\, f \cos^2\phi \sin 2\theta.$$

In this expression ϵ is the ellipticity of the earth and a its equatorial radius. For Eötvös's apparatus we may

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[19] The turning moment is zero for either $\theta = 0°$ or $\theta = 90°$. The former value, corresponding to the rod in the meridian, gives unstable equilibrium. In the prime vertical equilibrium is stable.

take $m = 40$ grams and $l = 20$ centimeters. With known values of ϵ and a the maximum turning moment (for $\theta = 45°$ and $\phi = 0$) is 1.67×10^{-4} dyne-centimeters. In latitude 45° the maximum turning moment is half of this.

FIG. 5.

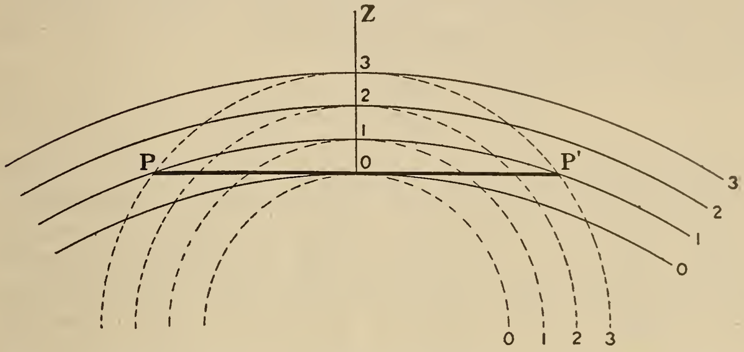

FIG. 5.—Sections of level surfaces in the meridian (dotted lines) and in the prime vertical (full lines); shows that the ends of the balance PP′ are lowest in the prime vertical.

This moment is certainly not large[20] but, given free play, it would swing the rod into the prime vertical. It is opposed by the torsion of the fiber, but fibers may be found strong enough to support the rod and yet so yielding that the minute forces of the earth's field will cause a measurable deflection of the rod.[21] The apparatus, torsion-head and all, is turned as a whole into various azimuths and the deflection of the rod in these positions with reference to the position of no torsion is read off on a telescope and scale. From these readings there can be deduced by a process too long to give here the values of $\frac{1}{R} - \frac{1}{N}$, where R and N represent now the minimum and maximum radii of curvature, which do not always—I might rather say "do not ever"—coincide with the radii

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[20] Its size may be perhaps made more vivid by the following comparison. A five-cent piece weighs about five grams. Take about a fifth of its weight and you have a gram. Take the weight of about a thousandth of a gram and you have a dyne. Our moment was about one ten thousandth of a dyne-centimeter. The distance factor was forty, so the force factor was only one four-hundred-thousandth of a dyne, one four-hundred-millionth of a gram, one two-billionth part of the weight of a five-cent piece.

[21] See references on a preceding page.
Art. A, p. 368; B, p. 340; E, p. 21.

in the meridian and the prime vertical, as we have been supposing. The directions of maximum and minimum curvature are also found by the balance. These curvatures may be interpreted in terms of the second derivatives of V, the potential function of the gravity field.[22] If we take rectangular axes, the z-axis being vertical at the center of the balance, an instrument of the first type will give the numerical value of

$$\frac{\partial^2 V}{\partial x^2} - \frac{\partial^2 V}{\partial y^2} \text{ and of } \frac{\partial^2 V}{\partial x\,\partial y}.$$

The Eötvös balance of the second type has its masses at the two ends of the rod at different levels, the counterpoise of the one loaded end of the bar being a suspended weight (see fig. 6). Without going into details it may be said that this balance brings into play forces derived from the change in the direction of gravity with elevation,

FIG. 6.

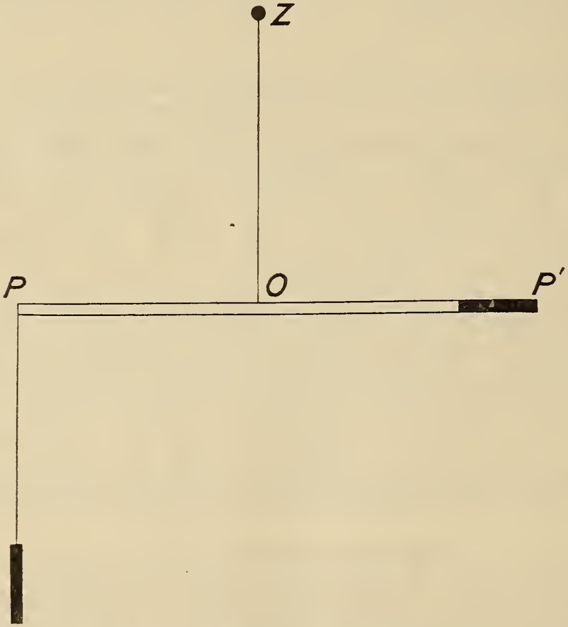

FIG. 6.—Schematic form of the Eötvös balance, second type.

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[22] See references in footnote on a preceding page.
Art. A, p. 355.
Art. I, p. 317 or Helmert, Höhere Geodäsie, Vol. II, pp. 35-40.

the same forces that make one end of Lake Michigan apparently higher than the other and that tend to draw the rolling sphere or the floating body towards the equator. With forces of this type are connected the derivatives

$$\frac{\partial^2 V}{\partial x\,\partial z} \text{ and } \frac{\partial^2 V}{\partial y\,\partial z}$$

and a balance of the second type enables us to find the numerical value of these derivatives.

What may be surprising at first is that the observed values of the second derivatives seem to bear absolutely no relation to the theoretical values. Here is a comparison expressed in two tables. The x-axis is in the meridian with its positive end towards the north; the y-axis has its positive end toward the east. One table gives the theoretical values for our assumed normal case with maximum curvature in the meridian, minimum in the prime vertical, and with a line of force lying in the meridian plane and convex toward the equator. The other table gives the values at several stations near Padua, Italy, as observed by Professor Soler in his "Seconda Campagna" (footnote, p. 139, reference H). The stations are fairly close together, so we might expect the values of the derivatives to agree pretty well with one another and with the theoretical values for latitude 45° (the latitude of Padua is 45° 24′). The unit of the table is one 10^{-9} C. G. S. unit, that is, the tabular values are the real values multiplied by an American billion (10^9).

Normal Values of the Second Derivatives of the Gravity Potential, V.

[Unit = one 10^{-9} C. G. S. Unit.]

Lat.	$\frac{\partial^2 V}{\partial y^2} - \frac{\partial^2 V}{\partial x^2}$	$\frac{\partial^2 V}{\partial x\,\partial y}$	$\frac{\partial^2 V}{\partial x\,\partial z}$	$\frac{\partial^2 V}{\partial y\,\partial z}$
0°	+ 10.1	0	0	0
15°	+ 0.7	0	+ 4.1	0
30°	+ 7.6	0	+ 7.0	0
45°	+ 5.0	0	+ 8.1	0
60°	+ 2.5	0	+ 7.0	0
75°	+ 9.4	0	+ 4.1	0
90°	+ 0.0	0	0	0

Values of the Second Derivatives of the Gravity Potential Observed near Padua, Italy.
[Unit = one 10^{-9} C. G. S. Unit.]

No. of Station	$\frac{\partial^2 V}{\partial y^2} - \frac{\partial^2 V}{\partial x^2}$	$\frac{\partial^2 V}{\partial x\, \partial y}$	$\frac{\partial^2 V}{\partial x\, \partial z}$	$\frac{\partial^2 V}{\partial y\, \partial z}$
I	+14.62	−11.69	− 4.91	−41.19
II	+ 8.39	+ 6.78	− 5.98	−35.26
III	+17.31	− 1.49	−14.53	−21.90
X	+41.58	− 0.26	−14.09	+ 4.59
XI	−15.28	+ 4.74	+ 0.18	− 3.07
XII	+37.93	− 1.32	+ 1.16	−13.47
XIII	+10.92	− 2.14	− 0.36	− 3.12
XIV	+ 5.74	− 6.15	+16.65	− 2.94

These values are not rare exceptions due to very abnormal local conditions. It would be easy to find still more erratic-looking observations.[23] The specimen given may be taken as fairly typical. Nor are these values the results of observational blunders. Repeated observation in the same spot reproduces consistently the same value and the results check with pendulum observations and with the observed deflections of the plumb line deduced from a combination of astronomic and geodetic operations. The details of the connection between these three kinds of results would take too long to explain here.[24] These peculiar-looking results are simply a numerical illustration of what the text-books tell us—that while the potential function and its first derivatives change continuously in the passage through discontinuities in density, the second derivatives are discontinuous whenever the density changes discontinuously. A surface of discontinuity in density, namely, the uneven surface of the ground, is necessarily near the instrument at all times. The observations are not taken at this surface itself, hence the derivatives obtained are not strictly discontinuous in value, but merely vary with great rapidity in a way intimately related to the irregularities in the density and shape of the matter near the surface.

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[23] See for instance footnote on p. 139, Art. D., p. 435, in which an observation is given in the canyon-like valley of Cimabanche in the mountains near the former Austro-Italian frontier, approximate latitude 46° 35′, approximate longitude 12° 10′ E. of Greenwich.

[24] Footnote as above under C. pp. 325-332, or under G. p. 59, or under H. p. 53.

This very sensitiveness of the instrument makes it available for the study of discontinuities in density concealed just below the surface; these discontinuities may often indicate the existence of conditions of geological or of commercial interest. It has been proposed to use the Eötvös balance in certain geologic investigations and I am informed that a business concern is considering a campaign with the Eötvös balance in order to locate salt deposits in Poland; another campaign with the balance is, or was recently, under way to locate lignite deposits in Austria.[25] The balance is not, of course, a divining rod; its usefulness for geological or commercial purposes depends on our ability to interpret irregularities in the second derivatives in terms of irregularities in the distribution of mass.

The second derivatives, erratic though they may be at individual stations, will be found to have about the theoretical average value when the results for considerable areas are combined. If this were not so, we should find that the discrepancies between the theoretical values of gravity and the observed values would be very considerable, while, as a matter of fact, they are nearly always small. The same might be said of the differences between the astronomical values of the latitude, longitude and azimuth and the values obtained by geodetic methods. Irregularities in the second derivatives imply irregularities in the curvature. The form of a level surface near the surface of the earth has been appropriately compared to that of a withered apple, which, considered as a whole, has a regular curvature, but which, taken in detail, is characterized by minute elevations and depressions. The argument for the existence of forces tending to cause motion toward the equator, although based on the theoretical form of the level surfaces, still holds good when we consider average conditions, though at any particular point the assumption previously made may be greatly at fault.

This brings us to the end of our list of mechanical curiosities connected with the earth's field of force. These may be summarized as follows:

(1) The limiting level surface with the sharp edge.

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[25] Akademie der Wissenschaften in Wien, math-naturw. Klasse, session of Jan: 8, 1920; reported in the Akademischer Anzeiger no. 1.

(2) The smooth lake with different elevations for its two ends.
(3) The tendency of large bodies to "fall" towards the equator.
(4) The tendency of a rod suspended horizontally like the Eötvös balance to "fall" by twisting about the supporting fiber.
(5) The existence of great local irregularities in the curvature of the level surfaces and the interesting possibilities that the study of these irregularities seems likely to offer.

APPENDIX A.

Motion of a Sphere under Gravity on an Equipotential Surface.

The general problem of a sphere rolling without slipping on a rotating surface of revolution, that surface being one of equilibrium for the attraction of the matter contained within it combined with the centrifugal force of rotation, would be somewhat complicated. In treating the general problem it would be a legitimate procedure, though not necessarily the easiest one, to treat the surface as without rotation provided the following additional forces were taken account of: (1) the centrifugal force of rotation; (2) the compound centrifugal acceleration. To obtain the resultant of these additional forces an integration would usually be required. In the restricted problem proposed, where motion is confined to the meridian, the procedure suggested is evidently the simpler (1) because the effect of the ordinary centrifugal force is implicitly contained in the gravity potential used; (2) because the compound centrifugal forces do not affect the motion when the latter is confined to the meridian.[26]

Let b denote the radius of the rolling sphere. Consider the locus of the points at a distance b from the level surface on which the sphere rolls, the distance being measured outward along the normals to the level surface. For definiteness, let us call this new surface to which the center of the rolling sphere is evidently confined, the parallel surface and let ds be an element of meridional arc of this parallel surface, s being reckoned from the equator toward the pole.

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[26] For the equations for motion relative to the earth, see Routh's Advanced Rigid Dynamics (5th Ed.), p. 27, or similar works.

Let Z be the component force acting on the sphere through its center normal to the parallel surface. From the manner in which the latter is constructed it is easily seen that the line of action of Z is also normal to the level surface, and let X be the component of force acting perpendicular to Z in the plane of the meridian, and positive when toward the equator. The attraction of the earth and the centrifugal force of rotation, both of which act on the sphere as if its mass were concentrated at the center, are included in X and Z. Let f denote the force of friction at the point of contact; f evidently is directed along a tangent to the level surface and parallel to X; it is the only force having a moment about the center of the sphere. Let R denote the reaction of the level surface at the point of contact.

Resolving the forces along tangent and normal, we find[27]

$$-m\frac{d^2s}{dt^2}=X+f \tag{1}$$

$$Z+R=0$$

and taking moments about an axis through the center and perpendicular to the meridian

$$-m\,k^2\,b^2\frac{d^2s}{dt^2}=f\,a \tag{2}$$

where m is the mass of the sphere and k its radius of gyration $=\sqrt{\tfrac{2}{5}}\,b$. Eliminating between (1) and (2) gives

$$-m\frac{d^2s}{dt^2}=\frac{b^2}{b^2+k^2}X. \tag{3}$$

Let g_ϵ be the intensity of gravity at sea level at the equator; then g, the intensity in latitude ϕ, may be written

$$g=g_\epsilon\,(1+\beta\,sin^2\,\phi), \tag{4}$$

β being a constant, and it may easily be shown[28] that α, the change in the direction of gravity for elevation b above the level surface, is given by

$$\alpha=\frac{b}{r}\beta\,sin\,\phi, \tag{5}$$

r being the radius vector of the earth. The direction

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[27] The general treatment of a sphere rolling on any surface is given in Routh, Advanced Rigid Dynamics (5th Ed.), p. 143.

[28] Clarke, Geodesy, p. 101. Helmert, Höhere Geodäsie, Vol. II, p. 98.

of gravity coincides with the normal at the level surface; at the parallel surface the components of force along the tangent and normal are

$$X = mg' \sin \alpha,$$
$$Z = mg' \cos \alpha,$$

or since α is small,

$$X = mg' \alpha$$
$$Z = mg' \tag{6}$$

in which g' is the intensity of gravity in latitude ϕ and elevation b. The latitude ϕ in formula (4) is usually taken as the geographic latitude, but to the same order of accuracy as is implied in equation (4) we may use any other latitude, as the geocentric or the reduced latitude, or we may put $\phi = \frac{s}{a}$, a being the mean radius of the meridian; to the same order of accuracy a may be put for r in (5), and g' may be taken as constant.

With these substitutions (4) becomes

$$\frac{d^2\phi}{dt^2} = \frac{-b^2\beta}{b^2+k^2}\,\frac{b}{a^2}\,g' \sin 2\phi,$$
$$= \frac{-c^2}{2} \sin 2\phi, \tag{7}$$

$\frac{c^2}{2}$ being written for $\frac{b^2\beta}{b^2+k^2}\,\frac{b}{a^2}\,g'$.

Multiplying both sides of (7) by $\frac{d\phi}{dt}$ and integrating and determining the constant so that $\frac{d\phi}{dt} = 0$ when $\phi = \gamma$, where γ is the initial latitude, gives

$$\left(\frac{d\phi}{dt}\right)^2 = \frac{c^2}{2}(\cos 2\phi - \cos 2\gamma)$$
$$= c^2(\sin^2\gamma - \sin^2\phi) \tag{8}$$

Equation (8) is similar to the equation for the motion of a pendulum where the vibration is not restricted to infinitesimal arcs. To integrate (8) put

$$\sin\phi = \sin\gamma \sin\theta,$$

whence (8) becomes

$$\frac{d\phi}{\sqrt{1-\sin^2\gamma\sin^2\theta}} = c\,dt.$$

This may be integrated in terms of the elliptic integrals, and if t be reckoned from the time when $\phi = \gamma$, i. e., when $\theta = \pi/2$, we find

$$t = \frac{1}{c}\left[F\left(\frac{\pi}{2}, \sin\gamma\right) - F(\theta, \sin\gamma)\right] \qquad (9)$$

where the F denotes an elliptic integral of the first kind with modulus $\sin\gamma$; or in expressing ϕ in terms of t,

$$\theta = \sin^{-1}\left(\frac{\sin\phi}{\sin\gamma}\right) = cn\,(ct) \qquad \text{mod. } \sin\gamma \qquad (10)$$

For numerical values we have for the sphere $\frac{b^2}{b^2+k^2} = \frac{5}{7}$, $\beta = 0.00529$, $g' = 9.8$ meters per sec. and $a = 6{,}368{,}000$ meters. For the sphere supposed in the text $b = 1000$ meters. These values give, for the second as unit of time,

$$c = 0.000001351.$$

The linear velocity (v) is $a\frac{d\phi}{dt}$, or by (8)

$$v = a\,c\,\sqrt{\sin^2\gamma - \sin^2\phi}$$

$$= \frac{a\,c}{\sqrt{2}}\sqrt{\cos 2\phi - \cos 2\gamma}. \qquad (11)$$

With the above numerical values

$$v = 6.09\sqrt{\cos 2\phi - \cos 2\gamma} \text{ in meters per second.}$$

The table given in the text (pp. 135-6) is readily computed from (9) and (11).

APPENDIX B.

The Effect of the Earth's Field of Force on a Floating Body.

As a simple example let us consider a sphere of radius r (fig. 7) and density σ floating in a liquid of density ρ, the outer surface of which forms a portion of the geoid. From the center of the sphere draw a normal to the geoid (conceived as continued into the sphere) and take the intersection of the normal with the geoid as the origin of a system of rectangular coordinates, with z-axis coincident with the normal, the positive direction being upwards and with the x-axis tangent to the geoid in the plane of the meridian, the positive direction of x being towards the equator. The forces acting on the sphere are the fluid pressure on its submerged surface and the pull of gravity.

The fluid pressure on any element of surface being normal to the surface, has no moment tending to turn the sphere about its center. Gravity acts as if the sphere were concentrated at its center and does not produce any moment about the center. We shall suppose that the sphere is submerged to such a depth that the pull of gravity along the z-axis just balances the z-component of the fluid pressure, so that the forces acting have a zero component along the z-axis; we suppose also that the field of force is symmetrical with respect to the meridian, so that there is no component along the y-axis. We are interested chiefly in determining whether or not the case of the floating sphere may resemble the case of the rolling one to the extent that there is a small component directed along the x-axis and toward the equator.

Fig. 7.

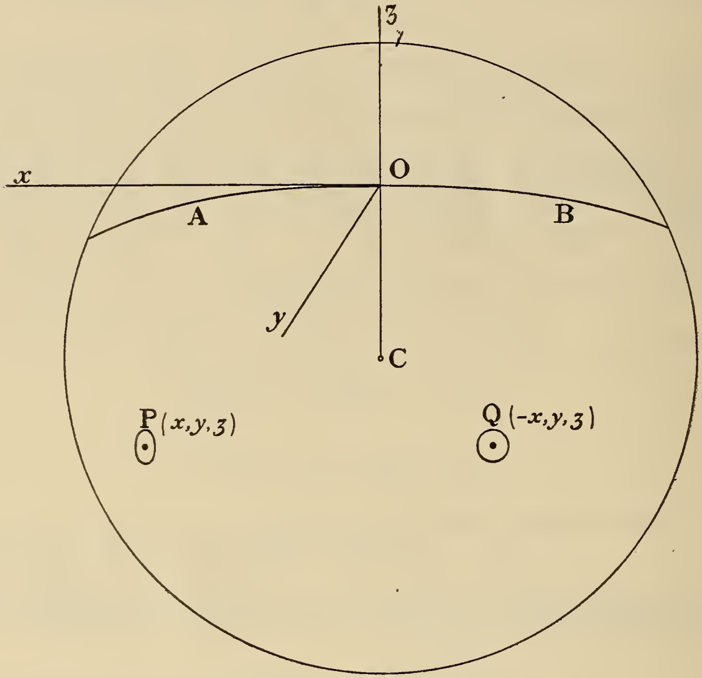

Fig. 7.—Coordinate axes for the problem of the floating sphere.

Consider the pressure of an element P of the spherical surface, whose coordinates are (x, y, z) and on Q, the element symmetrically situated and of equal size, whose coordinates are $(-x, y, z)$. If the intensity of pressure at Q is greater than the intensity at P, then, so far as these two elements are concerned, there will be a resultant pressure tending to move the sphere towards the equator. The intensity of pressure at any point of a homogeneous liquid in equilibrium is $(V-V_0)\rho$, where V is the potential of the field of force acting on the liquid, V_0 is the value of V for the free surface—here the geoid—and ρ is, as before, the density of the liquid. The potential V may be considered as consisting of two parts, (1) the part due to the earth itself; this we shall consider as normal, i. e., such that the geoid is a spheroid of revolution with an ellipticity equal to the mean ellipticity of the earth; (2) the part due to the attraction of the sphere; the direct attraction of the sphere is obviously symmetrical about the z-axis; there is also a small indirect effect due to the slight heaping up of the liquid around the sphere owing to the attraction of the latter; this effect may also be taken as symmetrical about the z-axis.[29] The effect of that part of V due to the attraction of the sphere is therefore the same at P and at Q and cancels out as far as the resultant pressure is concerned. In calculating this resultant pressure we may therefore use for V simply the normal part of it, or that due to the earth alone.

We shall assume that the normal part of the gravity potential may be represented by a polynomial of the second degree in x, y, and z, or

$$V - V_0 = -g_0 z + a x^2 + b y^2 + c z^2 + 2 h x z \qquad (1)$$

The absence of terms in x and y is explained by the fact that the direction of the vertical at the origin coincides with the z-axis. The absence of terms in xy and yz is explained by the fact that the x-axis is in the meridian, which is a plane of symmetry. The coefficient g_0 is the intensity of gravity at the origin; the other coefficients

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[29] There is a very slight deficiency in symmetry in this indirect effect, because the attraction of the sphere on the liquid in any given direction draws the liquid from a region where gravity is slightly different from what it is in a region symmetrically situated with respect to the z-axis. The effect of the asymmetry is only a small part of the whole effect, which is itself small, and so the effect of asymmetry may safely be neglected, even in comparison with the minute quantities involved in the discussion.

also have physical interpretations.[30] Thus

$$a = \frac{-g_0}{2R},$$
$$(2)$$
$$b = \frac{-g_0}{2N}$$

where R and N are respectively the radii of curvature of the earth in the meridian and prime vertical. The quantity c is connected with a and b by the relation

$$2\,(a + b + c) = -4\,\pi\,k\,\delta + 2\,\omega^2 \qquad (3)$$

In this equation k denotes the gravitation constant and ω the angular velocity of the earth about its axis; δ denotes the density of matter at the point considered, i. e., $\delta = 0$ for points above the geoid and $\delta = \rho$ for points in the liquid. Equation (3) is really a modified form of Laplace's equation or of Poisson's equation, according as $\delta = 0$ or $\delta = \rho$, the modification being the term in ω^2, which arises from the difference between gravity and gravitation already mentioned (p. 129). The quantity h serves to measure the rate of increase in gravity in going from the equator towards the poles. Evidently by Taylor's theorem for three variables

$$2\,h = \left[\frac{\partial^2 V}{\partial x\,\partial z}\right]_0,$$

where the subscript zero indicates the value at the origin.

If g denotes the intensity of gravity at any point in the field,

$$g^2 = \left(\frac{\partial V}{\partial x}\right)^2 + \left(\frac{\partial V}{\partial y}\right)^2 + \left(\frac{\partial V}{\partial z}\right)^2,$$

or by differentiating with respect to x,

$$g\,\frac{\partial\,g}{\partial x} = \frac{\partial V}{\partial x}\,\frac{\partial^2 V}{\partial^2 x} + \frac{\partial V}{\partial y}\,\frac{\partial^2 V}{\partial y \partial x} + \frac{\partial V}{\partial z}\,\frac{\partial^2 V}{\partial y \partial z}\,;$$

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[30] Helmert, Höhere Geodäsie, Vol. II, Chap. I. Eötvös bases the theory of his balance on an expression for the potential similar to (1) but containing terms here omitted because of symmetry. The values of a and b do not depend on any property of the gravity potential as such; similar expressions hold good approximately for any field of force having a potential and symmetrical in the way here supposed. Equation (1) would be exact for the field of force due to gravity in the interior of a homogeneous rotating ellipsoid; even in cases where additional terms would be needed to give an adequate expression for V, the effect of these terms for the case here treated would be nearly evanescent for reasons of symmetry.

for the origin this gives

$$\left[g\frac{\partial g}{\partial x}\right]_0=\left[\frac{\partial V}{\partial x\partial z}\,\frac{\partial V}{\partial z}\right]_0,$$

or since

$$\left[\frac{\partial V}{\partial z}\right]_0=-g_0,$$

we get

$$-\left[\frac{\partial g}{\partial x}\right]_0=\left[\frac{\partial^2 V}{\partial x\partial z}\right]_0=2\,h.$$

But

$$\left[\frac{\partial g}{\partial x}\right]_0=\left[\frac{\partial g}{\partial \phi}\,\frac{\partial \phi}{\partial x}\right]_0=-\frac{1}{R}\left[\frac{\partial g}{\partial \phi}\right]_0,$$

where ϕ is the latitude. As in Appendix A

$$\frac{\partial g}{\partial \phi}=g^{\epsilon}\,\beta\sin 2\phi,$$

where g_ϵ denotes gravity at the equator and β is a constant of the gravity formula = 0.00529 nearly. With sufficient accuracy we may substitute g_0 for g so that we get finally

$$2\,h=\frac{g_0}{R}\,\beta\,sin\,2\phi \tag{4}$$

The component of pressure along the x-axis, p_x, is evidently given by

$$p_x=-\iint p\,cos\,\alpha\,dS, \tag{5}$$

where p is the pressure on the element of dS of the submerged surface, and α is the angle between the external normal to the surface and the x-axis; the integration extends over the entire submerged surface. If we take points in pairs like P and Q in the figure, the two values of $cos\,\alpha$ are numerically equal but opposite in sign, and by writing $(V—V_0)\,\rho$ for the pressure, noting that $cos\,\alpha\,dS=dy\,dz$ and using V with subscripts P and Q to indicate the values of V at these points, we find

$$p_x=-\iint(V_P-V_Q)\,\rho\,dy\,dz. \tag{6}$$

The integration in (6) extends over a section of the sphere by the yz-plane, the bounding curves being the projection of the "water-line" on the yz-plane and that part of the great-circle section of the spherical surfaces that lie below the "water-line"; the element of area $dy\,dz$ is to be treated as positive. The fact that the portions of the "water-line" on the two sides of the yz-plane do not have quite the same projection upon it will be dealt with later. Neglecting the difference between the two projections we have from (1)

$$V_P - V_Q = 4\,h\,x\,z. \tag{7}$$

The x is, of course, the positive x of P; the z is essentially negative. Thus it is seen that p_x is essentially positive, since h is positive. It is evident that this must be so, for gravity is greater at any given depth on the poleward side of the sphere than on the equatorward side, so that pressure must be greater also.

Using (7) we get

$$p_x = -\,4\,h\,\rho \iint zx\,dy\,dz. \tag{8}$$

It may be noted that $x\,dy\,dz$ is the volume of an elementary prism and that $zx\,dy\,dz$ is the moment of this prism with respect to the xy-plane. If we call z_s the depth below the xy-plane of the center of gravity of the volume considered, and v_s the entire volume itself (on both sides of the yz-plane)

$$p_x = -\,2\,h\,\rho\,v_s\,z_s \tag{9}$$

The volume v_s is nearly the entire volume of the submerged portion of the sphere, differing from it by the small volume between the surface formed by the projection lines of the "water-line" and the surface of the geoid. This small volume is zero in the ordinary theory of floating bodies which treats the free surface as plane. The quantity z_s corresponds to the depth of the center of buoyancy in the ordinary theory.

The pull of gravity on the sphere is not exactly along the z-axis, since the direction of gravity at the center C is not quite the same as at the origin. The x-component of the pull is the mass of the sphere multiplied by the value of $\frac{\partial V}{\partial x}$ at the center, or calling g_x the pull of gravity, v the volume of the sphere, and ζ the z-coordinate of its center, we get

$$g_x = 2\,\sigma\,v\,h\,\zeta. \tag{10}$$

The resultant X, of all forces along the x-axis, is $p_x + g_x$, or

$$X = 2\,h\,(\sigma\,v\,\zeta - \rho\,v_s\,z_s) \tag{11}$$

It is easy to show that p_x is numerically greater than g_x, or that the resultant force is towards the equator, z_s and ζ being essentially negative.

The effect of the lack of symmetry with respect to the yz-plane, which we have so far ignored, is easily seen to be negligible. The equation of the free surface is found by putting the right-hand side of (1) equal to zero. If x or y be taken as a small quantity of the first order, z is easily seen to be of the second and z^2 of the fourth order, so that we may write for the point A, whose coordinates are $(x, 0, z_1)$,

$$z_1 = \frac{a\,x^2}{g_0 - 2\,h\,x} = \frac{a\,x^2}{g_0}\left(1 + \frac{2\,h\,x}{g_0}\right)$$

For the point B, approximately symmetrical, with coordinates $(x, 0, z_2)$

$$z_2 = \frac{ax^2}{g_0}\left(1 - \frac{2\,h\,x}{g_0}\right)$$

$$\tag{12}$$

$$z_2 - z_1 = \frac{4\,ah\,x^3}{g_0^2}$$

If in (12) we take x equal to r, the radius of the sphere, then,

$$\left|\frac{4\,ah\,r^3}{g_0^2}\right| = \frac{2\,\beta\,r^3}{R^2}$$

is the maximum possible depth of the strip on which the pressure is unbalanced; the maximum width in computing (6) or (8) is $2r$, and the maximum pressure, since the strip is at the "water-line," is evidently less than ½ (depth)^2 × width × $(g_0\,\rho)$, i. e., less than

$$4\,\beta^2\left(\frac{r}{R}\right)^4 g_0\,\rho\,r^3 \tag{13}$$

The quantity (13) is seen to be quite negligible when compared with (9) or (10), both on account of the additional factor β and a factor of the order $\left(\frac{r}{R}\right)^3$. This unbalanced pressure, such as it is, is furthermore toward the equator.

To form a numerical estimate of the equatorward force let us take $\sigma = 2.7$ and $\rho = 3.2$; these figures correspond roughly to the case of a mass of rock floating in a heavier basic magma. By neglecting the curvature of the earth and the vertical variation of gravity, it is easily seen that the spherical mass of rock will float with one-half of its radius above the liquid,[31] that is, with 5/32 of its volume above the liquid and 27/32 below, that is, with $\zeta = -\frac{r}{2}$ we find also $z_s = -\frac{5r}{8}$, $v = \frac{4}{3}\pi r^3$, and $v_s = \frac{9}{8}\pi r^3$. Therefore by (4) and (11)

$$X = \left(\tfrac{4}{3}\pi r^3 \times 2.7\right) \times \left(\frac{g_0 \beta r \sin 2\phi}{8R}\right)$$

The value $r = 3$ kilometers corresponds with an average elevation above the liquid of 833 meters, which is about the average elevation of the land surface of the earth; on the floating-crust theory the elevation of the land above the sustaining magma would exceed this amount. For this case the force X is 1/3000000 part of gravity for $\phi = 45°$. This force X, though small, would, if acting continuously without resistance, bring the sphere from latitude 45° to the equator in about three weeks.[32]

If the preceding discussion be examined, it will be noticed how little use has been made of the spherical form of the floating body. A symmetrical body, like a parallelopiped, if placed symmetrically with respect to the meridian, could be substituted in the discussion in place of the sphere. The parallelopiped would not be attracted by the earth exactly as if the former were concentrated at its center of gravity, but the error in assuming that it would be is very small. The chief difficulty arises from the fact that the resultant pressures have moments about the center of gravity of the parallelopiped; but it can be shown that these do not affect the general validity of the

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[31] This is simply a convenient coincidence; the problem of the floating sphere requires the solution of a cubic equation.

[32] If the sphere were not constrained to float along a meridian, the deflecting force of the earth's rotation would cause its path to take a curious wavy or looped form resembling a trochoid; if the sphere were to start from rest, the general direction of its advance, apart from the loops or undulations, would at first be at right angles to the meridian. The discussion of the exact form of the path is not necessary for the matter in hand, since the time needed to reach the equator is of the same order of magnitude, whether the sphere be confined to a meridian or not. Resistance would make the sphere move more nearly in the original meridian.

general conclusion, namely, the existence of an equatorward force. For a parallelopiped the equatorward force is approximately proportional to the average elevation of its upper face above the surface of the fluid.

For a body of irregular shape the existence of such a force may be inferred by a comparison of the potential of such a body floating at the equator, with its potential at some other latitude; the potential of the displaced fluid must be included in the calculation. The force itself may be conveniently evaluated by using for calculating the pressures the familiar transformations.

$$\iint \mathrm{V}\cos a\, d\mathrm{S} = \iiint \frac{\partial \mathrm{V}}{\partial x}\, dx\, dy\, dz.$$

The integral on the left is extended over the submerged surface and also, merely to form a closed surface, over the cap formed by the geoid surface within the solid, the cap being bounded by the "water-line." The integral on the right is a volume integral over the solid bounded by the submerged surface and by the cap.[33]

The statement on page 137 with regard to the force which tends to turn a floating body, so as to bring its axis of length into the prime vertical in low latitudes and into the meridian in high latitudes applies to a body in general conforming to the curvature of the earth and lying oblique to the meridian, with a uniform elevation of its upper surface above the surface of the liquid. In low north latitudes the northern end, being nearer to latitude 45°, where the equatorward pull is a maximum, would be drawn toward the equator more strongly than its southern end. This would tend to bring the axis of greatest length into the prime vertical. In high north latitudes (above 45°) the southern end would be drawn more strongly toward the equator and the force would tend to bring the axis of length into the meridian. This force resembles somewhat the force acting on the bar on an Eötvös balance, but has a different cause.

The motion of matter toward the earth's equator would, of course, have an effect on the position of the earth's axis of rotation. It has been assumed that the masses involved were negligible in comparison with

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[33] See almost any account of the potential function, as for example Peirce's *Newtonian Potential Function,* 3d Ed., page 66.

that of the earth,[34] and the effect in question has not been considered. Its existence, however, does not invalidate the argument for the equatorward force.

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[34] The effects dealt with have been of the order $g\beta\left(\frac{r}{R}\right)$, where r is the greatest dimension of the body involved and R the earth's radius. The ratio of the mass of the body to that of the earth would be of the order $\left(\frac{r}{R}\right)^3$ that is, we have considered quantities of the first order in $\frac{r}{R}$ but have neglected quantities of the third order.

ART. XI.—*Fauna of the Dallas Sand Pits;* by RICHARD SWANN LULL.

One of the characteristic features around Dallas, Texas, is the sand pits opened in the remnants of ancient flood plains on either side of the valley of the Trinity River. Several of these have been operated for many years, and in addition to the sand and gravel they have yielded as a by-product an interesting Pleistocene fauna. This is as yet incompletely known, largely through lack of appreciation, as the material has been often cast aside on the dumps to be destroyed by weathering. Professor Ellis W. Shuler, of the Southern Methodist University, has, however, with a high realization of their value, endeavored to save such specimens as have lately come to light, and to him I am indebted for the privilege of description.

There have thus far been recorded, since the first specimen was noted in 1887, the skulls of no fewer than thirteen elephants, one of which, bearing splendid tusks, although with the cranium largely restored, was on exhibition in the old Peabody Museum at Yale (Cat. No. 10028, Y. P. M., Shuler 1918, pl. 12). This and other specimens have been identified as *Elephas imperator*. In addition, Shuler[1] lists: "Bones of *Equus scotti*, the Texas horse; an ancient bison, species undetermined; bones of smaller animals, as yet undetermined; and bony scutes from the skin of the giant sloth." "Most of the specimens," he goes on to say, "are found in the sand pits just underneath the covering of clay or near the base of the pit." The sand pits of East Dallas are 50 feet above the Trinity. The date of deposition of these sand pits may be taken as Pleistocene . . . , since they are the highest river deposits in which fossils of Pleistocene mammals have been found. . . . Fossils are found occasionally in the lower sand and gravel pits, but such specimens show the effects of transportation by stream action."

A section of the Lagow sand pit, East Dallas, whence the present consignment of fossils has come, is thus described by Professor Shuler (letter of March 3):

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[1] E. W. Shuler, Univ. Texas, Bull. 1818, 26, 28, 1918.

	ft.	in.
Top soil. Medium grained sandy loam. Dark red to black ....about	2	7
Sandy clay, hard, tenacious. Red..............about	3	
Fine sandy clay with light calcareous segregations and streaks. Texture of sand varies. Color yellow. Fossils: antelope, bison, mammoth............about	2	10
Fine to coarse clean white sand and gravel. Gravel usually under 1 inch. Cross-bedded. Foreset beds not over 12-14 inches, usually 3-4 inches. Fossils usually found at bottom, especially larger bones. Bones clean and usually white or cream in color. Mammoth, camel ....about	14	
Austin chalk.		

Summary of Material.

- Class Mammalia.
  - Order Carnivora.
    - Family Felidæ.
      - Subfamily Machærodontinæ.
        - *Smilodon fatalis* (Leidy). Cranium.
  - Order Artiodactyla.
    - Family Cervidæ.
      - *Odocoileus* sp. Humerus, antler.
    - Family Antilocapridæ.
      - *Tetrameryx shuleri,* gen. et sp. nov. Cranium, maxillary.
    - Family Bovidæ.
      - *Bison alleni* Marsh. Left mandible.
    - Family Camelidæ.
      - *Camelops huerfanensis dallasi,* subsp. nov. Skull, etc.
      - Camel, gen. et sp. indet. Cannon-bone.
  - Order Perissodactyla.
    - Family Equidæ.
      - *Equus.* cf. *fraternus* Leidy. Cannon-bone, humerus.
  - Order Proboscidea.
    - Family Elephantidæ.
      - Subfamily Mammotinæ
        - *Elephas columbi* Falconer

Description of Material.

Smilodon cf. *fatalis* (Leidy).

(Fig. 1.)

A finely preserved occiput of a large sabre-tooth cat is present, bearing the catalogue number 1.52, Southern Methodist University collection (plesiotype). The specimen shows signs of stream transportation and is therefore apparently from the lower level of the Lagow sand pit.

Its affinities with *Smilodon* are clearly shown by the relatively great vertical extent of the mastoid processes, together with their being directed downward and forward so that the auricular fossa is nearly closed below, whereas in *Felis* it is wide open and the vertical extent of the mastoids is relatively slight. The occipital condyles are also *Smilodon*-like and show a great habitual range of vertical movement than in *Felis*. All this is correlated with the great development of the sternomastoid muscle in *Smilodon* for use in striking its prey, and is highly diagnostic of the genus.

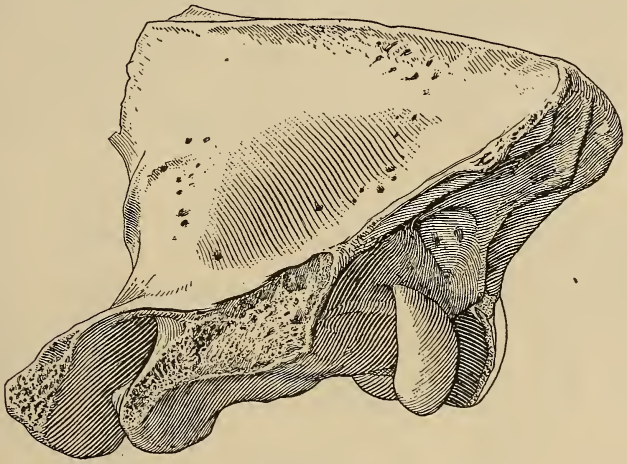

FIG. 1.—*Smilodon* cf. *fatalis* (Leidy). Cat. No. 1.52, S. M. U. Oblique aspect of cranium. × ½.

But one species of *Smilodon* has been described from Texas, *S.* (*Trucifelis*) *fatalis* (Leidy)[2], of which the type consists of a single upper carnassial with a small portion of the maxillary attached. As this element is unrepresented in the present specimen, comparison was made with a fine skull of *S. californicus* from the Rancho La Brea asphalt, Cat. No. 10204, Y. P. M., and the comparable ratios between that and Leidy's type on the one hand, and the Dallas specimen on the other, exhibit a close agreement, as the table of measurements shows.

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[2] Joseph Leidy, Jour. Acad. Nat. Sci., Phila. (2), 7, 366, pl. 28, figs. 10, 11, 1869.

Measurements.

	S. fatalis holotype after Leidy mm.	Ratio	*S. californicus* No. 10204, Y. P. M. mm.
Carnassial			
Depth, infraorbital foramen to base of crown	31.75	0.793	40
Breadth ant.-post. diameter of crown	33.337	0.803	41.5
Thickness at position of inner buttress	15.875	0.992	16
Depth of principal cusp	19.05	0.846	22.5
Average ratio		0.858	

	S. fatalis No. 1.52 S. M. U. mm.	Ratio	*S. californicus* No. 10204, Y. P. M. mm.
Length of parietal crest	110	0.866	127
Breadth of brain-case	93	1.022	91
Breadth of occiput at upper edge of foramen magnum	80	0.920	87
Height of occiput	65	0.890	73
Breadth across mastoids	123	0.898	137
Breadth across occipital condyles	60	0.87	69
Breadth at summit of occiput	50		80
Average ratio		0.876	

The Dallas specimen differs from *S. californicus* not only in its lesser size, but in its relatively narrower occiput, the proportions of which compare more nearly with those of the tiger. The brain-case, on the other hand, is relatively larger in the Texas specimen, and the sagittal crest thinner; another distinction lies in a sharp thin vertical keel on the basi-occipital in *S. californicus*. Some of these details, as in the more powerful occiput and greater size of the latter, may indeed have been sexual, but the assumption is that the species are distinct. I have, however, no assurance that the Dallas specimen is distinct from *S. fatalis,* with the proportions of which it approximately agrees. The discovery of a carnassial attached to the cranium in the Dallas sand pits alone can give assurance of identity or disagreement. Until then, this specimen must be referred provisionally to Leidy's species, and as it gives additional characters to those furnished by the original type, may be considered the plesiotype thereof.

Odocoileus sp.

Two stream-transported specimens, Cat. No. 1.62, S. M. U., are in the collection. One is a single spike-like antler which had apparently been shed by its owner, and the other the distal end of a left humerus. They pertain to a deer somewhat smaller than the black-tailed deer of to-day, the antler of course being that shed by a yearling buck. It is complete except for the tip, and shows no sign of branching. The humerus is essentially indistinguishable from that of *Odocoileus* except for proportions and size.

Measurements.

	Odocoileus No. 1.62 S. M. U. mm.	Ratio	Black-tailed deer No. 01413, Y. P. M. mm.
Antler:			
Length, estimated	90		
Maximum diameter over burr	17.7		
Humerus:			
Width of distal end	30	0.81	37
Ant.-post. diameter of distal end	31	0.89	35
Average ratio		0.85	

Tetrameryx shuleri, gen. et sp. nov.

(Figs. 2, 3.)

Holotype, Cat. No. 1.50, Southern Methodist University. Pleistocene, Lagow sand pit, Dallas, Texas.

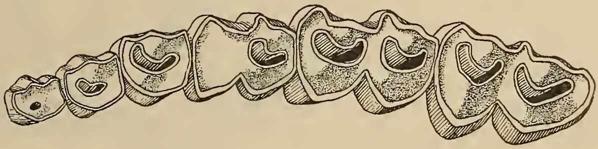

Fig. 2.—*Tetrameryx shuleri,* gen. et sp. nov. Holotype Cat. No. 1.50, S. M. U. Upper dentition. Nat. size.

The holotype consists of the left superior maxillary containing the entire series of cheek teeth, and the coalesced frontals bearing two pairs of practically perfect horn-cores.

Fig. 3.—*Tetrameryx shuleri,* gen. et. sp. nov. Holotype. Cat. No. 1.50, S. M. U. Right oblique aspect of cranium, showing horns. × ½.

Dentition.—The dental formula was probably that of *Antilocapra*: $I\frac{0}{3}$, $C\frac{0}{1}$, $P\frac{3}{3}$, $M\frac{3}{3}=32$ teeth. The cheek teeth are hypsodont, with prominent external styles, no trace of cingula nor of internal basal pillars. Crowns of the premolars curved backward as in *Antilocapra.* Compared with those of *Antilocapra,* the chief distinctions lie first in the relative size of the teeth, M^1 being approximately equal in each form. The other molars of *Tetrameryx* are progressively larger than in the prongbuck, while the premolars are progressively smaller. In *Tetrameryx* the mesostyle is more pronounced on M^3, while in the premolars the external styles are much less conspicuous. On the other hand, M^3 in *Antilocapra* bears a distinct hypocone which is lacking in *Tetrameryx.* The degree of hypsodonty is about the same.

Measurements.

	Tetrameryx No. 1.50, S. M. U. mm.	Ratio	*Antilocapra* No. 0180, Y. P. M. mm.
Length, premolar-molar series	76	1.05	72
P^2- P^4	25	0.89	28
M^1- M^3	52	1.099	47.5
P^2, length	6.7	0.87	7.6
P^4, height of crown	14	1.03	13.5
Length	8	0.89	9
M^1, length	13.3	1.02	13
M^2, length	17.5	1.16	15
M^3, length	21.4	1.20	17.8
Extreme height of tooth to apex of fang	46	1.12	41
Average ratio		1.03	

Palate.—The palate, in so far as preserved, corresponds to that in the prongbuck, except that in the latter the anterior margin of the posterior nares does not extend forward of the after limit of the dental series. In the fossil it extends to a point opposite the middle of M^3. It also seems to have had a more acute forward angle. The palatal foramen is about opposite the forward margin of M^3 in the two old prongbucks before me, while in two juvenile specimens it lies further forward; that of the fossil lies between the two. The position of the infraorbital foramen can not be compared.

Cranium.—Almost the entire area of the two frontals is preserved. All sign of the sutures, however, is obliterated as in *Antilocapra* No. 0180, which was individually slightly younger than was the fossil spcimen at the time of death. The skull contour is quite similar except that its dorsal surface bears two pronounced ridges which run forward toward the nasals and are separated by a deep median depression which in turn bears a longitudinal ridge in the wake of the interfrontal suture. The orbits, in so far as they are preserved, are approximately equal in the two genera, and the paired lacrymal ducts are in the same position. The supra-orbital foramina show no antero-posterior extension in the fossil, but the facial groove leading forward is wider and more pronounced.

Horns.—The anterior pair of horn-cores agree in form and position with those of *Antilocapra,* differing in small details such as a more rounded cross-section, especially at their base. They lie nearer together at their base than in *Antilocapra,* and their angulation outward agrees with that of a young male (RSL, male)[3] and is materially less than in No. 01518 Y. P. M. In the prongbuck the horns are connected by a transverse ridge across the skull; in *Tetrameryx* this lies between the posterior horns. The latter are much the longer and relatively slenderer and less rapidly tapering. Externally they bear a groove which passes around on to the anterior surface to become external again as the summit of the horn is reached. A similar, although less pronounced sulcus, is seen on the external face of the anterior horn in the fossil as well as in the recent form. There is little question of the homology of the anterior horn-cores of *Tetrameryx* with those of the prongbuck. Yale specimen 01515 bears, on the posterior side of the base of the horns, a slight prominence which by marked hypertrophy might conceivably give rise to posterior horns similar to those in the new form. In the young buck (RSL, male) these prominences are hardly discernible. The inference is that, as in the prongbuck, these horn-cores were sheathed with horns which were also probably deciduous. Because of the smoothly rounded anterior outline of the fossil horn-cores the presence of an anterior prong on the horn sheaths is doubtful.

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[3] See this Journal (4), 50, fig. 3, p. 89, 1920.

Measurements of Cranium.

	Tetrameryx No. 1.50, S. M. U. mm.	Ratio	*Antilocapra* No. 01518, Y. P. M. mm.
Breadth across orbits	112	0.82	136
Breadth between base of ant. horns..	44	0.76	58
Width between summits, ant. horns..	178	0.78	226
Length from orbital rim, ant. horns...	110	1.15	95
Length from orbital rim, post. horns.	297		
Width between summits, post. horns..	275		
Ant.-post. diam., base of ant. horns..	30	0.85	37
Transverse diam., base of ant. horns..	17	0.72	23.5

Relationships.—There is no doubt that *Tetrameryx* represents an aberrant genus of the family Antilocapridæ, characterized by the heretofore unique feature of deciduous horn sheaths over permanent cores, and differing from the typical genus, which it closely resembles in size and dentition, by the presence of the additional posterior horns and probably by the absence of the distinctive "prong" on the horn sheaths of the recent genus. It is a form which might well have arisen from the main phylum in Pliocene or early Pleistocene time, and because of its remarkable specialization represents a short-lived race. The generic name (from τέτρα-, four + μήρυξ, ruminant) is self-explanatory, while the specific name is given in honor of Professor Ellis W. Shuler, through whose courtesy I am enabled to describe this interesting form.

Bison alleni Marsh.

This species is represented by a well preserved left ramus, Cat. No. 1.53, S. M. U. As it shows signs of stream transportation, it must have come from the lower level of Lagow's sand pit. The extremities of the bone are lacking and it contains the alveoli of the canine, and $P_{2\text{-}3}$. P_4 and $M_{1\text{-}3}$ are present. The character of the teeth and their dimensions compare very closely with specimen No. 7706 in the U. S. National Museum referred to *B. alleni* by Hay.[4] The original type, preserved at Yale (Cat. No. 11911, Y. P. M.) consists of the horn-cores and frontals only, but the reference of the National Museum skull seems unquestionably correct, and further description of the Dallas specimen unnecessary.

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[4] O. P. Hay, Proc. U. S. Nat. Mus., 46, 183, 1913.

Measurements.

	Bison alleni No. 7706 U. S. N. M. mm.	Ratio	*B. alleni* No. 1.53 S. M. U. mm.
Length, premolar-molar series	175	1.03	±181*
Premolar series	60	1.05	± 63
Molar series	113	1.04	118
P_3, length	22		19†
P_4, length	25	1.00	25
M_1, length	30	1.00	30
M_2, length	35	1.00	± 35‡
M_3, length	48	1.04	50
Average ratio		1.02	

* Measured to alveolus of P_2.
† Alveolus, tooth lacking.
‡ Broken.

Camelops huerfanensis dallasi, subsp. nov.

(Figs. 4, 5.)

Holotype, Cat. No. 1.51; paratypes, Cat. Nos. 1.53, 1.57, 1.58, 1.59, 1.60, S. M. U. Pleistocene, Lagow sand pit, Dallas, Texas.

The material consists of a broken but otherwise admirably preserved skull, a cervical and a dorsal vertebra, right ulno-radius, astragalus, and metatarsal, the last incomplete. These remains indicate an animal about the stature of a modern Arabian camel or dromedary, as the relative measurements will show.

Skull.—The skull (holotype) consists of three separate portions: the palate with the right dentition complete from the third incisor back, the left partially so; the rear of the cranium, including the basi-occipital region and the parietal bones; and a detached, incomplete right frontal.

The occiput approximates that of the dromedary (*Camelus arabicus*, Cat. No. 01552, Y. P. M.), in size, but differs in the greater proportionate width, larger condyles, lighter and less overhanging nuchal crest, and in the deeper modeling of the occipital surface. The mastoid region differs markedly in the two forms, apparently correlated with the relative development of cervical VI (see below). The paroccipital process is larger in the fossil and points more nearly toward the rear, while

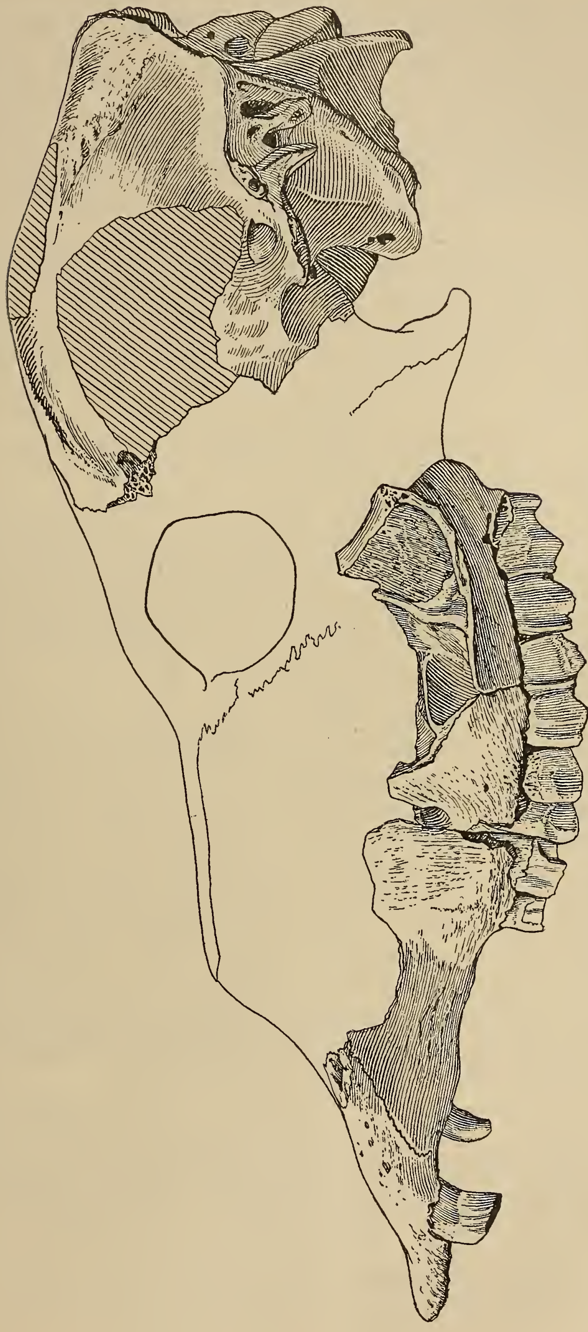

FIG. 4.—*Camelops huerfanensis dallasi*, subsp. nov. Holotype. Cat. No. 1.51, S. M. U. Skull, lateral aspect. × 1/3.

the auditory bulla is more inflated and has a much greater lateral area (see fig. 4). This greater development of the bullæ gives a longer contact with the basi-occipital bone and separates the anterior and posterior foramen lacerum much more remotely than in either existing genus. The basi-occipital bears a distinct antero-posterior groove which is lacking in the dromedary but present in *Auchenia.* The postglenoid process is lighter in the fossil.

On the other hand, the occiput of the Dallas specimen conforms rather closely with Hay's description[5] of the type of *Camelops huerfanensis* (Cragin). In it he speaks of the lambdoidal (nuchal) crest being thin and sharp, a point of agreement. He also says that the occipital surface in *C. huerfanensis* bears "a median descending ridge, rough and rounded, separating two deep excavations, on each side of which is another deep excavation at the bottom of which is placed the lateral foramen." In the Dallas specimen the median ridge is of less vertical extent, so that the excavations on either side are confluent below, while in *C. huerfanensis* they are entirely separate. Hay speaks of the paroccipital process being hooked at its extremity; this is not at all marked in the Dallas specimen.

Palate and dentition.—The chief tooth distinctions between the Dallas *Camelops* and the dromedary lie, first, in the total absence in the former of P^2, the great size of I^3, and the details of the cheek teeth, in which the mesostyle is less pronounced and is reflected forward. The last molar bears a strongly developed posterior pillar (metastyle) which is absent in the camel and but slightly developed in *Auchenia.* There is no trace of an internal basal pillar on the superior molar teeth. The dental formula is in agreement with *Auchenia* as in *Camelops,* while the teeth also agree quite closely with those of *C. huerfanensis* even to dimensions (with due allowance for wear), as the table of measurements shows.

The posterior palatine foramina lie opposite M^1 as in *C. huerfanensis,* although that on the left side is smaller and is accompanied by a second, some distance behind the first. In both *Camelus* and *Auchenia* the foramina lie opposite the fourth premolars, those of the latter being

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[5] O. P. Hay, Proc. U. S. Nat. Mus., 46, 270, 1913.

relatively somewhat further forward. The infra-orbital foramen of the left side only is preserved, and this lies just above the anterior crescent of M^1 in seeming correspondence with that of *C. huerfanensis;* in both living genera the foramen lies a little further forward, above P^4. The premaxillaries are broader and heavier in the Dallas specimen than in either of the recent genera.

One apparent distinction between the Dallas form and the type of *Camelops huerfanensis* lies in the position of the canine, which "must have emerged immediately behind the incisor just as it does in the Bactrian camel" (Hay, p. 269). The Dallas specimen has an incisor-canine diastema of 16 mm. on the left and 18 mm. on the right.

Measurements of Skull.

	1 mm.	Ratio	2 mm.	Ratio	3 mm.
Length over all	500	1.08	540*		
Height of occiput from up. margin of foramen mag.	68	1.00	68		
Breadth of occiput on line through lateral foramina	123	1.01–	124	1.12	110
Palate, width between P^4	35	1.15	40†	0.80	50
Width in front of M^3	72	0.96	69†	0.79	87
Width, premax. border to rear of M^3	315	1.08	340		
Length, premolar-molar ser., P^3-M^3	151	1.14	172.5	1.01	171
Teeth, front of P^4 to rear of M^3	130	1.19	154.5	1.16	152
Molar ser.	109	1.18	129	1.00	129
P^3, length	20.5	1.02	21	1.12	18.8
P^4, length	24	1.14–	27.3	1.09	25
M^1, length	34.5	1.07	37	0.96	38.5
M^2, length	44	0.97–	42.5	0.88	48
M^3, height	22		25.5‡		62
Length on grinding surface	43	1.21	52	1.15	45
Width	27	1.00	27	0.94–	28.5
Average ratios		1.08		1.00	

1 = *Camelus arabicus,* Cat. No. 01552, Y. P. M.
2 = *Camelops huerfanensis dallasi,* subsp, nov.. Cat. No. 1.51, S. M. U.
3 = *Camelops huerfanensis,* Cat. No. 7819, U. S. N. M., after Hay.

* Estimated.

† Restored.

‡ In the Dallas specimen the teeth are much more worn, hence heights are much less, and as the teeth are worn, the length (ant.-post. diameter) diminishes (except in the third premolar and the last molar), while the transverse diameter increases (Hay). This will account for most of the discrepancies.

Cervical vertebra VI.—A single well preserved cervical vertebra, No. 1.57, S. M. U., is present and appears to be of the same level as that of the skull. It is very remarkable for the huge development of the ventral branches of the transverse processes, which are deflected downward to such an extent that their axes are parallel. These processes are of less fore and aft extent than in the dromedary, but are much thicker and deeper. The centrum of the vertebra, on the other hand, is more slender in the fossil, which gives the forward articular surface especially a somewhat less area. The planes of the two centrum faces are not parallel, but indicate a marked upward flexion of the neck, more so than in the equivalent element of the dromedary (see fig. 5).

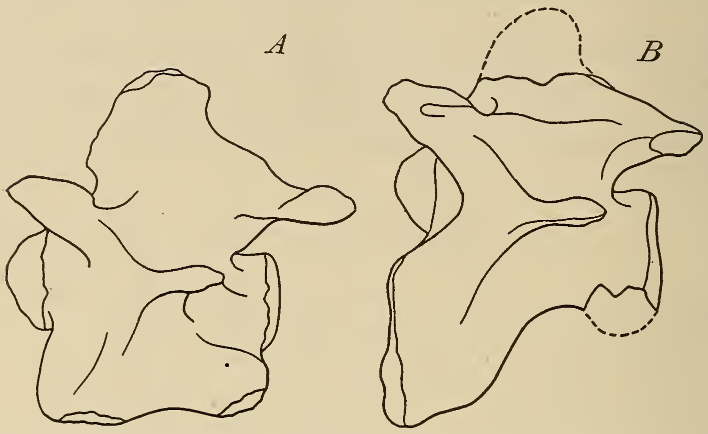

Fig. 5.—Cervical of (A) *Camelus arabicus,* Cat. No. 01552, Y. P. M.; and (B) *Camelops huerfanensis dallasi,* subsp. nov. Paratype, Cat. No. 1.57, S. M. U. × ¼

Dorsal vertebra.—A first dorsal, Cat. No. 1.60, S. M. U., perfect except for the spinous process, is also present. It shows signs of stream transportation (and doubtless comes from the lower level). It approximates the equivalent bone of the dromedary (01552, Y. P. M.) in size, but differs in having a somewhat heavier neural arch and shorter, broader centrum with a flatter ventral aspect.

Measurements of Vertebræ.

	Camelus arabicus No. 01552 Y. P. M. mm.	Ratio	*Camelops huerfanensis dallasi* No. 1.51, S. M. C. mm.
Cervical VI:			
Length of centrum	142	1.03	146

Length over zygapophyses	175	0.91	160
Height, prezygapophyses to inf. transverse processes	121*	1.43	176
Height over all	170*	1.35	230†
Average ratio		1.18	
			No. 1.60, S. M. U.
Dorsal I:	mm.		mm.
Length of centrum	92	0.86	79
Post. depth of centrum	54	0.94	52
Post. width	80	1.05	84
Width over all	120	1.08	130
Average ratio		0.98	

* Not completely ossified.
† Estimated.

Ulno-radius.—There is an admirably preserved right ulno-radius, No. 1.58, S. M. U., which compares closely with that of the dromedary (No. 01552, Y. P. M.). The ulna shows the same degree of reduction, but the bone as a whole is slightly shorter, wider, and flatter at mid-length, and shows a less degree of curvature.

Measurements.

	Camelus arabicus No. 01552 Y. P. M. mm.	Ratio	*Camelops huerfanensis dallasi* No. 1.58 S. M. U. mm.
Length over all	555	0.99	550
Length of radius	490	0.98	480
Width, mid-shaft	57	1.18	67
Thickness, mid-shaft	41.5	0.94	39
Width, prox. end	95	0.98	93*
Width, dist. end	94.5	0.95	90
Average ratio		1.00	

* Abraded.

Metatarsal.—A right metatarsal, No. 1.56, S. M. U., agreeing approximately in size with that of the dromedary (No. 01552), is present. It is not preserved throughout its entire length, having lost the distal end, but gives the impression of greater relative weight than in the recent form, and the longitudinal ridges on the posterior aspect are more nearly equal in prominence. It also seems somewhat straighter when seen in profile.

Measurements.

	Camelus arabicus No. 01552 Y. P. M. mm.	Ratio	*Camelops huerfanensis dallasi* No. 1.59 S. M. U. mm.
Length of shaft	337	1.05	355*
Width, prox. end	62	1.08	67
Width, mid-shaft	34.5	1.14	39.5
Thickness, mid-shaft	37	1.08	40
Average ratio		1.09	

Summary.—This Dallas form resembles *Camelops huerfanensis* in size and general proportions, in so far as comparison may be made, but differs in the details of the occiput, the presence of diastemata between I^3 and the canines, and in the larger size of the metastyle of M^3. These characters, if they are not merely sexual, are at least of subspecific rank. The name *dallasi* is given therefore to the form based upon the skull as holotype.

Camel, gen. et sp. indet.

No. 1.63, S. M. U., an almost perfect rear cannon-bone, represents a considerably smaller camel than *C. huerfanensis,* but I can not as yet identify it.

Measurements.

	No. 1.63 S. M. U. mm.	Ratio	No. 1.59 S. M. U. mm.
Length	275	0.77	355*
Width, prox. end	62	0.92	67
Width, mid-shaft	36.5	0.92	39.5
Thickness, mid-shaft	34†	0.85	40
Average ratio		0.86	

* Estimated.
† Abraded.

The ratios indicate a very short-footed camel for its bulk.

Equus cf. *fraternus* Leidy.

Cat. No. 1.61, S. M. U., a cannon-bone (mcp III), and No. 1.56, the distal halves of two right humeri, are all the horse material in the present collection. They represent a small horse or horses near to if not identical with *Equus fraternus* Leidy. I have compared them with the skeleton of a recent pony in the museum of the Yale Zoological Laboratory, with the following results:

	E. caballus mm.	Ratio	No. 1.61 S. M. U. mm.
Molar 1, fore and aft diameter	22	1.07	23.5*
Cannon-bone, length	207	1.06	220
Breadth, prox. end	46	0.91	42
Breadth, mid-shaft	44	0.88	40
Breadth, dist. end	29	1.09	31
Humerus, breadth, mid-shaft	30	1.23	37
Breadth, dist. end	70	1.10	77
Ant.-post. diameter, dist. end	66	1.21	80
Average ratio		1.07	

* Taken from *E. fraternus,* No. 9217, U. S. N. M. See Gidley, Bull. Amer. Mus. Hist., vol. 14, 113, 1901.

The ratios of teeth and cannon-bone are very close, the apparent discrepancies being due in part to erosion of the present fossil. The humeri, on the other hand, seem to pertain to slightly heavier horses, but the range of individual variation within the species might account for the difference in size.

Elephas columbi Falconer.

The proboscidean material from the Lagow sand pit now in my hands includes a tooth, No. 1.54, S. M. U., and a cervical vertebra, No. 1.55, S. M. U. The tooth is unquestionably from the upper level, having all the characters, color, preservation, etc., of the *Camelops* skull already described. The matrix on the cervical differs, however, resembling that of the camel ulno-radius.

The tooth appears to be a left upper second deciduous molar, and has four and a half elliptical enamel ridges, having a single plate intercalated between the two forward complete ellipses, and space beyond for another ridge of which the enamel is apparently worn away. The worn surface of the crown measures 78 mm. (about 3.5 inches) in length, as preserved, by 70 mm. in width. Five and one half folds in 3.5 inches is about equivalent to sixteen in 10 inches. Lucas gives the following: *Elephas imperator,* twelve in 10 inches; *E. columbi,* eighteen; *E. primigenius,* twenty-four. Our specimen comes nearest to *columbi.* The enamel is crenulated and in its present condition there is a fair amount of surrounding cement. The tooth was borne on at least two transverse roots.

The cervical represents the seventh cervical of a mature elephant, presumably *E. columbi,* although this same pit has yielded, apparently from its lower level, what I have identified as *E. imperator.* This is the Yale specimen, Cat. No. 10028, already referred to. Verification of the specific identity is at present impossible, as the specimen is in inaccessible storage. The centrum is approximately amphiplatyan, very short in its anteroposterior diameter, with the faces converging above, neural arch light, with a slender spinous process, and the prezygapophyses a little above the level of the postzygapophyses. Small tubercular rib facets are present just below and slightly external to the postzygapophyses, that on the right side being the lower. A trace of the capitular facet is also present on the right side well down toward the base of the centrum.

Measurements.

	mm.
Centrum, ant.-post. diameter at center	41
Width	170*
Height	150†
Breadth across prezygapophyses	220
Height of neural arch	80

* Approximate.
† Estimated.

A few fragments represent the cancellous tissue of the skull.

Art. XII.—*Dirca palustris* L. A morphological study; by Theo. Holm (with seven figures drawn from nature by the author).

The *Thymelaeaceæ* is a small family comprising only 36 genera with about 360 species according to Bentham and Hooker. Most of the species are natives of South Africa, the Mediterranean region and Australia; *Dirca,* however, is confined to North America, and only two species are known: *D. palustris* L. and *D. occidentalis* Gr., the former widely distributed from Ontario and Quebec southward to Florida; the latter is a native of California, and is described as follows:

Dirca occidentalis[1]

"Foliis ovalibus basi rotundatis; squamis involucri extus albido-villosis; floribus fructibusque fere sessilibus; perigonio breviter infundibuliformi-tri-quadrilobo. California, on the Oakland hills (perhaps in ravines), Dr. I. M. Bigelow (*D. palustris Torr. Bot.* Whippl. p. 77. non Linn). A second species of this before monotypical genus is of peculiar interest. The Californian *Dirca* was collected twenty years ago by Dr. Bigelow, "with flowers and young fruit" according to Dr. Torrey, but there are only vestiges of the former in my specimens. If they had been in good condition, Dr. Torrey would have noticed the characters of the species, which are now manifest. The white hairs of the floral bud-scales may not be constant; for in *D. palustris* they are occasionally pale; but the deep and rounded lobes of the more funnelform calyx are characteristic, being from one-fourth to one-third the length of the tube. Very commonly there are only three sinuses, one lobe being broader and emarginate. The stamens are uniformly eight. The original species may be thus characterized: *Dirca palustris* L. Foliis basi angustioribus; squamis involucri nigricanti-villosis; floribus pl. m. pedicellatis; perigonio tubuloso-infundibuliformi margine tantum repando. Nova Scotia to Lake Superior and Lake of the Woods, and southward to Florida along the Alleghanies."

Internal Structure of the Vegetative Organs of Dirca palustris.

The Root.—In mature specimens the roots are quite thick, very soft, and of a yellowish-brown color. A homo-

---

[1] Gray: Characters of new genera and species of plants. (Proceed. Am. Acad. of Arts and Sc., Vol. 8. Boston, 1873.)

geneous, thin-walled cork of several strata surrounds a broad zone of secondary, collenchymatic cortex, of which the peripheral two to three layers contain deposits of starch; in the cortex are many strands of stereids, with the lumen narrow, and the cell-walls neither porous nor lignified (fig. 3. St.). Narrow rays of starch-bearing parenchyma extend from the stele through the cortex to the cork. The stele represents a continuous, broad zone of leptome, interspersed with scattered strands of stereome or single stereids (figs. 3-4). Inside the leptome is a well developed cambium, a large mass of radially arranged libriform (S in fig. 3) and some isolated strands of vessels; the cells of the libriform are, however, rather short, but porous, and with the cross-walls oblique. The center of the stele is occupied by a few narrow, spiral vessels, and there is no pith.

With respect to the primary structure of the root, none of the roots of my material were sufficiently young for studying this state, but Van Tieghem[2] states, that in *Dirca* the young root is triarch, and that the leptome contains numerous stereids, which are strongly lignified, and that several of these border directly on the pericambium. Moreover in describing the root-structure in general of the *Thymelaeceæ* this author calls attention to the fact, that the exodermis shows the same degree of thickening as the endodermis, but while in the former (exodermis) the peripheral cell-wall is thickened and the interior thin-walled, the opposite is the case of the endodermis. According to Van Tieghem (l. c.) the presence of stereids in the leptome is a very rare occurrence, known so far only from *Anona, Celtis, Leguminosæ* and *Malvaceæ.*

[2] Recherches sur la structure et les affinités des *Thyméléacées* et des *Pénéacées,* Ann. d. sc. nat. Bot. Ser. 7, vol. 17, Paris, 1893.

Fig. 1.—Flower of *Dirca occidentalis,* laid open, showing four of the stamens; enlarged.

Fig. 2.—Flower of *Dirca palustris,* laid open; enlarged.

Fig. 3.—Cross-section of a thick, lateral root, showing the stereids (St.) in the leptome (L.); camb = cambium; S = libriform; V = vessel. × 496.

Fig. 4.—Cross-section of part of leptome of same root, showing the stereids × 600.

Fig. 5.—Cross-section of inner part of stem, showing cambium inside the hadrome; S-= spiral vessels. × 496.

Fig. 6.—Superficial section of dorsal face of leaf showing the stomata. × 320.

Fig. 7.—Cross-section of leaf; Ep. = ventral, Ep. * = dorsal epidermis; P. = palisade-tissue; P * = pneumatic tissue. × 496.

(Figs. 3-7 are *D. palustris.*)

1

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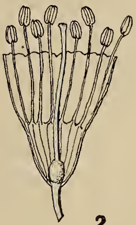

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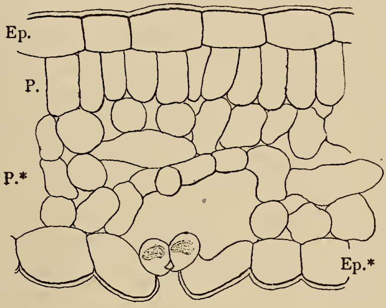

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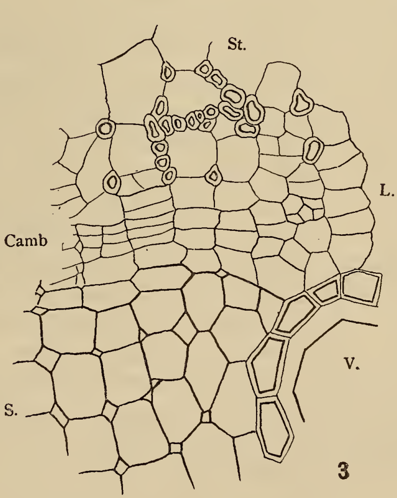

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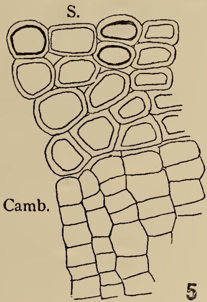

5

The stem.—A homogeneous, thin-walled cork replaces the epidermis at a very early state, and surrounds the broad parenchyma of the primary cortex; this tissue (the cortex) represents two distinct zones: a peripheral, collenchymatic of about five strata, and an inner, which is thin-walled; chlorophyll abounds in both parts of the cortex, while single (rhombic) as well as aggregated crystals of calcium-oxalate occur only in the inner zone, together with large groups of stereids. The stele contains a broad zone of leptome with strands of stereome, and some isolated strands of vessels, surrounded by numerous layers of radially arranged libriform; the medullary rays are narrow, mostly of a single row of compressed cells with deposits of starch. Strata of cambium are developed on the inner flank of the hadrome (fig. 5), thus in the periphery of the pith, an internal leptome arises from this cambium, becoming gradually interspersed with stereome. In other words, we have in the stem the type of mestome strands, known as "bicollateral." In the center of the stem is a narrow pith containing single and aggregated crystals.

This structure recurs in the fruit-bearing peduncle, but in this the entire cortex is collenchymatic, and extremely rich in aggregated crystals.

Finally may be mentioned, that a longitudinal section of the stem shows a very peculiar structure of the stereome-strands, which do not follow a straight, but a very distinctly undulate course; a similar structure was observed by Supprian[3] in *Peddiea Fischeri* Engl.

The stem-structure of the *Thymelaeaceæ* is quite interesting, and Solereder[4] has given a general review of the principal anatomical characters.

While the bicollateral structure of the mestome-strands is a feature common to all the genera of the family with the only exception of Drapetes, another peculiarity has been observed, namely the so-called "interxyläres Phloem," leptome developed in the hadrome-rays. This structure has been found in six genera of the family, but not in *Dirca,* and it seems very remarkable that this leptome contains also stereids.

---

[3] Beiträge zur Kenntnis der Thymelaeaceae und Penaeaceae, Engler's Bot. Jahrb., vol, 18, p. 306. Leipzig, 1894.

[4] Systematische Anatomie der Dicotyledonen. Stuttgart, 1899. P. 806.

The development of cambium as a closed ring on the inner flank of the hadrome as in *Dirca* (fig. 5) occurs furthermore in *Daphne* and *Aquilaria*. This cambium may give rise to both leptome and hadrome, inversely arranged, as described by Van Tieghem (l. c.) being characteristic of *Aquilaria Agallocha*.

The cork-cambium develops either in the epidermis or in the peripheral stratum of the primary cortex. Very little seems to be known about the cortex, which in *Dirca* exhibits quite a singular structure; in *Gnidia* and *Thymelaea* the parenchyma is developed in the shape of a palisade-tissue (Van Tieghem, l.c.).

The leaf.—The structure is dorsiventral; the cuticle is thin and smooth on both faces of the leaf-blade, and the epidermis shows only the outer cell-wall slightly thickened. Between the ribs the lumen of epidermis is relatively wide on both faces; in superficial sections the lateral cell-walls of epidermis are nearly straight on the ventral face, but prominently undulate on the dorsal (fig. 6). The stomata (fig. 6) lack subsidiary cells, and are sunk. Long, unicellular, pointed hairs abound on the dorsal face; they are slightly thick-walled and covered with cuticular pearls.

The mesophyll consists of a ventral layer of palisade-cells (fig. 7) covering an open pneumatic tissue of three layers; aggregated crystals abound throughout the mesophyll. The midrib is supported by a hypodermal layer of collenchyma passing into a dorsal water-storage tissue of about six layers, containing single and aggregated crystals. A single, bicollateral mestome strand constitutes the midvein, supported by an arch of stereome on both faces; there is no endodermis.

The very short petiole is hemi-cylindric, and very hairy. The epidermis is quite thick-walled, and the cortex is collenchymatic throughout, with chlorphyll in the ventral strata. It contains a central mestome strand of the same structure as observed in the midrib of the blade.

We have thus the bicollateral structure of the mestome strands represented also in the midvein of the leaf and the petiole although Van Tieghem (*l. c.*) enumerates *Dirca* among the genera, where this structure is confined to the stem. It may be that this author had no access to fresh material, since the structure is certainly very conspicuous in the living plant. With reference to the crystals of calcium-oxalate Van Tieghem credits the occurrence of styloids to *Dirca,* which evidently depends on an error, since this type of crystals was not found in any parts of the plant, although I had ample material for comparison.

Considering the fact that *Dirca palustris* is an inhabitant of damp, rich woods, and that the material, which I have examined came from shaded places in woods on the Potomac shore, the structure is somewhat anomalous. For sciaphilous plants are not, as a rule, equipped with such abundance of mechanical tissue as is the case of *Dirca.* The bark of the root and stem is so tough, that it is used in many parts of the country for ropes, a practice borrowed from the Indian tribes; this peculiar character is expressed by some of the popular names, viz: Leatherwood, Ropebark, and Bois de plomb in Canada. Moreover the structure of the stomata, being confined to the lower face of the leaf, and being sunk below the epidermis, is a heliophilous rather than a sciaphilous structure.

The internal structure of *Dirca* thus illustrates one of the numerous cases, where the anatomical characters cannot be brought in correlation with the surrounding medium, and may be explained most probably as simply inherited characters.[4]

Clinton, Md., March, 1921.

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[4] Compare Vesque, J: De l'anatomie des tissus appliqué à la classification des plantes, Nouv. Archiv. du Muséum d'hist. nat, Ser. II, vol. 4.

ART. XIII.—*A Pseudocycas from British Columbia;* by EDWARD W. BERRY.

The earlier workers with the profuse remains of cycadophyte fronds that are so characteristic of the Mesozoic throughout the world, recognized two general types, which from their resemblance to existing cycad genera, they christened Zamites and Cycadites.

It was very many years later and largely as a result of the anatomical studies of petrified trunks that it became apparent that the vast majority of the Mesozoic cycads represented extinct groups somewhat removed botanically from the still existing members of the phylum.

One of the most interesting of the frond genera, formerly called Cycadites and superficially much like the fronds of the existing oriental genus Cycas, is now known as Pseudocycas. This new proposal we owe to Nathorst, who in 1907 demonstrated that the supposed thick midrib of Heer's West Greenland material represented a median groove on the lower surface of the pinnule, to which groove the stomata were restricted.

A species of Cycadites was described by Dawson in 1883[1] from fairly complete specimens collected by Selwyn at Pine River Forks, Table Mountain, and on Peace River, 25 miles above Dunvegan, both localities in British Columbia. The sandstone from which the Table Mountain material was obtained is said to have contained *Inoceramus altus.* Dawson very naturally referred this form to the genus Cycadites of Brongniart, and compared it with *Cycadites dicksoni* Heer from West Greenland, calling attention to the facts that the former had a stouter rachis, more acute pinnules at more acute angles with the rachis. Subsequently Penhallow[2] tentatively identified *Cycadites unjiga* from two localities along the International Boundary Survey route. These were Sheep Creek valley just southeast of Roseland, and between Pasayten and Skagit rivers in the Cascade Range. These localities he was inclined to consider of Shasta age, but as this author's specific determinations are invariably unreliable these records may well be ignored.

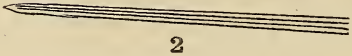
---

[1] Dawson, J. W., Trans. Roy. Soc. Can. ser. 1, vol. 1, sec. 4, p. 20, pl. 1, figs. 2, 2a, 2b, 1882 (1883).

[2] Penhallow, D. P., Idem., ser. 3, vol. 1, sec. 4, p. 308, 1908.

During the summer of 1920 Mr. E. M. Spieker collected a single specimen of this species from the Dunvegan sandstone at Moberly Lake, British Columbia. This specimen, although not as complete as Dawson's type material, abundantly confirms my previously entertained suspicion that *Cycadites unjiga* should be referred to the genus Pseudocycas. This species, which for the present it seems desirable to keep distinct from the two Greenland forms, may be more fully described as follows:


1


2


3

Pseudocycas unjiga (Dawson).

Rachis stout, channeled according to Dawson (my material does not permit an accurate conclusion on this point). Pinnules closely spaced, attached to the sides of the rachis by their entire and slightly expanded bases, linear-lanceolate in outline; their angles of divergence from 30 to 75 degrees; their dimensions ranging from 3 cm. to 6 cm.

in length by about 3 mm. in maximum width. There is practically no diminution in the size of the frond in material showing 13 cm. of rachis. The texture is coriaceous, and each pinnule shows very clearly a well defined longitudinal depression on its under side bounded on either side by a thin ridge, dividing the pinnule into three longitudinal areas of which the median is the widest as shown in fig. 2. This structure gives to impressions the appearance of having an extremely stout midrib.

The British Columbia material does not permit the outlines of the epidermal cells or the position of the stomata to be determined, but in *Pseudocycas insignis* and other species Halle[3] has corroborated the work of Nathorst[4] in showing that the stomata are practically confined to this central groove on the lower surface of the pinnule, and that the epidermal cells have sinuous walls.

A number of Mesozoic species of Cycadites have been examined by these authors as well as by Holden,[5] and in all cases the epidermal walls have been shown to have been sinuous and not like those of the modern Cycas. It is, of course, possible that all of the known fossil species from the Mesozoic that have been referred to Cycadites may belong to Pseudocycas and represent Williamsoniales or Cycadeoidales instead of Cycadales, but until such time as all of the forms can be studied microscopically, it seems advisable to retain the term Cycadites for similar appearing forms of undetermined relationship. In the case of *Cycadites unjiga*, the demonstrated median groove and double midrib renders its transfer to Pseudocycas eminently desirable.

No less than six other species have now been transferred to this genus. Two of these are Wealden forms and the other four come from Greenland beds that have generally been correlated with the Cenomanian stage of the Upper Cretaceous. One of the latter has been tentatively identified by Krystofovich[9] from Sakhalin Island.

The horizon from which *Pseudocycas unjiga* was collected is interesting since it is within the Colorado Group

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[3] Halle, T. G., Geol. Fören. Förhandl., 37, pp. 493-520, pl. 12, 13, 1915.

[4] Nathorst, A. G., Kgl. Sv. Veten.-Akad. Handl., 42, No. 5, pp. 1-11, pls. 1, 2; pl. 3, fig. 1, 1907.

[5] Holden, R., New Phyt., vol. 13, pp. 334-340, tf. 1, pl. 3, 1914.

[6] Krystofovich, A., Jour. Coll. Sci. Univ. Tokyo, vol. 40, art. 8, p. 37, 1918.

and therefore not older than Turonian, although it should be stated that many geologists are of the opinion that the Atane beds of Greenland are not as old as the Cenomanian, so that *Pseudocycas unjiga* may really have been contemporaneous with the Greenland species.

The specimen from Moberly Lake corresponds with Dawson's figure 2a and I have nothing like his figure 2. My material and Dawson's figure 2a are distinguishable with difficulty, if at all, from such specimens of *Pseudocycas insignis* as Nathorst's plate 1, figure 2 and, on the other hand, Dawson's figure 2, in so far as I can tell from the rather poor figure, is like the *Pseudocycas pumilio* of Nathorst. It may be that *Pseudocycas unjiga* represents these two Greenland forms and should be reduced to synonymy. With the continued exploration of the country adjacent to the Peace and Pine rivers, material that will permit of microscopical study is almost sure to come to light, at which time the question can be finally settled.

The Johns Hopkins University.
Baltimore, Md.

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THE
AMERICAN JOURNAL OF SCIENCE
[FIFTH SERIES.]

Art. XIV.—*Further Remarks on the Evolution of Geologic Climates*; by F. H. Knowlton.[1]

In the April, 1921 number of this Journal there are two articles critical of my recent paper on "Evolution of Geologic Climates." These are: "Paleobotany and the earth's early history," by A. P. Coleman, and "Evolution of geologic climates," by Charles Schuchert. These articles seem to call for brief consideration.

The thesis of my paper (p. 501) reads in part as follows:

> "Relative uniformity, mildness, and comparative equability of climate, accompanied by high humidity, have prevailed over the greater part of the earth, extending to, or into, polar circles, during the greater part of geologic time—since, at least, the Middle Paleozoic. This is the regular, the ordinary, the normal condition."

That the truth of this statement is very generally recognized is shown even by the admission of both Professor Coleman and Professor Schuchert. Thus the former says:

> "His [Knowlton's] account of the vegetation of the past confirms and heightens the impression left by paleozoology that during the greater part of the world's history temperatures have been genial even in the far north and far south where frigid climates now reign."

And Schuchert says:

"Any paleontologist who is familiar with the climatic aspects

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[1] Published with the permission of the Director of the U. S. Geological Survey.

of fossils will probably have to agree with Knowlton that the biotic evidence, and chiefly that of the floras, does in general bear out his conclusion that 'climatic zoning such as we have had since the beginning of the Pleistocene did not obtain in the geologic ages prior to the Pleistocene.' "

Let us take first the question of so-called "ice ages." I have freely admitted that there are evidences of refrigeration at a dozen or more points in the geologic column between Huronian and Eocene, but I have questioned whether more than three of them as at present known are entitled to be called "ice ages." Coleman says:

> "The presence of great ice sheets in Australia, South Africa, South America, and India, as admitted by Knowlton himself, is fatal to the theory he advocates, and no suggestion that the period of cold was short affects the conclusion."

If it could be proved that the glaciation on these continents took place with earth temperatures under solar control as Professor Coleman appears to believe, it would indeed be fatal to the theory I have advocated, but this has not yet been demonstrated. Glaciation in or adjacent to the tropics *at or near sea-level,* as attested by interbedded marine deposits, is to my mind impossible under the rays of a vertical sun!

The Permo-Carboniferous glaciation is one of the unexplained mysteries of geology, someone has said, and with the assumption of solar control this is undoubtedly true, but with the predication of dual heat supply it can be and is explainable.

The manner in which this principle is applied is explained at length in my paper and need not be here repeated. It is an explanation that has at least the merit of explaining certain phenomena that are matters of common knowledge and observation that obtrude in studies of geologic climates. It will be noted that nowhere in my paper has it been denied that there are repeated evidences of refrigeration, and it is more than likely that others may be discovered, but my main contention is that, with the exception of possibly three (Huronian, Permo-Carboniferous, Pleistocene), there is to my mind no adequate evidence available that they were more than local, and without widespread effect on temperatures, distribution of life, etc. This linking up of isolated localities all over the world without adequate age-determining data seems to me to be unwarranted.

The question of oceanic temperatures may be considered. On this point Schuchert says:

> "But what Knowlton actually holds is . . . that the temperature of the oceans was everywhere the same without 'widespread effect on the distribution of life.' "

A "careful reading" of my paper, such as Schuchert says he gave it, discloses that what I actually said was as follows:

> "It now seems to be settled beyond serious question that the waters of the early oceans were warm—in fact that they were not permanently cooled as they are now until the approach of the Pleistocene. This does not necessarily mean that there may not have been fluctuation in their temperature from time to time, for there doubtless was; but, taken by and large, the oceans were warm from the equator to the poles. On this point Ulrich says: 'Taking the geologic marine record, as preserved in the fossiliferous rocks from the Cambrian to the Tertiary, it suggests equable, mild, almost subtropical climates over the whole Northern Hemisphere in all the ages represented.'
>
> "Ulrich also adds that there is undoubted evidence, notably in the early Cambrian, and early in the Pennsylvanian, when 'frigid conditions occurred, at least locally.' This is the very crux of the matter, for it seems clear that while there are undoubted evidences of glaciation, they were, at least for the most part, so very local in their effect that they seem to have made very little impress on the temperature of the oceans, and hence on the continuity and distribution of marine life."

Professor Schuchert devotes several paragraphs to the testimony of marine fossils in reflecting temperature changes. Certain groups of animals were common in the far north "and even in arctic water" during the Silurian, Devonian, Pennsylvanian, and Jurassic, while at other times they were greatly restricted or absent from these regions. These, he thinks, "can only mean temperature influences, and that the northern waters were frequently under 65° F."

"On the other hand," he adds, "when the lands are largest and the marine faunas localized in small sea-ways and not widely accessible to the paleontologist, where are the cosmopolitan faunas and the larger forms?", etc.

This seems a rather futile question to ask, for if the faunas were confined to the small water-ways when the continents were emergent, there was little for them to do but back off into the deeper oceanic waters, where the temperature changes but slowly, there to await the return of more favorable conditions. Schuchert appears to recognize the potency of physical causes other than temperature in delimiting these stress-faunas, but adds: "yet the chief deterrent seemingly was the lack of proper warmth." But this appears to be opinion unsupported by corroborating facts, at least in this paper.

The testimony of a number of well-known invertebrate paleontologists may be cited on this point:

Thus, Doctor Ulrich has already been quoted as saying that the geologic marine record, from the Cambrian to the Tertiary, "suggests equable, mild, almost subtropical climates over the whole Northern Hemisphere in all the ages represented." There is evidence, Ulrich adds, of times when "frigid conditions occurred at least locally," but he makes no mention of any zonal disposition of temperatures.

Dr. John M. Clarke writes that while "there is of course plenty of evidence of cold weather periods and also of local cold throughout Paleozoic history, I can not say that such determinations are, in any single particular within my knowledge, dependent upon the fossils of the rocks; nor can I say that the obvious evidences of recurrent land glaciation are connected in any way or supported by any facts deducible from coexistent faunas and floras."

Dr. James Perrin Smith, after discussing the range of certain Triassic limestone with thick coral reefs, interprets the evidence as indicating "a nearly uniform distribution of warm water over a great part of the globe" during Triassic time.

Dr. T. W. Stanton permits me to say that in his extensive studies on the distribution of Jurassic faunas from Texas to Alaska he has failed to find any indication of climatic zones, and Burckhardt has had a similar experience in his studies of the Jurassic faunas of northern South America and Mexico, where he found a striking mixture of types that should appertain to two or more of the so-called climatic zones as interpreted by Neumayr.

If it is urged that some of the above examples relate to distribution in the middle portion of systems, examples are not wanting of beds closing or initiating systems that are likewise widespread and without evidence of climatic zoning. Thus Doctor Ulrich directs my attention to the

Richmond group, that ranges from Baffinland, Alaska, and Baltic Russia south as far as Texas and India. The earliest Niagaran had nearly the same wide-flung distribution. The earliest Devonian Helderberg group, as well as the earliest Mississippian black shale beds, were likewise widespread and without temperature zones.

As near as I am able to interpret certain recent remarks of G. R. Wieland,[2] he appears to hold that much of the paleobotanical data relied upon to interpret geologic climate was based on studies of lowland floras, whereas, when the highland floras are studied, if they are ever available, quite another story may be told. This is easily answered. Interpretations have been based on floras that are actually known and not on what may yet be discovered.

To return again to some of the objections raised by Professor Coleman. In discussing seasonal changes he says that after admitting the presence of growth rings in trees in the Pennsylvanian, Permian, Jurassic, Cretaceous, etc., I do "not explain how this can be reconciled with the uniform and steady supply of heat from the earth's interior under the assumed screen of clouds." I do not recall that I ever stated that the supply of earth heat was "uniform and steady," for I entertain no such view. My whole paper is predicated on a dual heat supply, that from the earth itself and that from the sun. The earth heat undoubtedly fluctuated from time to time as evidenced by vulcanism, to use no other example. When earth heat was at a maximum the cloud envelope was most complete and the sun shut out, but when earth heat diminished evaporation and the cloud spheroid also diminished. I have quoted on this point as follows in my paper (p. 541):

> "As the heat carried up from the earth's surface was more and more lost by radiation into space from the exterior cloud-surface, the isothermal shells would gradually descend, and the temperature of falling rains would become lower, so as under favorable conditions to fall as snow. It is clear that snow-fall might occur at any period of earth's evolution on high mountain ranges or plateaus, and there the accumulations of snow might at any period have formed nevees and glaciers with their well known effects."

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[2] Science, n. s., vol. 53, p. 437.

Under this postulate cooled, if not glaciated, areas could have been developed at any time and place where the conditions were favorable, and these could easily have been reflected in the growth-rings. But again it seems necessary to call attention to the fact that growth-rings are not dependent on changes in temperature, but are produced with equal facility by changes in the supply of moisture.

The so-called seasonal banding of Pleistocene clays is an attractive study, and it seems to many to have been demonstrated by De Geer and others with reasonable certainty as the result of seasonable changes in sedimentation. It must be admitted that the resemblance is striking between these Pleistocene clays and certain banded shales and slates of earlier geologic ages, but on consultation with a number of physical geologists it appears that not all are as yet prepared to accept it at its assumed face value. They point out that we still know so little of the physical conditions surrounding the sedimentation in which these bandings occur that it may be hazardous to attempt to connect them with seasonal fluctuations, especially when unaccompanied by evidence of glacial activities as many undoubtedly are. These "growth-rings" of the rocks as they have been called are obviously dependent on a periodic supply of moisture, but does it necessarily follow that this fluctuation was seasonal?

A circumstance recently reported to me by Prof. A. F. Foerste of Dayton, Ohio, may be of interest. All will recall the disastrous flood that swept Ohio some years ago. This flood was three days rising and four days receding. When it was possible to enter the town Professor Foerste found the floor of his laboratory covered with a layer of fine mud some six inches thick. This mud was *distinctly stratified*, there being not less than twenty-five distinct layers that must have been formed within less than a week.

I shall have to leave this so-called seasonal banding an open question.

Under evidence of aridity Professor Coleman says:

> "To dispute the formation of salt and gypsum beds by evaporation in times of dry heat without suggesting any other mode of forming such deposits is surely unwarranted."

Let us consider the formation of gypsum, pure deposits of which 30 to 60 or more feet in thickness are not uncommon. R. W. Stone[3] of the U. S. Geological Survey has recently reviewed the subject and, after pointing out that calcium sulphate constitutes only about 3.6 per cent. of the 3.5 per cent. of mineral salts held in solution in sea water, says:

> "With these facts in mind, it is difficult to account for the great thickness of some gypsum beds. The quantity of water of normal salinity which would have to be evaporated to make a gypsum deposit 30 or 60 feet or more thick is so great that no known ocean basin would hold it. From 1,000 feet of normal sea water about 0.7 foot of gypsum would be precipitated before the point of saturation for sodium chloride would be reached; to precipitate 30 feet of gypsum would require about 43,000 feet of water."

The explanation offered then is the evaporation of sea water in an inclosed basin which is shut off by a low barrier from continuous access to the sea but which is continually replenished by periodic incursions of the sea. Can Professor Coleman visualize the physical setting necessary to account for gypsum deposits in all parts of the world at all geologic horizons, and so nicely adjusted as to admit just the right amount of water at just the right times and just the right degree of concentration to keep the deposition a continuous and apparently uninterrupted process? Should not the layers of gypsum, if accumulated under these conditions, be of fairly uniform thickness and widely extended? It is well known, however, that gypsum deposits thicken and thin laterally within very short distances in a very disconcerting manner. Why are gypsum deposits unfossiliferous? Because the water had already reached such a degree of concentration as to be unfavorable to life, we are told, yet is it not rather remarkable that during the hundred of times the impounded water must have been replenished from the adjacent sea that no marine life or impurities of one kind or another found entrance? Stone states that 80 per cent of this impounded sea water must be evaporated before the deposition of gypsum begins, and seemingly every fresh incursion of sea water would so dilute it as automatically to stop the deposition of gypsum until the earlier deposited solids had been thrown down. The beds of gypsum should therefore be inter-

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[3] Stone, R. W., Gypsum deposits of the United States, U. S. Geo. Survey, Bull. 697, pp. 22-26, 1920.

rupted by layers of other solids, which it seems is ordinarily not the case. The deposition of a bed of pure gypsum from the evaporation of a single filling of this postulated inclosed basin is understandable, but when we must account for beds 30 to 60 feet thick, calling for the evaporation of a body of water from 8 to 15 miles deep, the proposition becomes top-heavy. A further complication also arises when it is recalled that many of the deposits containing gypsum are obviously continental deposits.

Of course deposition by evaporation from impounded water is not the only way in which gypsum may be formed. Thus, some deposits are now explained as deposition from solution in ground water and others as deposits produced by alteration, by action of sulphuric acid on calcium carbonate. Bedded limestone may be changed to bedded gypsum by contact with sulphuric acid derived from ground water from pyritic shales. The gypsum deposits in the Silurian of New York are thus explained.

In an abstract of a paper on "Some conclusions in regard to the origin of gypsum," just published, F. A. Wilder[4] says:

> "While admitting that this [salt-pan] theory best explains some gypsum deposits it seems probable that many important bodies of gypsum owe their origin to other causes and conditions. . . . Present day gypsum deposits are, for the most part, afflorescent deposits, periodic lake deposits, spring deposits, and deposits due to the alteration of carbonate to sulphate. There is reason to believe that many important gypsum deposits of earlier periods owe their origin to similar causes."

Professor Coleman says that to dispute the formation of gypsum beds "by evaporation in times of dry heat" is unwarranted. As to the matter of dry heat, I have been under the impression that evaporation depended on the relative humidity and pressure of the atmosphere, that is to say, if the air contains less moisture than it is capable of holding there will be evaporation quite irrespective of the temperature.

From the above discussion of the processes by which gypsum may be deposited and the difficulties that seem to beset its accumulation by the evaporation of impounded sea water, it appears to me that the blanket statement

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[4] Wilder, F. A., Geol. Soc. Am., Bull., vol. 32, p. 67, 1921.

that deposits of gypsum necessarily imply aridity is "surely unwarranted." That gypsum may sometimes be precipitated from impounded sea water is undoubtedly true, but that all or even a very considerable part is so formed is not proved, and, I may add, that to my mind it is not provable.

As a supposed sure indication of aridity the presence of red beds furnish another case in point. It now seems to be acknowledged that the formation of red rocks (except when derived from rocks originally red) is not now known to be going on under desert conditions at the present time, and hence there is little reason to suppose that they were so deposited in the past.

The presence of so-called sun cracks seems also a questionable indicator for aridity. They might better be called shrinkage cracks, for they are developed whenever and wherever mud dries out, whether the sun is shining on it or not.

Professor Coleman "finds it difficult to believe in a warmly humid world enveloped in rain clouds that never parted to let in the sun until the Pleistocene."

Again I must call attention to the fact that I have nowhere stated that the sun never shone through the cloud envelope, but rather that it did not gain permanent control of earth temperatures until or approaching Pleistocene time.

Both Professor Coleman and Professor Schuchert appear to have overlooked or perhaps failed to appreciate one of the principal objects I had in mind in writing the paper on geologic climates, namely, the search for the explanation of certain of the fundamental principles that must have operated in determining and delimiting the climates of the past.

For example, has the sun dominated earth temperatures throughout all geologic time as it is acknowledged to have done during and since Pleistocene time?

If the sun causes a zonal disposition of temperatures on the earth's surface, what caused or permitted the nonzonal disposition that all agree to have obtained for at least vast stretches of time when climates were undoubtedly equable over the whole earth?

What was the source or sources of heat that warmed the early oceans?

Is the postulate of a dual heat supply a logical and legitimate proposition?

These and other problems of similar import are left untouched. Constructive criticism is always helpful; destructive criticism is less so. I asked for bread but thus far have received little but striated pebbles.

ART. XV.—*A Study of Diceratherium and the Diceratheres;*[1] by EDWARD L. TROXELL.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

TABLE OF CONTENTS.

INTRODUCTION.

At present there are but two species of *Diceratherium*, *D. armatum* and *D. annectens*, which are accepted without reservation by students of paleontology; yet species from two continents have been referred to the genus, as well as all specimens from the John Day region of Oregon and those from the Lower Miocene of the Great Plains.

Our inability to classify harmoniously all the two-horned rhinoceroses under this genus does not tend to lessen its importance nor its distinction, and although there is a wide variation in John Day rhinoceroses, it is necessary to put them together into one group and at the same time separate that group from all others. Following is a list of the Oregon species of the true *Diceratherium*:

Diceratherium hesperium (Leidy) 1865. Inadequate. Figured heautotype, Cat. No. 10239, Y.P.M.
Diceratherium pacificum (Leidy) 1871. Inadequate. Figured heautotype, Cat. No. 10287, Y.P.M.
Diceratherium annectens (Marsh) 1873. Holotype, Cat. No. 10001, Y.P.M.
Diceratherium armatum (Marsh) 1875. Genoholotype. Holotype, Cat. No. 10003, Y.P.M.

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[1] This is the last of the series of four papers on the American rhinoceroses. Three other parts appeared in this Journal for July, 1921. It is a pleasure to state that all of the drawings in these four papers were made by Rudolph Weber, whose work is so well known to scientists everywhere.

Diceratherium nanum (Marsh) 1875. Holotype, Cat. No. 10004, Y.P.M.
Diceratherium truquianum (Cope) 1879. Holotype, A.M.N.H. (Cope Coll.), Cat. No. 7333.
?Diceratherium oregonense (Marsh) 1873. Incertæ sedis. Holotype, Cat. No. 10002, Y.P.M.
Diceratherium lobatum, sp. nov. Holotype, Cat. No. 12487, Y.P.M. Fig. 6.
Diceratherium cuspidatum, sp. nov. Holotype, Cat. No. 12007, Y.P.M. Fig. 7.

THE TRUE DICERATHERES.

Diceratherium Marsh.

The genoholotype, *D. armatum,* based on a large skull (Cat. No. 10003, Y.P.M., fig. 5) from the middle John Day beds of Oregon, has unusually simple teeth and enlarged broad nasals with rugosities not rounded, but elongated antero-posteriorly, separated and directed outward. Its size and the simple, primitive teeth make us think that the living conditions were not severe, that there was an abundance of nourishing food, and a moist climate. The molars resemble those of *Metamynodon.*

Diceratherine species from the Great Plains are here separated from *Diceratherium* Marsh and put under separate generic groups: *Metacœnopus* Cook and *Menoceras,* gen. nov.

The species with simpler teeth, of larger size but with more subdued nasal eminences, belong with the genus *Metacœnopus,* genoholotype *M. egregius* Cook. The smaller animals from the Agate Spring quarry, of slightly later age, with teeth more progressive in their subhypsodonty and in the development of additional folds of enamel, with horn rugosities even more prominent than in *Diceratherium,* are grouped under *Menoceras* nobis, the genoholotype of which, *D. cooki* Peterson, is defined later.

Diceratherium armatum Marsh.—The following points may serve in part to define this species: (1) males with well developed, widely separated, oval rugosities on the nasals in maturity; (2) moderate deepening of sinuses and pits of teeth, or increase in height of ridges, reaching an extreme in later rhinoceroses (*?D. oregon-*

ense); (3) cingula broken on the molars, weak on the tetartocones, with a tendency toward elimination; (4) development of minute folds into a crochet, but virtual absence of a true crista; (5) moderate grooves on the protoloph of molars, separating the protocones from the protoconules, absent on premolars; (6) incisors and canines lost from premaxillary, except first and possibly second incisor; (7) milk dentition rather complex; (8) in size one of the largest rhinoceroses of the time; (9) geological age, middle John Day, corresponding to the Upper Oligocene or Lower Miocene of the Great Plains.

FIG. 1.

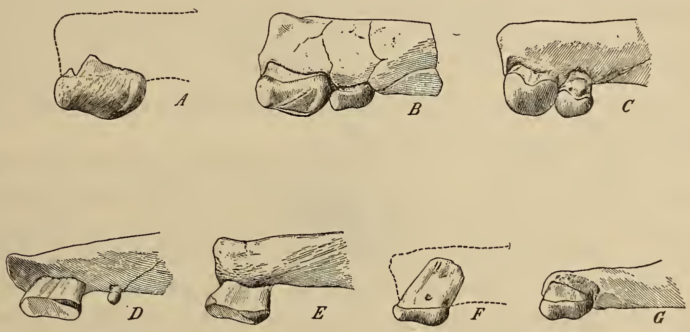

FIG. 1.—Premaxillaries showing the development of incisors in various species of *Diceratherium* in the Yale collections. All shown from the left outer side. × 1/3.

A, D. armatum. Cat. No. 10005. Second incisor unknown and bone restored in outline.

B, D. armatum. Cat. No. 11068. Two moderately large incisors present.

C, D. lobatum, sp. nov. Holotype. Cat. No. 12487. Lobate character of incisors and relatively large size of second one are unusual features. See figure 6 and the text description.

D, D. nanum. Cat. No. 11184. Drawn reversed. Note persistent small second incisor. In this old individual the prominent horn rugosities are wide spreading.

E, D. nanum. Holotype. Cat. No. 10004. See figure 2 and the text description. No second incisor present.

F, D. annectens. Holotype. Cat. No. 10001. See the text description following, and also figure 3.

G, D. annectens. Cat. No. 12019. A young specimen with premolars almost exactly like those of the holotype (fig. 3) but slightly smaller. Nasals broad but no prominences have developed.

Diceratherium annectens (Marsh) is a smaller species of rhinoceros, also from Oregon; it was named by Marsh from a specimen (Cat. No. 10001, Y.P.M.) consisting of the four upper premolars, the large upper incisor (see fig. 1 *F*), and the distal end of the tibia. The premolars (fig. 3) measure in length three fourths those of *D. armatum*, the incisor less than two thirds. The species differs so markedly from the type species of the genus that it might justly be put in some other group: (1) the crochet is almost lacking, possibly due to wear, the crista being much more distinct; (2) the cingula are entirely obsolete on the inner side of the deuterocone, but are strong around the tetartocone; and (3) the size is much smaller.

In certain features this species is more progressive: the deeper pits and sinuses, the cristæ, and the grooves marking off more distinctly the deuterocone in $P^{3.4}$. It has a close similarity to *Menoceras cooki* in its size, broken cingula, and the general form of the cross lophs; but the differences, especially the foldings of enamel, are greater and more fundamental.

Peterson (1920) is justified in putting *Diceratherium nanum* Marsh in a minor taxonomic position, because the type is so incomplete; there is, however, a difference from *D. annectens* of one fifth in the size of the incisors, the only parts duplicated. The worn teeth and broken skull of the holotype of *D. nanum* are nevertheless of value in showing the reduction of the incisors to the formula, $I\frac{1}{2}$, and in showing the long diastema between the incisors and premolars, and the true *D. armatum* type of horn cores. (See fig. 2.)

FIG. 2.

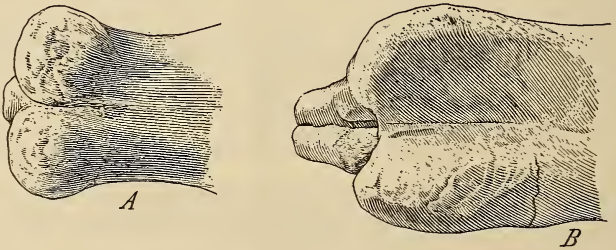

FIG. 2.—A comparison of the horn rugosities in (*A*) *Menoceras cooki* (Peterson), gen. nov., Cat. No. 10273, Y. P. M., where they are rounded knobs; and (*B*) *Diceratherium nanum* Marsh, holotype, Cat. No. 10004, Y. P. M., showing the broad nasals with elongated narrow ridges typical of all true diceratheres. × 1/3.

Of the six species of rhinoceros named from the John Day beds, *D. hesperium* (Leidy), *D. pacificum* (Leidy), *D. truquianum* (Cope), *D. nanum* Marsh, *D. annectens* (Marsh), and *D. armatum* Marsh, we agree with Peterson that only the last two constitute valid species, although some of the others may give valuable hints on the fauna.

FIG. 3.

FIG. 3.—*Diceratherium annectens* (Marsh). Holotype. Cat. No. 10001, Y. P. M. Premolar teeth with simple parallel lophs. × 1/3.

FIG. 4.

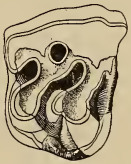

FIG. 4.—Restoration of *Rhinoceros* (*Diceratherium*) *oregonensis* Marsh. Holotype. Cat. No. 10002, Y. P. M. Probably the fourth premolar of an undetermined genus from the Mascall formation of the John Day Valley, Ore. × 1/3.

Rhinoceros (*?Diceratherium*) *oregonensis* Marsh, known only by the fragment of a tooth (Cat. No. 10002, Y.P.M., fig. 4), shows the presence of a large, much advanced genus in the Mascall beds of Oregon, comparable to the Miocene or Pliocene rhinoceroses elsewhere.

FIG. 5.

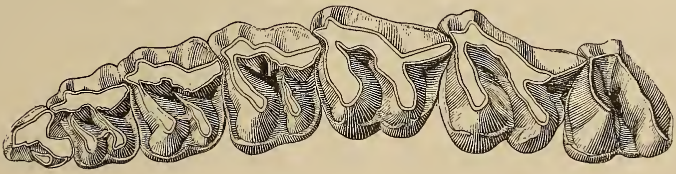

FIG. 5.—*Diceratherium armatum* Marsh. Holotype. Cat. No. 10003, Y. P. M. Crown view of molars and premolars. Note simplicity of the teeth, molar-like form of premolars, and large size. × 1/3.

Diceratherium lobatum, sp. nov.

(Fig. 6.)

Holotype, Cat. No. 12487, Y. P. M. Probably from the true Diceratherium zone, Turtle Cove, John Day River, Oregon.

The holotype consists of the anterior portion of a skull, collected in 1875 by William Day. Although slightly smaller than *D. armatum*, the new species shows a much greater complication of enamel, in which respect it is more advanced in its evolution; but it is more conservative in that it still possesses two incisors (see fig. 1 *A*, *B*, and *C*, comparing referred specimens of *D. armatum*).

Dentition.—The premaxillaries are quite slender, both laterally and vertically, and extend well beyond the premolars. The first or median incisors are smaller in antero-posterior dimension than even those of *D. annectens* (see fig. 1) and are rounded and lobate rather than elongated and pointed in front. I^2 is more than half as large as I^1, an unusual thing for this tooth is commonly very small or absent. Both teeth are rounded and lobate as viewed from the side and resemble the form of an elk tooth; it is this feature which suggests the specific name.

Fig. 6.

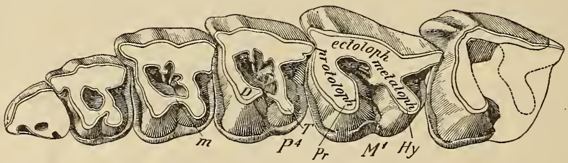

Fig. 6.—*Diceratherium lobatum*, sp. nov. Holotype. Cat. No. 12487, Y. P. M. Crown view of premolars and molars, excepting M^3, showing the complication of enamel and the cross ridges united by the "mure", *m*, a wall across the median valley. The designations of the ridges or lophs: ectoloph, protoloph and metaloph, apply both to molars and premolars; *D*, deuterocone, and *T*, tetartocone, to the premolars; *Pr*, protocone, and *Hy*, hypocone, to the molars. See also figure 1 *C* for premaxillary and incisors of the same specimen. × 1/3.

The premolars are distinctly bridged from loph to loph and united by a wall, which may be technically known as the *mure*, projected across the median valley effectively damming it up in such a way as to form the deep central pit completely surrounded by an enamel border.

The mure is entirely absent from P^4 of *D. armatum* and is incipient on $P^{2.3}$. It is a feature of varying development in *Cœnopus* and *Metacœnopus* of the Great Plains also but is not homologous with the encircling protoloph of more primitive forms.

Premolar teeth seem to reflect most quickly the evolutionary changes of a race. Here are shown the crista and crochet, supplemented by numerous small folds giving a distinctive air of advancement, features which were not simply lost by wear in *D. armatum* but which never existed.

Both molars and premolars of *D. armatum* have deep postfossettes. In the new species, these are shallow and narrow and the metaloph rises from the posterior cingulum direct. The teeth have the appearance of being slightly longer-crowned than usual, and they have decidedly straighter outer surfaces. In *D. armatum* there is a deep groove, especially on P^4 just in front of the paracone, and a second distinct ridge in the middle of the ectoloph.

The development of the crochet and antecrochet in the first molar results in a closing of the median valley and the raising of its floor a full centimeter above the deepest part. This is not homologous with the mure of the premolars. In M^1 of *D. armatum* there is scarcely a change of level of the valley bottom.

The cingula are almost obsolete on the outer side of all teeth, but one is present about the protocone of each molar. There is a coating of cement on the outer sides of the cheek teeth.

Whether or not this specimen had heavy nasals for the support of horns we have no way now of determining, but it is of minor importance since both types are well known among the John Day diceratheres and it is considered a sexual variation simply.

A very large antorbital foramen was traversed by the blood vessels and nerves to the lips and face; indicating that there may have been a large facile lip like that of the African black rhinoceros of to-day.

Diceratherium cuspidatum, sp. nov.

(Fig. 7.)

Holotype, Cat. No. 12007, Y. P. M. Middle John Day, near Bridge Creek, John Day Valley, Oregon.

The holotype of this new species consists of both maxillaries with all the cheek teeth save P^1. As compared with *D. armatum*, the smaller specimens seem generally to be more progressive in the development of enamel folds on the teeth, and this new species, especially, shows the complex pattern crenulations, together with additional cusps and irregularities of the cingulum to an unusual degree.

Fig. 7.

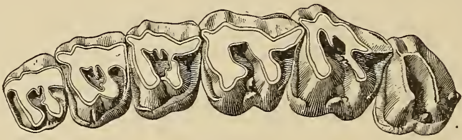

Fig. 7.—*Diceratherium cuspidatum*, sp. nov. Holotype. Cat. No. 12007, Y. P. M. P^1 is missing. The teeth have many folds of the enamel and there are strong internal basal cusps. × 1/3.

The species name is chosen because of the small conical tubercles arising from the floor of the median valley in the first and third molars, which in M^3 come to be high cusps 6 or 7 mm. tall and 4 mm. broad at the base, a feature unique in the rhinoceroses. Except for this internal cusp and a short segment of the cingulum, the valleys of the molars are open; they are not obstructed by the crochet and antecrochet as in *D. lobatum* and the slender protocones are not set off by distinct grooves from the antecrochet.

A conspicuous style marks the outer end of the posterior cingulum on M^3, but with the exception of M^1 neither molars nor premolars have a trace of cingulum on the outer side.

The size is approximately that of *D. annectens* (fig. 3), but a marked difference is shown on the premolars by the cristæ and crochets, the cingulum encircling the deuterocone, and the shape of the medifossette inclosed, in $P^{3.4}$, by a mure. As in *D. annectens*, P^2 is subquadrate, but the protoloph is less prominent and does not extend beyond the metaloph. The anterior portion of the ectoloph is not so prominent on any of these premolars, but in P^2 it is unusually subdued. A small internal basal cusp may be seen on this tooth also. $P^{3.4}$ each show the mure joining the two inner lophs. On these teeth the crochet is situated well out on the metaloph; it is not directed forward but inward toward the slender crista as though in anticipation of a continuous wall in later forms.

In each premolar the metaloph is compressed and very narrow between the central and posterior fossæ. The medifossette itself approaches a cylinder in form in that the sides are nearly parallel vertically; this marks a beginning of hypsodonty, and is a character to be noted in *Menoceras cooki* and other Miocene diceratheres.

In this species the posterior nares extend forward to the first molar.

Measurements of Holotypes.

	D. armatum	*D. lobatum*	*D. annectens*	*D. cuspidatum*
	No. 10003	No. 12487	No. 10001	No. 12007
	Y. P. M.	Y. P. M.	Y. P. M.	Y. P. M.
	mm.	mm.	mm.	mm.
I^1, ant.-post. diameter	34*	20	21	
P^1, length, ant.-post.	29	24	20	?19
Width, transverse	27	21	18	
P^2, length	33	31	24	24
Width	39	36	29	30
P^3, length	39	38	29	28
Width	47	47	35	36
P^4, length	40	39	29	30
Width	51	52	37	39
M^1, length	52	53		39
Width	53	54		41
M^2, length	55			42
Width	57	54		43
M^3, length	47			34
Width	50			37
Molar-premolar length	254			?190
Molar series, length	144			105
Premolar series, length	129			?97

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* Measure of plesiotype, No. 10005, Y. P. M., fig. 1 *A*.

THE DICERATHERES OF THE GREAT PLAINS.

Menoceras, gen. nov.

Scarcely a more conspicuous or better known species of extinct rhinoceroses is mentioned in our literature than that which includes those specimens found and named by Peterson (1906) from the famous Agate Spring quarry on the ranch of Mr. Harold Cook at Agate, Neb. With the approval of Mr. Peterson, this species, *Diceratherium cooki*, is here made the type of a new genus, *Menoceras* (μένος, strength, κέρας, horn) and the following forms may be classed under this head, most of which Peterson considers invalid as species:

Diceratherium cooki Peterson 1906. Genoholotype.
Diceratherium arrikarense Barbour 1906.
Diceratherium schiffi Loomis 1908.
Diceratherium stigeri Loomis 1908.
Diceratherium aberrans Loomis 1908.
Diceratherium loomisi Cook 1912.

After a comparison with the genoholotype of *Diceratherium, D. armatum*, with which it has always been associated, it is very clear that *Menoceras* is probably the farthest removed from *Diceratherium* of all the Miocene-Oligocene rhinoceroses. This great difference was recognized by Peterson (1920), who calls attention to the features of *Menoceras cooki* here briefly enumerated: (1) form of the horn cores (fig. 2), (2) form of the muzzle and anterior nares, (3) expanded zygomatic arch with rugose angles, (4) complication of the cheek teeth and union of the crochet with the ectoloph. Other distinctive features, widely differentiating it from *Diceratherium,* are the smaller size, great geographical separation, unusual deepening of the pits and sinuses on both molars and premolars, almost complete absence of cingula, an extra transverse loph on the second deciduous premolar, and the closing of the external auditory meatus below.

It has been suggested by Peterson (1920) that *M. cooki* is derived from *Cænopus mitis*, a lower Oligocene species. *C. dakotensis* Peterson, also based on a lower jaw, but from the Protoceras beds, is considered by its author to be a connecting link because of the short symphysis and diastema, the curving of the lower border of the ramus, and the everted angle. A comparison with *C. tridactylus proavitus* offers a further answer to the question of the ancestry of *M. cooki,* for in both we see the broad sagittal crest with converging straight lines, the heavy rugose angles of the temporal bone, and in the former an early stage of horn evolution.

Cænopus tridactylus in the Oligocene shows foldings of the enamel which may have given rise to the complex pattern of *M. cooki,* and it is reasonable to suppose that, just as favorable conditions must have influenced the opulent development of *D. armatum* in Oregon, so an unfavorable environment required a better dental mechanism and greater protection by the horns, at the expense of increased stature, on the Great Plains: *M. cooki* is scarcely two thirds as large as *D. armatum.*

FIG. 8.

FIG. 8.—Milk teeth, $Dp^{2,3}$, of *Diceratherium annectens?* Cat. No. 12003, Y. P. M. For comparison with those of *Menoceras cooki,* see Peterson 1920, pl. 65, fig. 2. × 1/3.

The anterior portion of the skull and jaws (No. 12500, Y.P.M.) of a specimen of *M. cooki* was found by Professor Lull in 1908 near Rawhide Buttes, Wyoming, showing the distribution of the species in places other than the Agate Spring quarries.

Metacænopus egregius (Cook).

M. egregius (Cook) has for its holotype a fine skull and portions of the lower jaws in the private collection of its author. Although the species is considered by Peterson (1920) to be a synonym of *M. niobrarensis,* it seems to warrant the rank of a subspecies at least, and in any case should be retained as the type of the genus so happily named. Important features of the genus are: the larger size, smaller horn rugosities on the male skulls, the simpler teeth, and a distribution limited to the Great Plains. From the shape of the skull and the incipient horn rugosities one is led to believe that its ancestor was *Cænopus tridactylus* and therefore closely related to the true *Diceratherium* of Marsh.

This genus may include the following species:

Metacænopus niobrarensis (Peterson) 1906.
Metacænopus petersoni (Loomis) 1908. Inadequate.
Metacænopus egregius (Cook) 1908. Genoholotype.
Metacænopus gregorii (Peterson) 1920. Of doubtful validity.

M. petersoni Loomis, whether or not it is specifically distinct from *M. niobrarensis* or *M. egregius,* is of importance as showing that the Agate Spring quarries have a variety of rhinoceroses, and not *Menoceras cooki* alone.

M. gregorii Peterson is specifically indistinguishable from *M. egregius*; it is unfortunately based on a fairly complete skull but with characterless teeth; however, it is of interest in so far as it shows the spread of *Metacænopus* into the region of South Dakota.

SUMMARY.

In restudying the American horned rhinoceroses of Oligocene-Miocene time, one is impressed with the need of a systematic grouping which, first, will distinguish those of the Great Basin of Oregon, *Diceratherium* Marsh, from those of the Great Plains; second, will differentiate that well known group of animals from Nebraska and Wyoming, here designated *Menoceras cooki* (Peterson) gen. nov. from *Metacænopus* Cook; and third, will separate all from *Aceratherium* Kaup of the Old World.

In the present paper, all the known species of diceratheres are classified, the more important ones are redescribed, and two new species are proposed from the abundant material collected by Professor Marsh. From this study the conclusion is reached that in the light of our present knowledge it can not be reasoned that a hornless rhinoceros is of an aceratherine species, for the adult male may have been well armed.

Art. XVI.—*Fossil Vertebrates and the Cretaceous-Tertiary Problem;* by W. D. Matthew.

Recent contributions to *Science* by Professor Schuchert, Dr. Cross and Dr. Knowlton[1] have brought up again the old controversy as to the dividing line between Cretaceous and Tertiary formations in America. As the fossil vertebrate faunas afford an important part of the evidence on this dispute, very considerably increased by collecting and research in recent years, I have been asked to give a brief résumé of this evidence and of the conclusions to which my interpretation of it has led.

Recent Additions to the Vertebrate Evidence.

When the problem was discussed in 1913 by the Geological Society of America I contributed a paper[2] setting forth the data up to date especially as regarded the Paleocene formation. Since then considerable advances have been made in the study of the Vertebrata. I have been engaged jointly with Mr. Walter Granger upon a revision of the Lower Eocene mammals, now mostly published, and of the Paleocene mammals of New Mexico, still in progress.[3] Mr. Gilmore has contributed two most valuable memoirs, one on the vertebrates of the Ojo Alamo formation, the other upon the reptiles of the Puerco and Torrejon formations of New Mexico.[4] A very large amount of new information is now at hand as to the faunas of the late Cretaceous vertebrates of Alberta, partly in the published contributions by the late Mr. Lambe,[5] Mr. Barnum Brown,[6] Professor Osborn[7] and

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[1] Schuchert, 1921, Science, 53, p. 45, Jan. 14; Cross, 1921, ibid., p. 304, April 1; Knowlton, 1921, ibid., p. 307, April 1.

[2] Evidence of the Paleocene Vertebrate Fauna on the Cretaceous Tertiary problem, Bull. Geol. Soc. Am., 25, pp. 381-402.

[3] See various articles by Granger, Sinclair and the writer, in Bull. Am. Mus. Nat. Hist., 1914-1919.

[4] Gilmore, 1916, U. S. G. S. Prof. Pap. 98 Q, pp. 279-302; 1919, idem, Prof. Pap. 119, pp. 1-68.

[5] Lambe, 1914, Ottawa Naturalist, vol. 27, pp. 130-135, 145-155; vol. 28, pp. 13-20; 1915, Can. Geol. Sur., Mus. Bull. No. 12, pp. 1-49; 1917, Ottawa Nat., vol. 30, pp. 117-123, vol. 31, pp. 65-73; Can. Geol. Sur., Mem. No. 100, pp. 1-84; 1920, Can. Geol. Surv., Mem. No. 129, pp. 1-79.

[6] Brown, 1914, Bull. Am. Mus. Nat. Hist., vol. 33, pp. 539-548, 549-558, 559-565, 567-580; 1916, idem, vol. 35, pp. 701-708, 709-716; 1917, idem, vol. 37, pp. 281-306.

[7] Osborn, 1917, Bull. Am. Mus. Nat. Hist., vol. 35, pp. 733-771.

Professor Parks,[8] the major part unpublished. Mr. Gidley is still engaged upon the important mammal fauna of the Fort Union, but a portion of his researches are published and available. Dr. Schlosser has recently described[9] and illustrated a small collection of Cernaysian fossils in Berlin Museum, and discussed their affinities and geological correlation. Finally, but not least in importance, M. Teilhard de Chardin has been engaged upon a very able and thorough revision of the Paleocene and Lower Eocene mammal faunas of the Paris basin and has published a brief résumé of his conclusions.[10]

Characteristics of Late Cretaceous Vertebrate Faunas.

In summarizing the vertebrate evidence it will perhaps be best to begin with the faunas above and below those in dispute, whose position in the Cretaceous and Tertiary respectively is beyond question.

1. The Judith or *Belly River* formation on the Red Deer River, Alberta, lies conformably beneath the upper part of the marine Upper Cretaceous Fort Pierre. Its position in the Cretaceous is undisputed. It is equivalent to a part of the Upper Senonian chalk of Western Europe Upper Cretaceous but by no means at the end of the conformable Cretaceous succession, as it is followed by the Maestrichtian and Danian divisions of the chalk representing a long period of time. It contains a splendidly preserved vertebrate fauna.

2. The *Wasatch* formations in Wyoming, New Mexico and elsewhere contain a vertebrate fauna of Suessonian, Lower Eocene, age, corresponding and very closely related to the fauna of the *Argile plastique* of the Paris basin and the London Clay of England. They have yielded a very large and varied mammalian fauna, and some reptiles, etc.

Between these two undisputed horizons lie the formations under discussion. They belong either just above or just below the boundary line, a line whose precise position must be fixed either by precedent or by agreement.

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[8] Parks, 1920, Univ. Toronto Stud., Geol. Ser., No. **11**, pp. 1-76.

[9] Schlosser 1921, Palæontographica, LXIII, pp. 97-144, 2 pl.

[10] Comptes Rendus, Dec. 6, 1920, pp. 1161-1162.

The Cretaceous fauna consists of six families of gigantic terrestrial reptiles, popularly lumped under the term dinosaurs, but belonging to two distinct orders, five families of chelonians, two families of crocodilians, one of rhynchocephalians, and two of mammals. The range of these families is shown in the accompanying table.

		Mesozoic					?	Cenzoic			
Geologic Range of Vertebrate Fauna of Upper Cretaceous Judith R. = Belly R. = Ojo Alamo.		Jurassic	L'r Cret.	Judith R.	Edmonton	Lance	Paleocene	Eocene	Oligocene	Mio.-Plioc.	Pleist.-Rec.
SAURISCHIA	Deinodontidæ	..	X	X	X	X					
	Ornithomimidæ		X	X	X	X					
ORNITHISCHIA	Hadrosauridæ			X	X	X					
	Iguanodontidæ	X	X			X					
	Ceratopsidæ			X	X	X					
	Scelidosauridæ	X	X	X							
	Nodosauridæ		X	X	X	X					
CHELONIA	Pleurosternidæ			X		X	X				
	Baenidæ			X	X	X	X	X			
	Plastomenidæ			X		X	X	X			
	Dermatemydidæ			X		X	X	X	- - -	- - -	- - -
	Trionychidæ			X		X	X	X	X	X	X
PLESIOSAURS		X	X		X						
ICHTHYOSAURS		X	X								
SQUAMATA	Mosasauridæ		- -	- -							
CROCODILIA	Crocodilidæ			X		X	X	X	X	- -	- -
CHORISTODERA	Champsosauridæ			X	X	X	X				
MULTITUBERCULATA	Plagiaulacidæ	X	X	X		X	X				
MARSUPIALIA	Cimolestidæ			X		X					

Dinosaurs are the dominant vertebrates of a Cretaceous land fauna, as plesiosaurs, mosasaurs, etc., are of the marine facies. The turtles include five families, one of which survives to the end of the Paleocene, three to the end of the Eocene (one with a few relatives still living in Central America), the fifth is still abundant. The crocodiles include Mesozoic marine groups, but the essentially Tertiary Crocodilidæ make their first appearance in the Upper Cretaceous. The mammals are all Metatheria, an essentially Mesozoic stage, and belong to the marsupial and multituberculate orders. Both these orders occur in the Jurassic, Lower and Upper Cretaceous, and the marsupials survive to the present day.

Characteristics of Paleocene Mammal Faunas.

The principal Paleocene mammals in order of their importance, abundance and variety are:

1. *Taligrada,* two families, Periptychidæ and Pantolambdidæ; limited to the Paleocene.

2. *Condylarthra,* two families, Mioclænidæ and Phenacodontidæ, the first limited to the Paleocene, the second surviving into Lower Eocene.

3. *Carnivora,* of the very primitive creodont families, Oxyclænidæ, Arctocyonidæ and Mesonychidæ, the first two surviving as rarities into the Lower Eocene, the last found throughout the Eocene. But the progressive Miacidæ also have a representative in the Torrejon.

4. *Tæniodonta,* peculiar archaic types allied to the edentates. Two families, Stylinodontidæ and Conoryctidæ, only the former surviving into the Eocene, as a rarity.

5. *Multituberculata* are fairly common and represented by several genera allied to the Lance and Belly River Plagiaulacidæ. They give a distinctly Mesozoic aspect to the fauna. A single specimen of a multituberculate has been found in the lower Wasatch of Wyoming.

6. *Insectivora.* Besides the Leptictidæ, which survive until the Oligocene, there are some genera of more uncertain affinities: Mixodectidæ peculiar to the Torrejon, *Pentacodon* supposed to be related to the Eocene Pantolestidæ, and an interesting Zalambdodont genus *Palæoryctes.*

7. *Marsupials.* The true opossums appear in the Puerco, taking the place of the nearly related but more archaic Cimolestidæ of the Judith and Lance. They last through to the present time, though always rare fossils.

At the close of the Paleocene, in the Tiffany and Cernaysian and especially in the Clark Fork, an increasing number of Eocene mammal groups are represented. The Plesiadapidæ of the Tiffany, Cernaysian, Clark Fork and Eocene are on the border between menotyphlan insectivores and Primates, and in the Tiffany the earliest true primate appears, a tarsiid (''anaptomorphid''). Two primitive members of the Eocene oxyænid family and the Lower Eocene genus *Coryphodon* are found in the Clark Fork horizon. These few precursors, however, are scarcely enough to affect materially the great faunal change that comes with the true Eocene, with its abundant perissodactyls, its artiodactyls, rodents, adapid primates, progressive creodonts, and abundant *Coryphodon*.[11]

The antique character of all these Paleocene faunæ is seen in their retention of primitive characters in teeth and feet, as urged by Cope long ago, and abundantly confirmed by our later studies. They stand in marked contrast with the prevalent fauna of the Lower Eocene (Wasatch), already much advanced in tooth and foot structure. They can only be understood as representing a varied, often specialized, but unprogressive series of faunæ, which was largely displaced at the beginning of the Eocene by a far more advanced one, the survivors lingering along for a time but dropping out one by one in spite of their continued specialization on their more archaic lines.

Characteristics of Early Tertiary Vertebrate Faunas.

In the following tabulation of range I have starred those families and orders which I regard as modernized and essentially Tertiary[12] in type. It will be seen that some of them appear somewhat before the Wasatch, but the great majority make their first appearance at that stage.

The Tertiary land vertebrates consist principally of placental mammals, the greater part of them of modern orders (perissodactyls, artiodactyls, Carnivora, rodents, Primates, etc.) and including the ancestral stock of the modern quadrupeds; but in the Eocene there is also a

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[11] *Coryphodon* has been recorded from the 'Montien' upon the evidence of a tibia which I had opportunity to examine last summer through Dr. Dollo's courtesy. It may be a large taligrade, or of some other group; it is not characteristically amblypod, still less *Coryphodon*. My doubt in 1914 in regard to the correlation value of this record was warranted by what I knew at the time regarding the evidence, and is now fully confirmed. Dollo has recently secured from the Orsmael locality many separate teeth of a tiny mammal, which when studied and identified will be very interesting and important.

[12] The criteron used is not the geological range as per the known record, but the fact that the principal evolution and specialization of the family, its differentiation from the generalized ancestral stock, took place during the Tertiary. Also, and supplementing this criterion when the data are insufficient for definite conclusions as to the derivation and evolutionary history of the group, the evidence that it was most abundant, varied and flourishing during the Tertiary serves to indicate its essentially Tertiary character.

		Meso-zoic	Paleo-cene			Cenozoic					
						Eocene					
Geologic Range of Vertebrate Fauna of the Wasatch Group. Suessonian or Lower Eocene.		Up. Cret.	Puerco	Torr.-Ft. U.	Tiffany-Cern.	Lower	Middle	Upper	Oligocene	Mio.-Plio.	Pleist.-Rec.
REPTILES											
CHELONIA	Bænidæ	X	X	X		X	X	X			
	Plastomenidæ	X				X	X				
	Dermatemydidæ	X	X	X		X	X	X	X	-------	-------
	Trionychidæ	X		X		X	X	X	X	X	X
	*Emydidæ					X	X	X	X	X	X
	*Testudinidæ					X	X	X	X	X	X
SQUAMATA	*Lacertilia, fam. div.					X	X	X	X	X	X
	*Ophidia, fam. incert.			X		X			X		X
CROCODILIA	Crocodilidæ	X	X	X	X	X	X	X	X	-------	-------
BIRDS											
	?Gastornithidæ, etc.				X	X					
MAMMALS											
CARNIVORA	Oxyclænidæ		X	X	X	X					
	Arctocyonidæ		?	X	X	X					
	Mesonychidæ			X	X	X	X	X			
	*Oxyænidæ				?	X	X	X			
	*Hyænodontidæ					X	X	X	X		
	*Miacidæ[a]			X		X	X	X			
INSECTIVORA	Pantolestidæ, etc.			X		X	X				
	Leptictidæ			X	X	X			X		
	*Talpidæ, Soricidæ					X	X		X	X	X
MENOTYPHLA	Plesiadapidæ				X	X	X				
	?Microsyopidæ					X	X				
*PRIMATES[b]	*Tarsiidæ				X	X	X	X	-----------	-----------	-----------
	*Adapidæ					X	X	X	----		
*GLIRES[c]	*Paramyidæ, etc.					X	X	X			
EDENTATA	Metacheiromyidæ				?	X	X				
TAENIODONTA	Stylinodontidæ		X	X	X	X	X				
*TILLODONTIA	*Esthonychidæ					X					
	*Tillotheriidæ					?	X	X			
CONDYLARTHRA	Phenacodontidæ			X	X	X					
	Meniscotheriidæ					X					
	Hyopsodontidæ				?	X	X	X			
ENTELONYCHIA	Arctostylops					X					
AMBLYPODA	Coryphodontidæ					X					
	*Eobasileidæ				?	X	X	X			
*PERISSODACTYLA	*Equidæ					X	X	X	X	X	X
	*Tapiridæ					X	X	X	X	X	X
	*Lophiodontidæ[d]					X	X	X			
	*Titanotheriidæ					X	X	X	X		
*ARTIODACTYLA[e]	*Dichobunidæ					X	X	X			
	*Entelodontidæ					X	X	X	X	X	

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[a] The modern families of Carnivora are derived from the Miacidæ.

[b] The higher primates are probably a branch from the Tarsiidæ, but do not appear in the record until the Oligocene, and are unknown in the North American Tertiary. The Adapidæ are related to the lemurs.

considerable minority of archaic orders which disappear in the course of the Eocene. Marsupials are rare, multituberculates have disappeared. The reptiles are represented by modern families of crocodiles (Crocodilidæ), chelonians (Emydidæ, Testudinidæ) etc., the Mesozoic groups having mostly disappeared, except that as with the mammalian orders some of the Cretaceous turtles survive, the Bænidæ to the end of the Eocene, the Dermatemydidæ (rare) and Trionychidæ (common) to the present day.

General Relations of the Faunas in the Disputed Formations.

The formations that intervene between the undisputed Cretaceous and undisputed Tertiary are mostly non-marine. They fall into two groups, one characterized as to its vertebrates by dinosaurs and metatherian mammals, the other by archaic placental mammals and no dinosaurs. The former have been generally referred to the Cretaceous by vertebratists, the latter to the Tertiary, but distinguished as Paleocene in recent years as the marked faunal difference from the true Lower Eocene came to be better understood. It has been assumed by most writers that the dinosaur faunas were all older than the placental mammal faunas, and the line between the Cretaceous and Tertiary has been drawn between them. In my paper of 1914 I analyzed the evidence and showed that this was not really proven, and that there was reason to suspect that the Paleocene faunas were partly contemporary with the latest dinosaur faunas, representing a different faunal facies rather than a real change of fauna. I also pointed out the marked distinction between the archaic placental mammals of the Paleocene and the modernized placental mammals of the true Eocene. I have no reason to change any of the conclusions there set forth, but the evidence in support of them has been extended and confirmed in certain particulars.

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[c] The relationship of the Eocene rodents to the multitudinous later groups is in dispute.

[d] The rhinoceroses probably branched off from the Lophiodontidæ. They first appear in the upper Eocene.

[e] The higher Artiodactyla appear to have evolved during the Tertiary from primitive Old World stocks of Eocene and later age. They are not descended from those two families.

Summary of New Evidence.

1. Mr. Gilmore's description of the fossil vertebrates from the Kirtland and Ojo Alamo beds, underlying the Paleocene of New Mexico, confirms their correlation with the Judith or Belly River, upper Senonian, and my conclusion that while the Puerco or Lower Paleocene mammal fauna was later than the Judith River, there was no direct proof that it was not contemporary with or even slightly older than the Lance and equivalents.

2. The fossil mammals of the Fort Union described by Mr. Gidley confirm the view that they are Upper Paleocene. They may be equivalent to the Torrejon of New Mexico, possibly later, approaching the Cernaysian and Tiffany. This statement represents my own judgment. I do not know what Mr. Gidley's opinion may be.

3. M. Teilhard has shown that the Cernaysian and with it probably the entire Thanetian of Western Europe is the equivalent of the uppermost Paleocene of America, the Tiffany horizon. It is not, as had been previously supposed, as old or older than the Torrejon. He also emphasizes the sharp distinction between the Paleocene and the true Lower Eocene of the European succession, and the correspondence and close affinities of the new fauna that appears with the true Eocene in both Europe and America. Dr. Schlosser, while his conclusions accord with those of M. Teilhard on most points, is disposed to regard the Cernaysian as somewhat older than the Torrejon; but for obvious reasons he had not the full data at hand for a decision on this point.

4. Mr. Granger and I have continued our work on the Paleocene mammals, confirming the position assigned to the Tiffany fauna, the distinctness of the Puerco and Torrejon faunas as lower and upper Paleocene, and the very marked break between the Paleocene and Eocene faunas. The Tiffany is not much older than the lowest true Eocene in time, but it is wholly Paleocene in type, lacking all of the Tertiary orders so abundant in the Eocene, with the exception of one family of Primates.

5. Additional specimens of the rare mammals of the Belly River described by Dr. Smith Woodward and myself[13] confirm my conclusion that the Lance and Belly

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[13] A. Smith Woodward, 1916, Geol. Mag., vol. 3, p. 333; Matthew, 1916, Bull. Am. Mus. Nat. Hist., 35, pp. 477-500.

River mammals belong to the same families, but that the Lance mammals are a more specialized and advanced stage. This conforms to the evidence of the dinosaurs and other reptiles, indicating that the Lance is considerably later in time than the Belly River but that no great migrational change in fauna occurred during that time.

6. The researches upon the upper Cretaceous dinosaurs by Brown, Lambe, Gilmore, Osborn and Parks, have placed the correlation and succession of the later dinosaur-bearing formations upon a very broad and solid footing, so that it is hardly likely to be seriously questioned or materially modified. The exact relations of the older phases of the Belly River and so-called Judith River in southern Alberta and northern Montana have been partly cleared up, but the complete results are not yet available.[14]

Succession and Correlation of the Vertebrate Faunas as now understood.

The Judith River formation of Montana containing the Ceratops fauna is interbedded with the Fort Pierre and its fauna is correlated with the Belly River. The Milk River dinosaurs may be somewhat older. These need hardly be discussed. The Ojo Alamo group in New Mexico (Fruitland, Kirtland and Ojo Alamo formations) contain a fauna correlated with the Judith and Belly River.

The Lance of Wyoming, Hell Creek of Montana, Arapahoe and Denver of Colorado contain the Triceratops fauna. The same six families of dinosaurs are found, but some if not all are represented by more specialized genera and species. The same groups of turtles, crocodiles and Rhynchocephalia are present, in some cases at least with more specialized representatives. The mammals (chiefly from the Lance) belong mostly, probably all, to the metatherian families Plagiaulacidæ and Cimolestidæ, but include more specialized genera than are found in the Senonian. Detailed comparisons indicate a very considerable lapse of time as measured by the phyletic changes, but no great faunal break or change, due to the invasion of a new fauna from elsewhere.

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[14] See Brown, 1917, Bull. Am. Mus. Nat. Hist., 37, pp. 281-282.

Close above the Lance and Hell Creek lie the Fort Union beds, devoid of dinosaurs, but not separated by any stratigraphic break, and containing a flora very closely allied to that of the Lance and to the upper Paleocene floras of Western Europe. A considerable mammal fauna has also been found in the Fort Union, correlated, as above noted, with the better known Torrejon fauna, or perhaps intermediate between this and the Cernaysian, in any event Upper Paleocene.

In the San Juan Basin, New Mexico, the Puerco formation overlies (unconformably) the Ojo Alamo= Judith River. It contains a large mammal fauna which is wholly unknown elsewhere. Multituberculates form a considerable element but the major part is archaic placentals. There are no dinosaurs; but the crocodiles, rhynchocephalians and turtles are of the same groups as those of the Judith and Lance, and not perceptibly more advanced. The Torrejon overlies the Puerco conformably, and contains the same and some additional families of archaic mammals, both multituberculates and placentals. Some of the Puerco phyla can be followed through, apparently as direct descendants, and in these there is evidence of considerable evolutionary change, representing a considerable lapse of time.[15]

Over the Torrejon, unconformably, lies the Wasatch group, of which the basal member is the Tiffany. This is still faunally Paleocene, the mammals archaic placentals. The phyla that can be traced through show in some instances a considerable advance beyond the Torrejon, indicating considerable lapse of time, and are very close to the succeeding Wasatch horizons of the true Eocene. But in the Tiffany as in the Torrejon, the modernized placentals, abundant in the overlying horizons of the Wasatch, are almost wholly absent. There is between Tiffany and true Eocene very little lapse of time but a great change of fauna. For various reasons impossible to present here I hold that the change is not explainable as due in any degree to difference in facies,

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[15] In the Puerco and also in the Torrejon, there are two distinct fossiliferous levels, and the collections from each of these show certain differences in facies, but no evidence of lapse of time. Each formation is a faunal unit, although differences of facies or accidents of sedimentation result in different relative abundance of species in the different levels. This explanation appears advisable in order to prevent any misunderstanding of typical sections of these formations which have been published by Professor Osborn.

but must be due to migration. The same relations hold partly true in the sub-Wasatch beds of the Bighorn basin in Wyoming, Clark Fork Beds, and in the Cernaysian-Sparnacian succession of France. A new fauna, practically identical in Europe and North America, suddenly displaces in the record an old one which had endured for a long time, gradually evolving in loco. This new fauna then undergoes the same process separately in the two continents, of gradual evolution in loco, throughout the Eocene, when another great migration imposes a new and at first identical fauna in Europe and America, to be evolved and differentiated through the Oligocene.

Above the Tiffany horizon comes the true Lower Eocene with the well known "Wasatch Fauna" everywhere characterized, in Montana, Wyoming, Utah, Colorado, New Mexico, as in France and England, by *Eohippus* (=*Hyracotherium*), *Phenacodus, Coryphodon, Pachyæna*, etc.

The Alberta succession, commencing with the Belly River = Pierre = Upper Senonian, is followed by the upper Pierre, then the Edmonton, and this by the Paskapoo, formations separated by unconformities of no very marked character. The Edmonton contains a large fauna of dinosaurs and other Reptilia, including the same groups and phyla as the Belly River fauna below and the Lance fauna of later age, in an intermediate stage of evolution. No mammals have been found in the Edmonton. The Paskapoo contains no dinosaurs but a small fauna of mammals, the major part identical with those of the Lance, but including also a number of archaic placentals, which are not found in the Lance and may be identical with Fort Union mammals, although exact comparisons have not yet been made. They compare less closely with the Torrejon fauna, and I have seen nothing in them characteristic of the Puerco. This Paskapoo fauna is extremely interesting but too fragmentary for any more than provisional conclusions. So far as it goes, it suggests correlation with the Lance or Fort Union or something between the two; some obscure difference of facies may account for the absence of dinosaurs and the presence of two mammal faunas elsewhere distinct. It tends to confirm the palæobotanists' insistence on the near relation of Lance and Fort Union, for which I have already pointed out strong confirmatory evidence in the vertebrate correlations.

From the above it will appear that:

(1.) The Tiffany, Clark Fork and Cernaysian represent the top of the Paleocene.

(2.) The Torrejon and Fort Union are Upper Paleocene, correlated by the palæobotanists with the Lower Thanetian of Europe (Gelinden and Sezanne).

(3.) The Puerco, Lower Paleocene, is post-Senonian but may be as old as the Lance or older. The fauna shows it to be considerably earlier than the Torrejon-Fort Union and the near relations in stratigraphy and flora between Lance and Fort Union are strongly against intercalating between them the very wide time gap which is involved by placing the Puerco as later than the Lance.[16] If so, we must conclude that the latest dinosaur faunas were contemporary with the older Paleocene mammalian fauna, and that it is owing to some imperfectly known differences in facies that they are not found associated. Some indirect evidence in support of this view is afforded by the Paskapoo, in which Lance mammals and Paleocene placentals are found associated.

(4.) The position assigned by Brown to the Edmonton, intermediate between Lance and Belly River, has been fully and to my mind conclusively confirmed by the researches of Brown and Lambe upon the finely preserved dinosaur skull and skeletons from the three horizons. Many phyla have now been traced through and compared in detail. The flora according to Knowlton and Hollick is of Fort Union age, except for one small lot of plant remains which Knowlton regards as of Cretaceous aspect; the formation is positively stated by Brown to be a stratigraphic and faunal unit from top to bottom. Brown's explanation of the discrepancy[17] seems reasonable, but it should be observed that it weakens the force of the evidence from the flora in the correlation suggested in a preceding paragraph (2).

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[16] It has been suggested that the Puerco=Lower Fort Union. But there is not the slightest evidence in favor of this, and against it, in addition to the considerations I have cited, is a small amount of very fragmentary evidence indicating that the Fort Union carries the same mammal fauna from bottom to top.

[17] Brown, 1914, Bull. Geol. Soc. Am., vol. 25, p. 375.

The position of the Edmonton as indicated by its dinosaurs is about half way between the Lance and the Judith-Belly River. It confirms the view that the faunal change from Judith to Lance was due to time, not to migration.

(5.) The correlation of the Lance with the latest marine Cretaceous of the American succession is very strongly supported by Dr. Stanton's Cannonball memoir. This and other evidence of invertebrates, plants and stratigraphy lie outside the limits of this contribution.

(6.) Whether the foregoing correlations be exactly or only approximately correct they make it possible to trace the evolution and succession of vertebrate faunas between the Mesozoic and Tertiary. In my article of 1914 I stated briefly the reasons for regarding a faunal break, involving extensive migrations as shown by the sudden appearance of an identical new fauna in widely separated regions, as the best practical evidence of widespread diastrophism, and hence indicating the commencement of a new period in theory, as it is convenient in practice to draw the line at such a point. Direct stratigraphic evidence is necessarily local, its correlations over any wide regions are dependable only in so far as they conform to the palæontological evidence, and an unconformity is not a practicable or suitable basis for a universal time-division. I do not mean to minimize its practical importance in the making of geological maps.

Interpretation and Conclusion.

In my paper of 1914 I pointed out the wide differences between the Lance and Paleocene vertebrate faunas and concluded that it was in part due to difference in facies, in part to migration, but that it probably did not represent any great time break. I regard it at present as chiefly due to difference in facies. The placental mammals appear to be in adaptation a largely terrestrial dryland or upland fauna, the dinosaurs in the main a swamp, lagoon and lowland fauna, which was still in a flourishing state in Judith time, but progressively reduced in numbers and variety, and restricted in Lance time to a few highly specialized survivors. The marsupials and multituberculates would represent arboreal types, likely to be found in either facies, but comparatively rare, like most arboreal animals.[18] If the Puerco is as old as the Lance, or older, the terrestrial placentals were contemporary with the swamp dinosaurs in Western America, but to find them associated in the same formation would be a rare and fortunate accident.

There is no evidence that the dinosaurs survived to the end of the Paleocene. And I do not think the evidence affords anything like conclusive proof that they were contemporary with the Lower Paleocene placentals. Nevertheless the past seven years have much strengthened the indications to that effect.

The placentals of the Paleocene are to my mind essentially Cretaceous—Mesozoic rather than Cenozoic mammals. They belong—except the Carnivora—to extinct orders. They are related only to a minor and disappearing element of the typical Tertiary placentals. And—also with the exception of the Carnivora—they show both in Torrejon and Puerco a certain fixity of types in species, and limitations in their specializations, that are characteristic of long established groups moving toward extinction, rather than of newly appeared and flourishing groups. In essentials they have the aspect of the last Cretaceous mammals rather than the first Tertiary mammals—a concept long ago recognized by Osborn in his division of the placental orders into Mesoplacentals and Cænoplacentals. The Carnivora[19] are an exception. They appear as forerunners of the Eocene placental invasion—just as in South America they appear in the Pliocene as forerunners of the great northern invasion of the Pleistocene. In a Cretaceous fauna their position would be that of a progressive element which was later to expand and displace the rest. (All the Tertiary ungulates are probably to be derived from unknown primitive stocks of Cretaceous creodonts.)

The reptiles of the Paleocene are also Cretaceous types, every one of them. As with the mammals, some groups

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[18] Like the dinosaurs the Multituberculates are a Mesozoic group in course of progressive extinction, but they last until the end of the Paleocene. They are replaced in the Eocene by placentals of similar adaptations, plesiadapids, rodents, tillodonts and tæniodonts.

[19] The creodonts are included as a primitive suborder of the Carnivora. To consider them as a separate order, as many authors do, might seem to strengthen the present argument, but I do not think it is warranted by the facts of their anatomy. See Matthew, 1909, Mem. Am. Mus. Nat. Hist., vol. 9, pp. 313-335.

disappear at the end of the Paleocene, others survive to the end of the Eocene, and some still exist precariously; the soft-shell turtles alone are flourishing. The dinosaurs and plesiosaurs apparently become extinct before the close of the Paleocene.

The true Eocene, however, is sharply distinguished by the sudden appearance of the modern orders of mammals, and of the principal modern chelonians, the same new fauna appearing both in Europe and America and flourishing and evolving throughout the Cenozoic, while the older groups of vertebrates drop out one after another. This is a great and sudden faunal break, clearly due to migration, and represents the incoming of the Tertiary vertebrates into the known parts of Holarctica. It is a faunal change comparable with that of the Pleistocene, not more marked as to percentage of change in the families than that at the end of the Eocene, but considerably greater than the Oligocene-Miocene or Mio-Pliocene breaks. It is important, however, as introducing for the first time the Cenozoic mammals and reptiles, save for the few forerunners noted. It coincides quite nearly with the classic line between Cretaceous and Tertiary in Europe, but would include the Thanetian in Cretaceous, as it would include the Tiffany in America.

Diastrophism and the Migration of Land Faunas.[20]

The hypothesis that appears to fit best with the data at present known is:

(1.) That Asia was the primary center of evolution and dispersal of the terrestrial vertebrates.

(2.) That epochs of diastrophism, uplift and continental connection afforded opportunity and environmental pressure that caused them to spread out thence into the marginal parts of the Holarctic realm and ultimately into the marginal regions (Africa, South America, Australia).

(3.) The long intervening epochs of rest, peneplanation, subsidence and isolation induced evolution in loco, parallelism and expansive evolution of lowland, marsh and shallow water faunas.

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[20] See in this connection Matthew, 1915, ''Climate and Evolution,'' Ann. N. Y. Acad. Sci., vol. 24, pp. 171-318, where the distribution of land vertebrates is interpreted in accordance with this hypothesis.

(4) Preliminary stages of diastrophic epochs are marked by (a) reduction of the marsh faunas to a limited number of highly specialized survivors, (b) invasion of the lowland by the regional upland fauna, (c) appearance of a few forerunners (mobile types) of a great invasional fauna from the center of dispersal.

(5.) Culmination of diastrophism is marked by the maximum of new invading types from the more central regions, partial or complete extinction of the autochthonic faunas, and wide dispersal of identical fauna of upland adaptation.

(6.) Dying stages of diastrophism are marked by partial readaptation of the new fauna to lowland or marsh type, by its parallel evolution in isolation in different regions. Survivors from a previous submergence stage may re-expand, or may become extinct as unable to compete with the expanded new fauna.

(7.) It is unnecessary here to discuss the effect of oceanic or climatic barriers in modifying this sequence.

In accord with the above hypothesis the post-Senonian formations are viewed as representing the earlier stages of a period of world-wide diastrophism which culminated at the end of the Paleocene, the Eocene being an epoch of decreasing diastrophism and isolation faunas. The Judith fauna is the Cretaceous marsh fauna in the climax of its prosperity, the Edmonton and Lance are stages leading to its extinction. The Puerco represents the regional upland fauna expanding and invading the lowland, the Torrejon-Fort Union a later stage of the same local invasion. The creodonts are regarded as forerunners of the great invasion from the center of dispersal (?Asia) which culminates in the Wasatch, and as newcomers in the region in the Puerco.[21]

The dispersal of terrestrial faunas affords a measure of the intensity of world-wide diastrophism. The culmination of diastrophic movements in Colorado or in Western Europe may not, probably did not, coincide with the maximum intensity of the general movement. But if we are to use diastrophism as a logical basis for geologic time divisions, it is the general maxima and not local

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[21] The Casamayor fauna of South America is regarded as of Eocene age, derived from a Cretaceous upland fauna of North America in which Carnivora had not yet appeared. Hence the absence in it of true Carnivora and development of marsupials to take their place.

maxima that must be the standards. Correspondence in the sequence of diastrophic movements by no means proves their synchronism. A correct interpretation of the faunal changes is the only means whereby this can be proven. The initiation of diastrophism is demonstrably far from synchronous in different regions; it cannot well serve as a basis for world-wide time divisions. Lee has strongly insisted that the Tertiary as a whole (beginning with the Lance and Paleocene) is a period of continuous and increasing diastrophism.[22] But this, however true of certain parts of the Rocky Mountain region, is totally at variance with the stratigraphic record in other regions, or with the inferences from the history of the land vertebrates, which accord far better with the views outlined by Schuchert in 1909.

It appears from the above outline of present evidence that the base of the true Eocene is the proper dividing line on both theoretical and practical grounds between Cretaceous and Tertiary; that the Paleocene and the latest dinosaur faunas are best regarded as the uppermost Cretaceous. They might be referred to a distinct post-Cretaceous system as advocated by Cope, if the evidence of a widespread stratigraphic break between them and the Judith be regarded as sufficient. But the vertebrate fauna lend no support to the view that there was a distinct post-Cretaceous period. In any event, they are not true Tertiary, and to call them Eocene is to confuse two widely different faunæ, one of Mesozoic and the other of Cenozoic type.

Value of the Vertebrate Evidence.

The foregoing discussion has been confined to the vertebrates and their interpretation, not from any desire to minimize the importance of other data, palæontologic, stratigraphic or tectonic, but because it is the group in which I can lay claim to some special competence. Most of the evidence is in the American Museum, in my charge, and I have been working and studying on various parts of it for twenty-five years. It is a matter of regret that so much still remains inadequately published or illustrated, and that in consequence the statements made here

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[22] Lee, 1915, U. S. Geol. Sur., Prof. Pap. 95, p. 57; 1917, idem No. 101, p. 11.

rest so largely on unpublished material. It should be added that the methods of interpretation and conclusions are my own; other vertebratists have interpreted the evidence differently. Professor Osborn, who has studied the correlation thoroughly, adheres to the classic view that the extinction of the dinosaurs marks the close of the Mesozoic; Mr. Gidley agrees with the palæobotanists. This divergence of conclusions, to a certain type of mind, demonstrates the worthlessness of vertebrate evidence. But that is not its real significance; it is caused by the attempt to interpret and evaluate the evidence, to discover its real meaning rather than to rely upon superficial relations and rule-of-thumb methods.

I have elsewhere pointed out[23] that owing to the comparatively rapid, obvious and well understood changes which vertebrate races, and especially mammals, undergo in the teeth and characteristic parts of the skeleton, they are able to afford much more precise and sure evidence in problems of exact correlation than is furnished by the fossil remains of more slowly changing groups of animals or plants. Presumably all races of highly complex organisms alter in various respects with time, but if the parts preserved as fossils are of relatively simple structure we may not be able to observe the changes in many of them, or to distinguish fully between the results of migration, of time (evolution in loco), or of varying facies in the faunas compared. We are then reduced to the crude statistical methods formerly universal, and still widely employed in palæontology, especially in palæobotany. These statistical methods will bring approximately correct results through the laws of averages, provided the material be ample and no migration or differences of facies be involved; but so long as they fail to differentiate adequately the three elements of change—time, facies and migration—in the faunas or floras compared, so long will their results be untrustworthy and more or less at variance with the evidence where these elements can be and have been more fully distinguished. In practice, fossil vertebrates, and especially fossil mammals are capable of affording much more precise and exact results than invertebrates or plants, when there is sufficient evidence at hand. Where they are very rare or fragmentary

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[23] Matthew, 1914, l. c., p. 390; 1915, in Problems of Amer. Geol., p. 406.

the evidence is more conjectural and the results provisional. If correctly and judicially used they can even then provide very precise correlation data; but like all other instruments of precision they require expert knowledge and handling. A scalpel is much better for accurate dissecting work than an ax; but not in the hands of a lumberjack. Doctor Cross quite naturally despises the "poor little mammals." But they have their uses none the less, to those who know how to use them.

American Museum of Natural History,
New York City.

SCIENTIFIC INTELLIGENCE

I. CHEMISTRY AND PHYSICS.

1. *The Estimation of Sodium Hydrosulphite.*—JAMES HOLLINGSWORTH SMITH, who uses for this salt the name "sodium hyposulphite," which, although not incorrect, is somewhat confusing on account of the extensive commercial use of this old name for sodium thiosulphate, has found that the usual methods for determining its purity are unsatisfactory because they require either extreme care to exclude air or unusual reagents. He has therefore modified the gravimetric method of Seyewetz and Bloch which consists in treating the dry salt with an ammoniacal solution of silver chloride and collecting and weighing in a Gooch crucible the metallic silver formed according to the equation $Na_2S_2O_4 + 2AgCl + 4NH_4OH = 2(NH_4)_2SO_3 + 2NaCl + 2H_2O + 2Ag$. This method has the advantage over the use of iodine, permanganate or ferric sulphate as oxidizing agents in the fact that sulphite or thiosulphate as impurities do not affect the result, but it has the disadvantage of being inaccurate on account of the fact that any insoluble impurity in the salt is weighed with the metallic silver. Smith has therefore modified the method by dissolving the metallic silver, after washing it with an ammoniacal solution of ammonium nitrate, in nitric acid and determining the silver volumetrically by means of a thiocyanate solution. Instead of silver chloride he uses silver nitrate in ammoniacal solution for the original precipitation. The method appears to be a very good one.—*Jour. Amer. Chem. Soc.*, **43**, 1307.

H. L. W.

2. *The Calculations of Analytical Chemistry;* by EDMUND H. MILLER. 8vo, pp. 201. New York, 1921 (The Macmillan Com-

pany).—This appears to be an unchanged reprint of the third edition of the book published in 1905. It gives clear explanations and numerous examples for practice of a wide variety of calculations, including those dealing with atomic weights, formulas and factors, and with gravimetric, volumetric and gas analysis. There are also chapters dealing with calorific power, and electric and electrolytic calculations. An appendix contains a number of useful tables, including four-place logarithms and antilogarithms.

The book appears to present a satisfactory list of topics in a generally satisfactory manner, but it may be criticized in connection with its lack of precept and example in regard to the number of figures that deserve to be given in the results of calculations with approximate numbers. This fault may be found in nearly all the text-books dealing with the subject, and it is noticed here in the hope of bringing about future improvement in this matter. A striking example of this kind is found on page 71 of the book where from "3.0 cc", obtained as the difference between two titrations which are recorded only to the nearest 0.1 cc, an amount of K_2CO_3 is calculated as "0.20745 g." Now, leaving out of consideration any accidental errors, since the positive or negative third figure of 3.0 is unknown, the third decimal of the result must be uncertain and hence it is unreasonable to carry the figures of the answer beyond 0.207, while 0.21 would perhaps be a more satisfactory statement of the result. In many other cases the data of problems are treated as exact numbers, although in practice they would be approximate ones. For instance, on page 34 a calculation is based on "0.05 g" of available oxygen. It would have been preferable to state this as 0.0500 g in order to show three significant figures and to make the four-figure answers appear reasonable. H. L. W.

3. *Ammonia and the Nitrides;* by Edward B. Maxted. 12mo, pp. 116. Philadelphia, 1921 (P. Blakiston's Son and Co. Price $2.00 net).—The first two chapters of this little book give an account of the experimental work and general principles upon which the commercial synthesis of ammonia from gaseous hydrogen and nitrogen is based. This discussion is largely mathematical, but there are explanations and illustrations of several forms of experimental apparatus.

The nitrides, nearly all of which may be regarded as derivatives of ammonia, are discussed from a descriptive and historical point of view, and the author calls attention to the meagerness of our knowledge of these important compounds and the desirability of further investigation of them.

The final chapter of the book gives an excellent account of that interesting modification of a usually very inactive gas called active nitrogen. H. L. W.

4. *A Course in General Chemistry;* by William McPherson and William Edwards Henderson. 8vo, pp. 737. Boston, 1921 (Ginn and Company).—This is the second edition of what may be regarded as one of the best of our text books for the use of college students in this subject. It gives an excellent presentation of the fundamental laws and theories of chemistry, together with a satisfactory amount of descriptive matter in connection with the theoretical discussion. A good feature is the introduction of well-selected lists of questions and problems at the ends of the chapters.

The new edition has been largely rewritten in order to introduce improvements that have been suggested by the use, since 1913, of the previous issue, and to bring the work up to the views of the present time. There is an interesting discussion, occupying about nine pages, of the recent views in regard to the structure of atoms. H. L. W.

5. *Introduction to Qualitative Chemical Analysis;* by Th. Wilhelm Fresenius. Seventeenth Edition of the Original Work by C. Remigius Fresenius. Translated by C. Ainsworth Mitchell. 8vo, pp. 954. New York 1921 (John Wiley & Sons Inc. Printed in Great Britain).—This standard work on qualitative analysis which was begun as long ago as 1840, now appears as an English translation of a considerably modernized and enlarged German edition. The general plan and scope of the work have been preserved, however, while most of the old illustrations have been retained, with few additions, and a large part of the text remains practically unchanged, so that the book has a very familiar aspect to those who are acquainted with the previous English translations. Since the last English translation of the work published in America was issued in 1897, nearly 24 years ago (by the writer of this notice), it is evident that a new edition was needed, and there is no doubt that its appearance will be widely welcomed as a very important work for reference and study. The translation of the new edition appears to have been very well done. H. L. W.

6. *Diaphragms Capable of Continuous Tuning.*—In the field of under-water acoustic signalling it is highly desirable to possess a diaphragm capable of being tuned over a certain range of frequency so as to utilize selective transmission and reception, analogous to the method employed in radio-telegraphy. The design of such an instrument has been effected by Professor L. V. King of McGill University. The diaphragm is accurately turned from a single block of suitable metal, such as nickel-chrome steel, fashioned so as to have a heavy rim of nearly square cross-section connected to a relatively thick and rigid central disk by a much thinner ring-shaped plate. The diaphragm so constructed serves as a gas tight cover to a box which is essentially a hollowed bronze

block. By increasing the gaseous pressure within the box the diaphragm may be made to bulge slightly outwards and contrariwise by exhausting the gas the diaphragm is deflected inward. The tension of the thin annular part is accordingly increased or diminished and consequently the frequency of the central portion of the diaphragm is raised or lowered. Thus by the variation of the gas pressure within the box the fundamental pitch of the diaphragm may be changed continuously between certain limits. To adapt it to the reception of signals from a submarine sound generator a simple microphone receiver with the usual battery and head-telephone is attached to the underside of the diaphragm.

In an experimental test of a three-inch diaphragm of this design it was found that a variation of the pressure by 2 mm. of mercury produced a noticeable change of audibility at the resonance frequency. The variation of this frequency with the applied pressure below the diaphragm was determined both under water and in air, and was found to be a nearly linear relation, the absolute values of the frequency of course being less in the former case. The range of frequencies under water obtained was from 330 to 545 vibrations when the pressure was changed from —30 cm to + 30 cm. A variation of pressure from + 10 cm to — 30 cm, which is easily furnished by the lungs alone, permits the diaphragm to be tuned from 320 to 480 vibrations.

The mathematical constants of the diaphragm and the damping factors are discussed at length as an aid to the design of particular receivers.—*Proc. Roy. Soc.* **99**, 163, 1921. F. E. B.

7. *Philosophy and the New Physics;* by LOUIS ROUGIER. Pp. xv, 159. Philadelphia, 1921 (P. Blakiston's Son & Co.).—The recent development of physical theories has furnished a new grist for the technical philosophers, of which product the present work is an example. It is a re-writing of the work of physicists and was origially published uder the title of *La Matérialisation de l'Énergie.* The author's thesis is that with the ascription momentum to radiant energy, and its deflection in a gravitational field, the conception of matter can be dispensed with. In the eight chapters of the book he passes in review the various speculations which have been made as to the dualism or unity of matter and energy; the electron theory; the inertia and weight of energy according to the relativity theory; and the structure of energy as suggested by the quantum theory.

Unfortunately the author does not seem to be familiar with recent radiation theory and the structure of the atom which presents the quantum in a much more plausible light. He is apparently of that iconoclastic temperament which is sure the old is wrong and that the new must be right. To another it would seem that he is not sufficiently critical of his own exposition to see that the new speculation introduces difficulties just as troublesome as the old. For until the positive nucleus is in some way disposed of we have a primordial element which is quite on a parity with the conception of mass. And again, for example, the corpuscular radiation of an energy cell into a non-thing does not give a very satisfactory picture of what we ordinarily understand by an electro-magnetic wave.

The translation has been made by MORTON MASIUS with the intention of giving the author's views a wider circulation.

F. E. B.

8. *The Chemical Effects of Alpha Particles and Electrons;* by SAMUEL C. LIND. Pp. 182. New York, 1921 (The Chemical Catalogue Co.).—This is one of a series of scientific and technologic monographs projected by the American Chemical Society, for which the editors have selected writers who are recognized as authorities in their respective fields. It is believed that when men who have spent years in the study of important subjects are willing to co-ordinate their knowledge and present it in concise and readable form they will perform a service of the highest value to their fellow chemists and also by furnishing a well digested survey of the progress already made in that field they will assist in promoting research by pointing out directions in which investigation needs to be extended.

The contents of the present volume would properly be described by the title radio-chemistry on the analogy of electrochemistry, thermo-chemistry, etc., except that the former term has been frequently used to describe the separation or preparation of the radioactive elements which are topics not here considered. The first three chapters outline the scope of the work, the nature of radioactivity, the general properties of the radiations and their ionizing effects. Six succeeding chapters take up both the qualitative and quantitative chemical reactions produced by the radiations in considerable detail. Chapter X is devoted to the cognate subject of photo-chemical reactions. In Chapter XI the author discusses positive rays, recoil atoms, and summarizes the present knowledge and most recent work on isotopes. In the final chapter will be found a brief discussion of Rutherford's rather startling discovery of atomic disintegration by the alpha particles. Very full indices of both subject matter and authors are provided at the end. These together with foot-notes in the text, giving references to the original papers, supply a satisfactory bibliography of all the subjects treated. Various tables and diagrams are also reproduced.

The typography of the mathematical formulæ is apparently by a compositor who is not used to work of that character. Ambiguities or errors have been noticed which make it desirable that the original authority be consulted before a formula quoted is submitted to any important calculation. F. E. B.

9. *The Copernicus of Antiquity;* by SIR THOMAS L. HEATH. Pp. 59. London, 1920 (Society for Promoting Christian Knowledge).—This is one of the series of *Pioneers of Progress,* in which the author traces the speculations by which the Greek philosophers sought to explain the astronomical observations of the time. The most remarkable of these was the heliocentric hypothesis proposed by Aristarchus of Samos (310-230 B. C.) who also made estimates of the sizes and distances of the sun and moon. This theory of Aristarchus was known to Copernicus and mentioned in his writings but it failed of acceptance largely on the authority of Hipparchus who rejected it for the reason that a system in which the earth and planets revolved in circles about the sun as a center did not afford as exact a description of the phenomena as the rival theory of epicycles. The book contains a bibliography, and notes about all that is known of astronomical theory before the time of Ptolemy. F. E. B.

10. *Mathematik in der Natur;* by HERMANN EMCH. Pp. 85 and 132 figures. Zürich, 1921 (Rascher & Cie).—A popular account of mathematical relations in plants, animals, and crystals, which arise from the ordered arrangement of their cells or molecular structure, or derive from the operation of physical forces. Two chapters are devoted to geometrical forms among crystals and organized matter. One is given to number groups such as appear in the leaf arrangement of plants, or in the teeth and scales of fish. The three remaining chapters are occupied with various consequences of mechanical laws and a brief discussion of atomic structure. A few of the statements appear to be of doubtful validity. It is a book that will interest the curious reader rather than the student of science. F. E. B.

II. GEOLOGY.

1. *The Circulation of the Earth's Crust;* by Lieut.-Col. E. A. TANDY, R. E. (Survey of India). The Geographical Journal, May 1921, vol. 57, No. 5, pp. 354-376.—Colonel Tandy uses the expression "Circulation of the earth's crust" as a substitute for the words "isostatic adjustment." He is dealing with the process by which disturbed sections of the earth's crust resume their state of isostatic equilibrium. His paper is well worth reading by any one having to do with structural and dynamic geology, for he raises objections to many old and generally accepted theories and he advances substitutes which he feels are more logical and in better accord with the observed geodetic and geologic data. There are few, however, who will, in my opinion, give approval to many of Col. Tandy's views. There are the best of reasons for believing that there is a sub-crustal undertow from areas of deposition to those of erosion but we cannot accept Col. Tandy's view when he says:

''My own ideas are chiefly based on a far more lively conception of this process. I propose to describe the whole movement, above the surface and below it, as the Circulation of the Earth's Crust, because I am supposing this movement to be a universal characteristic of the crust, and the ultimate cause of all the great changes in its surface. I would also regard this Circulation as acting in the most detailed manner between every adjacent elevation and depression.''

The author recognizes the improvement of the theory of isostasy over other theories of the earth's crust, but he thinks the theory of isostasy is still too incomplete to be of much use to the practical geologist and the object he had in mind is to ''try to advance it a further stage in its development.'' In this view of isostasy he is correct, for up to this time there have not been many papers dealing with the processes by which isostasy is brought about and maintained. The literature has dealt mostly with the accumulated geodetic data and the results of investigations which have proved that the condition of isostasy exists, at least within the regions covered by the data used. From this point, Col. Tandy discusses Deeps and Rivers, showing that he differs from the views generally held by geologists.

Under the heading River Deltas, he refers to Barrell's use of deltas in his ''The Strength of the Earth's Crust'' to prove that the earth's crust is able to hold up great loads. Tandy differs from Barrell, though his reasoning is not convincing that he, Tandy, is correct. He simply refers to the fact that the old assumption that the mountains are extra loads has been proved incorrect, and by inference the crust is not strong enough to support a delta.

Col. Tandy sets forth some views under the heading ''Differences of Crustal Temperature'' which conform very closely with some of mine contained in two recent papers.[1] Each of us worked in entire ignorance of what the other was doing. Tandy calls attention to the views expressed by some geologists that differences in elevation of the surface of the earth are due to differences in crustal temperature. He believes that this theory or idea is in material and remarkabe harmony with the main principle of isostasy. He holds that the crust in high regions consists of expanded matter and in low regions of condensed matter. He says, ''The varied expansion of the crust, shown by differences of elevation at its surface, may be due to differences of crustal temperature and chemical changes generated by the circulation of the earth's crust.''

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[1] Some Geologic Conclusions from Geodetic Data, Proceedings of National Academy of Sciences, vol. 7, No. 1, pp. 23-28, Jan., 1921.

The Relation of Isostasy to Uplift and Subsidence, this Journal, vol. 2, July, 1921.

This is in close accord with my views outlined in the paper on isostasy already referred to (this Journal, July, 1921.) On page 19 of that article we read:

"Aside from these changes in the elevation, I do not know of any others which are caused by isostatic adjustment. They must be due to other causes which, I believe, are decreases and increases of density in the isostatic shell."

Again, on page 16, it is stated: "We are led to the conclusion that the cause of the mountain formation is a local one, and the only local cause seems to be a change in density in the column."

It is seen from the above that Tandy and I agree as to the probable cause of uplift. We do not hold the same views as to the zone within which the horizontal movement takes place to restore the isostatic equilibrium after erosion and sedimentation have taken place. Tandy expresses the view that:

"It is considered doubtful if movement is generally possible after depths of 30 miles or so, though in my view this depth will vary greatly according to the activity of the circulation. Beyond this depth, things merge into the condition of the nucleus, which we will provisionally regard as inherently solid, cold, and inert." This view ignores the geodetic investigations, the results of which indicate in the strongest way that the isostatic compensation must extend to an average depth of the order of 60 miles. Tandy's theory as to the depth within which horizontal movement occurs falls when it is realized that we cannot have isostatic compensation extending far below the zone of flow.

Under the headings "Crustal Conditions," "Generation of Heat by the Circulation," "Contraction and Expansion" and "Evidence and Examples" Tandy sets the stage for bringing out the main idea of his paper, "The Circulation of the Earth's Crust." Some of the ideas advanced are good, but most of them are speculative and difficult to accept. He says:

"The whole theory must stand or fall on the principle that the circulation is of the most detailed character, so that every stream and depression in the mountains will be an area of deposit, as already discussed. The highest mountains of the world are all very steep folded mountains, and the avalanches, land-slides, and other erosion down the sides of such mountains must be enormous. So that, if we believe that the great bulk of this deposit is not carried forward, but sinks directly into the beds of the streams and rivers, and finally circulates back, under the adjoining heights and spurs, we at once get a circulation far more powerful and rapid than has hitherto been conceived."

At another place the author states, "I also think that the circulation in high mountain regions takes place only a few miles below the surface."

If these conditions should exist, we would have the outer portion of the crust so plastic that the differences in elevation now existing would very quickly flatten out. It implies no rigidity whatever to the earth's outer material, which idea we cannot accept. Besides, the movement, according to Tandy's views, would be from a column with a surface of low elevation to a column with a surface much higher. Unless the transfer of matter takes place at or near the depth of compensation we should have matter flowing against stress differences, which is impossible. It is not conceivable that each small column with a cross section not greater than the area of a small mountain valley or a hillside is, independently, in isostatic equilibrium. It is impossible that each small feature is independently compensated, for, should this be true, there would have to be an almost total lack of friction between the small columns of the isostatic shell. It is true that in making the computations for the effect of isostatic compensation we assume complete local isostasy, but this must be done to facilitate the operations.

I strongly recommend to the student of the earth's crust that he read and study Col. Tandy's paper. Some of it is sound; other parts seem to me weak, but the author must be looked upon as a crusader in the field of geology, fighting some theories which are generally accepted but which are not in accord with the accumulated geodetic and geophysical data. Like the crusader, he lets his feelings, at times, warp his judgment.

WILLIAM BOWIE.

2. *A Reprint of the more inaccessible paleontological Writings of Robert John Lechmere Guppy;* by G. D. HARRIS. Bull. Amer. Paleontology, No. **35**, 198 pp., 10 pls. and portrait, 1921.—*Illustrations and Descriptions of fossil Mollusca contained in the Paleontological Collections at Cornell University;* by KATHERINE E. H. VAN WINKLE. Ibid., No. **36**, 12 pp., 1 pl., 1921.—*New Eocene Species from Alabama;* by T. H. ALDRICH. Ibid., No. **37**, 32 pp., 3 pls., 1921.—Of the forty-two more important paleontological papers written by Rev. Robert J. L. Guppy and relating to West Indian Cenozoic fossils, twenty-five are here reprinted in Bulletin 35. The remainder were published in well known journals and are accessible to most paleontologists, but those here reprinted were originally printed in obscure places and so were no longer obtainable. In Bulletin 36, Miss Van Winkle describes a small number of new and old Cenozoic species in the Cornell collections, and in Bulletin 37, Mr. Aldrich describes fifty-three species, of which nearly all are new. C. S.

3. *Gründzüge der Paläontologie* (*Paläozoologie*); by KARL A. VON ZITTEL, reworked by F. BROILI. I. Abteilung, Invertebrata,

5th ed., viii + 710 pp., 1457 text figs. Munich and Berlin (R. Oldenbourg), 1921.—The fourth edition of this valuable work (1915) was briefly noted in the October 1917 number of this Journal. Now we have the fifth edition, somewhat enlarged, and with many emendations and additions, but rather in details than in matters of a fundamental nature. Upwards of 7500 genera are described, and of these 1400 are illustrated. The more important genera are now marked with an asterisk, an improvement that will be appreciated by teachers and students of paleontology.

Professor Broili has of course been greatly hampered in not having access to all of the literature published during the Great War. He has, however, added to the bibliographies many important new references. All in all, the book keeps up the great reputation of Zittel and Broili, and that of the printer as well, although we wish more attention had been given to the newer classifications and to placing many groups of fossils more definitely in the systems rather than leaving them, as at present, as appendices at the end of the classes. Certainly the trilobites deserve another disposition than as an order of the subclass Entomostraca. The Anthozoa and Vermes also need a fundamental revision to bring out the relationships of the various stocks to one another. Finally, the Conulariidæ have nothing at all in common with the pteropods or the molluscs in general, since Ruedemann has shown them to be sessile attached animals.

C. S.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Carnegie Foundation for the Advancement of Teaching.* Bulletin XV. *Training for the public Profession of the Law.*—The Carnegie Foundation, which has carried through a number of exhaustive studies of different departments of education in this country, as, for example, of the medical schools, has now returned to the study of the legal profession. It will be remembered that Bulletin VIII by Professor Redlich of Vienna University discussed this subject a number of years since (see vol. **39**, p. 611, and **42**, p. 88.) The central point now argued in detail is that lawyers, because of their difference in training and in their professional activities, cannot rightly be regarded, as here and in Germany, as constituting a single undivided profession, or "bar." The historical aspect of the whole subject is treated in eight parts, beginning with the English system prior to the American Revolution and extending to the time of the war with Germany.

In the last period particularly the growth of evening, or part-time, law schools, has made it impossible to regard all law schools as alike. This is especially true because other schools now demand a college training as a necessary preliminary. This movement toward part-time schools is regarded as something to be commended notwithstanding their recognized deficiencies at the present time A list is given of one hundred and forty-two contemporary schools with indication of the time required to secure their degrees, including the three elements of the amount of preliminary education required for admission, the length of the law school course, and the hours at which class sessions are held.

Taking as a basis the amount of time required for obtaining a degree, the schools are tentatively divided into four groups, three of which are recognized as legitimate types that need to be separately strengthened and improved. Also, as a step toward securing professional and popular recognition of vital distinctions among different types of lawyers, the suggestion is made that, in the case of younger applicants for admission to bar associations, the requirements for membership may well be based upon the requirements for graduation already in force in the more advanced group of law schools.

2. *Publications of the College of Agriculture of Cornell University, Ithaca, N. Y.*—The following have recently been issued:

The Crane-Flies of New York Part II; by Charles Paul Alexander. This part, Memoir 38 of the Agricultural Experiment Station, deals with the biology and phylogeny of the crane-flies and gives representative crane-fly life histories, external and internal morphology, and concludes with keys and descriptions. The monograph contains about 450 pages.

The Genetic Relations of Plant Colors in Maize, by R. A. Emerson, Professor of Plant Breeding. Memoir 39 of the Experiment Station. It contains about 120 pages with 11 color plates, and gives the results of studies carried on for the last dozen years.

Copies of the above publications may be obtained by those interested (so long as the supply lasts) from the Bureau of Publications, College of Agriculture, Ithaca. The second memoir is stated to be highly technical in character.

3. *Congress of Applied Chemistry.*—The *Société de Chimie Industrielle* makes the following announcements:

(1) Members of the Society, both French and foreign, will unite in an annual meeting on the 9-12 October, which will include all the thirty-four sections corresponding to the various applications of industrial chemistry. The subjects to be considered are named in detail in the preliminary circular and it is added that the more important departments will be handled by eminent specialists. The Congress will hold its sessions in the *Conservatoire des Arts et Métiers.* A banquet will follow the close of the meetings in the *Palais d'Orsay* with M. L. Du Prey, Minister of Agriculture, as presiding officer.

(2) A Chemical Exposition, under the auspices of the Society, will be held from the 7 to 16 October. Only two sections will be represented but full development is anticipated for the future.

These are: (1) the equipment of the laboratory and its industrial management; also (2) the coloring matters developed. The leading French firms will take part and the exhibits will show the novelty and diversity of the apparatus and the variety of the products manufactured.

4. *Personnel Relations in Industry;* by A. M. Simons. New York, 1921 (The Ronald Press Company).—This is one of several books, recently published, summarizing experience in developing more satisfactory human relations in industry. The information presented was first used in classes in the extension Department of the University of Wisconsin. As most of the members of these classes were executives in industrial management, the data brought together by the teacher, Mr. Simons, were subjected to practical discussion by the pupils who could apply the test of daily practice. The author believes that ''human nature'' is the ''basic characteristic'' of all industrial problems. He is also confident that ''scientific methods of analysis'' will prove to be ''the contribution of our age to the ever-present problem of labor.''

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THE

AMERICAN JOURNAL OF SCIENCE

[FIFTH SERIES.]

Art. XVII.—*The Crystal Structure of Alabandite* (MnS); by Ralph W. G. Wyckoff.

Method of Investigation.—The determination of the crystal structure of this mineral furnishes an illustration of the manner of combining, as a source of the data upon which to base the study of the structure of a crystal, (1) the reflection measurements from a single face of a crystal, which give the absolute dimensions of the unit cell together with the number of chemical molecules to be associated therewith, and (2) reflections from the powdered substance. The general method of obtaining the structure of the crystal from these data is the same which has previously been used[1] and is based primarily upon the analytical results of the theory of space groups.[2]

The Crystallography of Alabandite.—The specimen used for this investigation was a cube nearly a centimeter upon a side.[3] Alabandite is usually assigned to the tetrahedral class (hemimorphic hemihedry) of the cubic system on the basis of its showing tetrahedral faces and faces of the form (211). From the existing crystallographic evidence, however, it seems equally capable of assignment to the tetartohedral class of symmetry.

The Number of Chemical Molecules within the Unit Cell.—A comparison reflection photograph of the L series lines of tungsten using as gratings the (100) face

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[1] Ralph W. G. Wyckoff, this Journal, 1, 138, 1921; etc.

[2] Ralph W. G. Wyckoff, this Journal, 1, 127, 1921, and other work as yet unpublished; P. Niggli, Geometrische Krystallographie des Discontinuums, Leipzig (1919).

[3] This material was loaned by the United States National Museum through the courtesy of W. F. Foshag. Locality: Puebla, Mexico. Museum No. 19565. Though its exact composition is unknown, it seems to be quite pure manganese sulphide.

of calcite and the (100) face of the crystal of alabandite was prepared in the usual manner. From the known reflection from calcite an accurate measurement was obtained of the distance from the reflecting crystals to the photographic plate; this determination was then used in the calculation of the spacing of alabandite. From the application of these measurements to the usual equation

$$n\lambda = 2d \sin \theta_n \tag{1}$$

a mean value of d_{100}/n, where d_{100} is the length of the side of the unit cube and n is the order of the reflection, for this crystal of alabandite was found to be

$$d_{100}/n = 2.607 \times 10^{-8} \text{ cm.}$$

The density of this mineral is variously stated to lie between $\rho = 3.95$ and $\rho = 4.04$.[4] From a knowledge of the spacing against the cube face and of the density of the substance the ratio of the cube of the order of the reflection, n, to m, the number of chemical molecules associated with the unit cube, becomes with the aid of

$$n^3/m = M/(d_{100}/n)^3 \times \rho \tag{2}$$

(where M is the weight of a single chemical molecule of the compound)

$$n^3/m = 2.038 \quad \text{when} \quad \rho = 3.95, \text{ or}$$
$$n^3/m = 1.994 \quad \text{when} \quad \rho = 4.04.$$

From this it is evident that the measured reflection is either the second-order one from a crystal whose unit contains four chemical molecules or a fourth-order reflection from one having a unit composed of thirty-two chemical molecules.

The Possible Arrangements of the Atoms within the Unit Cube.—If alabandite has tetrahedral cubic symmetry then it must be assignable to one of the space groups showing a hemimorphic hemihedry; if tetartohedral, it must have the symmetry of one of the space groups T^{1-5}.

Four Molecules in the Unit.—Two space groups, $T_d{}^1$ and $T_d{}^2$, having the symmetry of the hemimorphic hemihedry, furnish two special cases with four equivalent positions within the unit cell.[5] Three tetartohedral

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[4] P. Groth, Chemische Krystallographie, I, p. 146.

[5] These results are taken from tables, yet unpublished, which give a complete analytical representation of the theory of space groups.

groups, T^1, T^2, and T^4, likewise have special cases with four equivalent positions. These special cases are as follows:

Tetartohedral symmetry:

Space Group T^1:
4*a* uuu; $u\bar{u}\bar{u}$; $\bar{u}u\bar{u}$; $\bar{u}\bar{u}u$.
Space Group T^2:
4*b* 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$.
4c $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; $00\frac{1}{2}$; $0\frac{1}{2}0$; $\frac{1}{2}00$.
4d $\frac{1}{4}\frac{1}{4}\frac{1}{4}$; $\frac{1}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{3}{4}$; $\frac{3}{4}\frac{3}{4}\frac{1}{4}$.
4e $\frac{3}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{1}{4}$; $\frac{1}{4}\frac{3}{4}\frac{1}{4}$; $\frac{1}{4}\frac{1}{4}\frac{3}{4}$.
Space Group T^4;
4f uuu; $u+\frac{1}{2},\frac{1}{2}-u,\bar{u}$; $\bar{u},u+\frac{1}{2},\frac{1}{2}-u$; $\frac{1}{2}-u,\bar{u},u+\frac{1}{2}$.

Tetrahedral symmetry (hemimorphic hemihedry):

Space Group T_d^1: 4*a*.
Space Group T_d^2: 4*b*, 4*c*, 4*d*, 4*e*.

From these special cases all of the possible ways of arranging the atoms in a unit of alabandite which has four chemical molecules within it are as follows:

(I) Mn: uuu; $u\bar{u}\bar{u}$; $\bar{u}u\bar{u}$; $\bar{u}\bar{u}u$.
S: $u'u'u'$; $u'\bar{u}'\bar{u}'$; $\bar{u}'u'\bar{u}'$; $\bar{u}'\bar{u}'u'$.

On the basis of the symmetry of the *arrangement* of its atoms this structure would possess tetrahedral symmetry.

(II) Mn: 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$.
S: $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; $00\frac{1}{2}$; $0\frac{1}{2}0$; $\frac{1}{2}00$.

The symmetry of this arrangement is the complete symmetry (the holohedry) of the cubic system. If a crystal having this arrangement of its atoms exhibits a lower symmetry than the holohedral, as alabandite does, this low degree of symmetry must be accounted for by some such effect as a dissymmetry in the shape of the fields of force surrounding the atoms.

(III) Mn: 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$.
S: $\frac{1}{4}\frac{1}{4}\frac{1}{4}$; $\frac{1}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{3}{4}$; $\frac{3}{4}\frac{3}{4}\frac{1}{4}$.

The symmetry of this arrangement is tetrahedral. The other arrangements deducible from the space groups T^2 and $T_d{}^2$ are capable of reduction to this same arrangement.

(IV) Mn: uuu; $u+\frac{1}{2},\frac{1}{2}-u,\bar{u}$; $\bar{u},u+\frac{1}{2},\frac{1}{2}-u$; $\frac{1}{2}-u,\bar{u},u+\frac{1}{2}$.
S: $u'u'u'$; $u'+\frac{1}{2},\frac{1}{2}-u',\bar{u}'$; $\bar{u}',u'+\frac{1}{2},\frac{1}{2}-u'$; $\frac{1}{2}-u',\bar{u}',u'+\frac{1}{2}$.

The symmetry of this arrangement is tetartohedral. It may be noted that arrangements (II) and (III) are special cases of this arrangement.

Thirty two Molecules in the Unit.—It has already been shown in the course of the treatment of a somewhat similar case[6] that with the present lack of precise knowledge concerning the mechanism of scattering it is impossible to rule out with certainty the complicated structures having thirty-two molecules associated with the unit cell. Such an elimination is equally impossible in the present instance. It consequently becomes necessary, for the present at least, to make the assumption that the correct structure is simple. In this case it is to be assumed that four molecules of MnS are to be associated with the unit.

The Choice of the Correct Structure for Alabandite.—The expression

$$\mathrm{I} \propto f\left(\frac{d}{n}\right)\left\{\sum_r\left[\sigma_r \cos 2\pi n\,(hx_r+ky_r+lz_r)\right]^2 + \sum_r\left[\sigma_r \sin 2\pi n\,(hx_r+ky_r+lz_r)\right]\right\} \quad (3)$$

(where I is the intensity of reflection, $f(d/n)$ is some function of the spacing between like planes of atoms, and σ_r, the scattering power of the atom r for X-rays, seems to be roughly proportional to the atomic number, the summation is to be carried out over each of the atoms (coordinates$=xyz$) within the unit cube), has been used to obtain a measure of the intensity of reflection to be expected from any plane (hkl) for any conceivable arrangement of atoms within the unit cell of a crystal.

The two arrangements (II) and (III) are in a sense limiting structures for the less simple ones (I) and (IV); thus, (II) results from (I) by assigning to u and u' the values ¼ and ¾ (and for convenience in computation transferring the origin to the point (¾¾¾)). Similarly both (II) and (III) arise from (IV) by assigning to u and u' the values 0 and ½ for (II) and for (III) the values 0 and ¼. These two limiting cases, (II) and (III), can be most simply distinguished in their diffraction effects by a consideration of the reflections from the plane (111); the simplest plane all of whose indices are

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[6] Ralph W. G. Wyckoff, this Journal, 1, 138, 1921.

odd. Writing A for the evaluation of the cosine terms and B for the corresponding sine terms, the application of expression (3) to these two possible arrangements leads to the following:

Arrangement (II):

$$I \propto f(d/n) \times (A^2 + B^2).$$

When the indices are two odd and one even:

$A = 0$, when $n =$ odd,
$A = 4\overline{\mathrm{Mn}} + 4\overline{\mathrm{S}}$, when $n =$ even,
$B = 0$ always.

When the indices are two even and one odd:

$A = 0$, when $n =$ odd,
$A = 4\overline{\mathrm{Mn}} + 4\overline{\mathrm{S}}$, when $n =$ even,
$B = 0$ always.

When the indices are all odd:

$A = 4\overline{\mathrm{Mn}} - 4\overline{\mathrm{S}}$, when $n =$ odd,
$A = 4\overline{\mathrm{Mn}} + 4\overline{\mathrm{S}}$, when $n =$ even,
$B = 0$ always.

Arrangement (III):

$$I \propto f(d/n) \times (A^2 + B^2).$$

When the indices are two odd and one even:

$A = 0$, when $n =$ odd,
$A = 4\overline{\mathrm{Mn}} + 4\overline{\mathrm{S}}$, when $n =$ even,
$B = 0$ always.

When the indices are two even and one odd:

$A = 0$, when $n =$ odd,
$A = 4\overline{\mathrm{Mn}} \mp 4\overline{\mathrm{S}}$, $-$ when $n = 2$, $+$ when $n = 4$,
$B = 0$ always.

When the indices are all odd:

$A = 4\overline{\mathrm{Mn}}$, $B = 4\overline{\mathrm{S}}$, when $n =$ odd,
$A = 4\overline{\mathrm{Mn}} \mp 4\overline{\mathrm{S}}$, $-$ when $n = 2$, $+$ when $n = 4$, $B = 0$.

From these two sets of expressions it is evident that if the arrangement of the atoms of alabandite is that of (II) or is an arrangement of (I) lying close to (II) then the first order reflection from the (111) plane must be weak; if on the other hand the grouping is that of, or approaches close to that of, (III) then this reflection must be great. Hence a study of the relative intensity of this reflection and of the reflections from other strongly reflecting planes will serve to distinguish between these limiting cases

Fig. 1.—A scale useful for reading approximate values of d/n directly upon the powder photograph.

and to locate the atoms of manganese sulphide with all of the accuracy which the present knowledge permits. In this instance this comparison is most readily carried out by a study of the powder reflection.

The Powder Photograph.—A small piece of the crystal of alabandite was powdered, formed into a film with collodion as the binding material and a powder photograph prepared in the usual manner using molybdenum radiation which had been rendered monochromatic by a zirconium oxide filter.[7] The reflections were registered upon a hemicylindrical film so that spectrum lines were obtained upon either side of the undiffracted image of the slits. Measurements of the distance of these reflections from the zero image were made by halving the distance between corresponding spectrum lines on either side of the center. A check was furnished by observing the coincidence of the zero lines as determined in this fashion. The spectrometer was standardized through a measurement of a sodium chloride spectrum. Accurate spacings of the planes producing each of the lines in the spectrum were determined with the aid of the usual expression

$$n\lambda = 2d \sin \theta_n \qquad (1)$$

by remembering that the ratio of the distance of a spectrum line from the central image to the distance from the powder to the film measures 2θ in radians. For the identification of the different lines and for their approximate measurement, a scale constructed for the particular spectrometer used and reading the values of the spacings, d/n, directly, is very convenient (figure 1).

An approximate calculation of the relative intensities of the reflections from the simple planes, which will furnish the strongest spectrum lines in the powder photograph, can be readily made for each of the possible arrangements with the aid of the intensity expressions already derived for these groupings. For the reasons already outlined these computations need be extended only far enough to include the first order reflection from the (111) face and the reflections from two or three other simple planes which will serve as comparisons. Before these calculations can be made, however, it is

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[7] A. W. Hull, Phys. Rev. (2), 10, 661, 1917.

necessary to assign a value to $f(d/n)$. An approach to the correct form of this function seems to be furnished by writing

$$f(d/n) = (d/n)^2.$$

Introducing this approximation and remembering that the intensity of the powder reflection from a kind of face is given by the product of the intensity of reflection from one of the faces into the number of like planes, such calculations yield for the four strongest lines.

For the grouping (II):

Plane	Order (n)	d/n	I	Intensity (of powder reflection)
100	2	0.500	6,670	40,000 units (arbitrary)
110	2	.354	2,460	29,600
120	2	.223	1,325	31,800
112	2	.204	1,115	26,800

For the grouping (III):

Plane	Order (n)	d/n	I	Intensity (of powder reflection)
111	1	0.577	4,680	37,400
110	2	.354	3,333	40,000
113	1	.301	1,270	30,500
112	2	.204	1,111	26,700

The estimation of intensity and measurement of spacing for the four strongest lines in the powder photograph furnish

d/n				
Measured	Calculated	for the Plane	n	Estimated Intensity
2.61 A.U.	2.60 A.U.	100	2	10
1.84	1.84	110	2	8
1.17	1.16	120	2	6
1.06	1.06	112	2	5.5

From a study of these measurements it is evident, assuming of course that four molecules are associated with the unit cell, that the arrangement of the atoms of alabandite is described by (II) or by such values of u and u' in either (I) or (IV) that the arrangement approaches that of (II).[8] A definite choice between there three possibilities upon the basis of a study of their diffraction effects cannot be made until the scattering powers

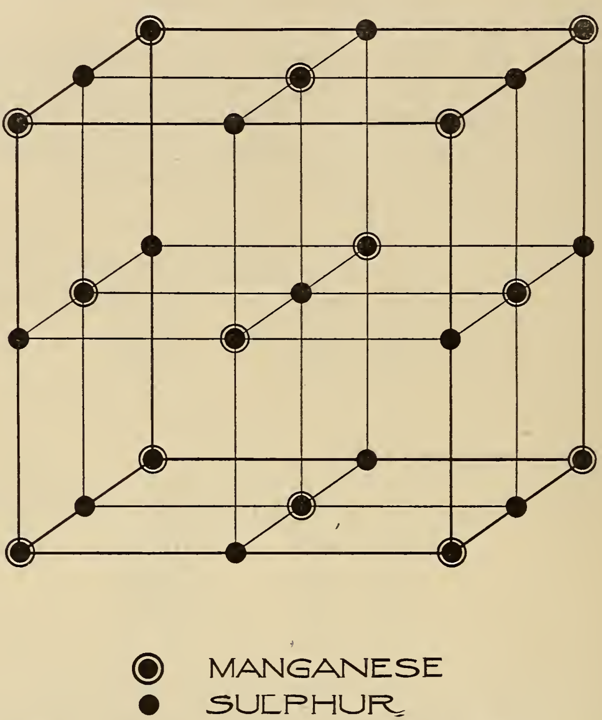

Fig. 2.—The arrangement of the atoms in alabandite if it has exactly the "sodium chloride arrangement."

of the different atoms for X-rays is known with accuracy and until the form of $f(d/n)$ is carefully determined. If the atoms lie exactly in the "sodium

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[8] Other weaker lines appear in the powder photograph. As will be seen from the following table they are in equally good agreement with the "sodium chloride arrangement," (II), or a close approach to this grouping.

d/n					Calculated (for II)
Measured	Calculated	for the Plane	n	Estimated Intensity	Intensity
1.50A.U.	1.50A.U.	111	2	3	17,700 units
1.31	1.30	100	4	2	10,000
0.87	0.87	122	2	2	17,700
0.83	0.83	130	2	2	16,000

At least a portion of the lack of quantitative agreement can be ascribed to the approximate character of the assumption that $f(d/n) = (d/n)^2$.

chloride arrangement," (II), then the observed low degree of symmetry must be ascribed to some sort of a lack of symmetry in the shape of the fields of force about the atoms of manganese or of sulphur or of both. If the low degree of symmetry is in this instance to be accounted for by the arrangement of the atoms and if the symmetry is really that of the tetrahedral class (hemimorphic hemihedry), then grouping (I) with values of u and u' such that there is but slight departure from the "sodium chloride arrangement" would be in agreement with the existing information; if, on the other hand, the symmetry is tetartohedral, a similar arrangement based upon (IV) would be possible. The definite elimination of this last possibility could be effected if a careful crystallographic investigation showed the crystal to be

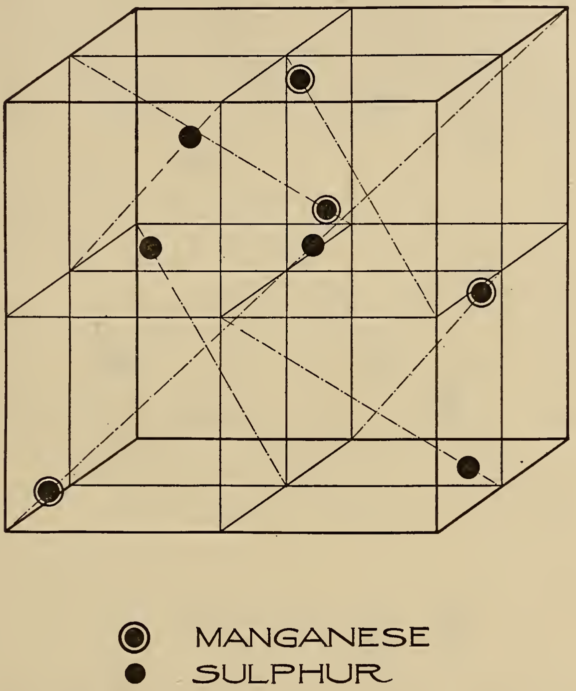

Fig. 3.—A possible arrangement for the atoms of alabandite. The positions of the manganese and sulphur atoms can be but slightly displaced, however, from the positions which they occupy in the grouping of figure 2. This arrangement is a possible one only if the symmetry of alabandite is tetartohedral.

tetrahedral.[9] This seems never to have been done and the author does not have at his disposal material upon which to make such a study. The three possible structures for alabandite are shown in figures 2, 3 and 4.

Alabandite is usually classed in the same group with zinc blende.[10] This determination of its crystal structure, however, definitely indicates that it is in no way isomorphous with the zinc sulphide. In this connection it is of interest to note that alabandite does not have the dodecahedral cleavage of zinc blende but rather the cubic cleavage of the (from the standpoint of its crystal structure) similarly arranged sodium chloride and magnesium oxide.

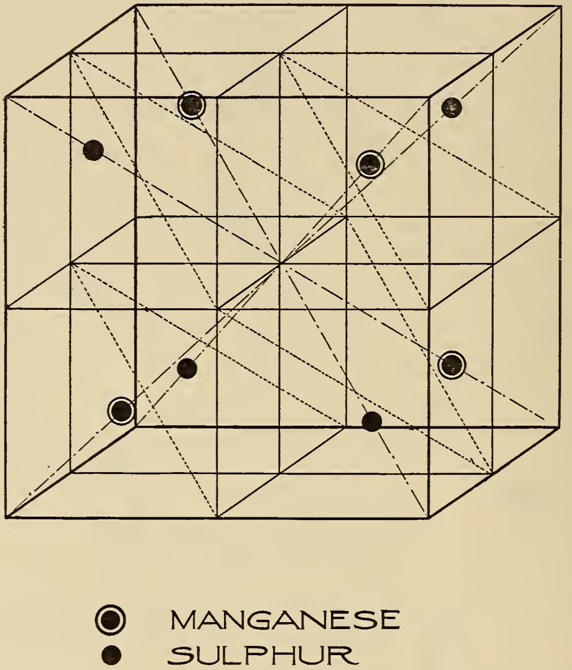

Fig. 4.—The last of the three possible structures for alabandite. In this case also the positions of the manganese and sulphur atoms can differ but slightly from those of figure 2.

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[9] The proof that the crystal was actually tetartohedral would not in a corresponding manner eliminate (I) since it is a special case of T^2 as well as of T_d^2.

[10] Dana, System of Mineralogy, 6th Edition, p. 59.

Taking its crystal structure as a criterion, one would say that alabandite is in chemical nature also similar to magnesium oxide in that it is composed of divalent "ions" of manganese and of sulphur.[11]

Summary.

By a combination of a reflection spectrum from a known crystal face with a powder reflection, and employing the general method based upon the theory of space groups, it is shown that the arrangement of the atoms in alabandite is either that of the "sodium chloride grouping" or is a grouping approaching very close to this arrangement.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C.
July, 1921.

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[11] Ralph W. G. Wyckoff, this Journal, **1**, 138, 1921.

Art. XVIII.—*Later Cenozoic Mammalian Remains from the Meadow Valley Region, Southeastern Nevada;* by Chester Stock.

Contents.

Introduction.

In the progress of investigations relating to problems of correlation of western Tertiary deposits, conducted under the leadership of Professor John C. Merriam at the University of California, it has become evident that an extensive territory of later Cenozoic beds in the Meadow Valley region of southeastern Nevada, mapped by Spurr[1] as Pliocene, has remained for a number of years a field from which palæontological materials indicative of Tertiary mammalian faunas were unknown.

With the special purpose of examining the deposits for vertebrate remains, the writer accompanied by Mr. R. J. Russell visited Meadow Valley during the field season of 1919, at the request of Professor Merriam and in the interest of the Department of Palæontology, University of California. While fossil collecting did not yield the results that had been anticipated, sufficient materials were encountered in beds exposed near the village of Panaca in Meadow Valley, and again in Muddy Valley between the villages of Overton and Logan, to give some information as to age and relationship of these deposits.

Information relating to the Meadow Valley region, although dependent upon an examination of a compar-

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[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California, U. S. Geol. Surv. Bull. 208, 1903.

atively small portion of the great area in which later Cenozoic deposits are exposed, appears worthy of record as it not only furnishes palæontologic data for correlation studies of the Great Basin Tertiaries, but may also be of service in an interpretation of the geologic history of the Grand Canyon of the Colorado.

Previous Knowledge.

We are indebted to the reconnaissance study of Spurr[2] for the first account of the geologic features of southeastern Nevada. The observations which Spurr has recorded concerning beds determined as of Pliocene age in the Meadow Valley region will suffice for purposes of the present paper and need only receive attention.

The group of deposits so determined includes the sedimentary series of Meadow Valley typically exposed in the vicinity of Panaca, Lincoln County, Nevada, and discussed in the text of Spurr's report although not indicated on the geological reconnaissance map which accompanies the paper. Beds similar in appearance to those occurring in Meadow Valley, but located some 30 miles south of Panaca, are mapped as Pliocene, the sediments extending from this point to the south along the western base of the Mormon Range. They are well exposed in the Meadow Valley Wash. Along the Muddy River east of the Mormon Range and in the valley of the Virgin River the sedimentary strata, approaching closely in general appearance those exposed in the Meadow Valley Wash, are regarded by Spurr as probably of Pliocene age.

With reference to the accumulation of the Pliocene series, Spurr remarks:

> "As observed by the writer in the Meadow Valley Wash, they have the appearance of having been deposited in a lake, although it is possible that they represent the valley accumulation of the Colorado River, at a period when the streams of this system occupied wide valleys, in which they worked laterally and deposited the material which they derived from the erosion of the mountains, the carrying power of the streams at that time not being equal to the amount of load received. These sediments occupy the older valleys which were eroded in the Paleozoic limestones and in the

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[2] Spurr, J. E., *op. cit.*, 1903.

earlier Tertiary sediments and lavas, but they were laid down before the down cutting of the latest sharp gorges, for they stand as the walls of these. They lie against the Carboniferous limestones, and, as described by Marvine, against the Archean granites along the Grand Wash.''

The basis for determination of age of the horizontally bedded sediments as Pliocene is given by Spurr in the following statement:

''According to Dutton (Second Ann. Rept. U. S. Geol. Surv., p. 67) the greater part of the general denudation of the Colorado drainage region was probably accomplished in Miocene time, whereas the cutting of the Grand Canyon probably began in the early part of the Pliocene. The conglomerates and sandstones under consideration were evidently deposited just before the period of rapid canyon cutting, and this, in conjunction with the evidence afforded by the underlying unconformable Tertiary rocks in Meadow Valley Canyon, may be sufficient grounds for specifying their age provisionally as Pliocene.''

Everett Carpenter[3] in a paper on the ground water in southeastern Nevada discusses the Meadow Valley region. Concerning the geology of Meadow Valley, Carpenter states:

''The valley fill consists largely of gravel, sand, and variously colored clay. Its depth is probably great. There are good exposures of the unconsolidated sediments in the valley, but no fossils have been found to give a definite clue as to the age. The three terraces on the alluvial slopes indicate that there have been at least three epochs of accumulation, which alternated with three epochs of erosion. The terraces and the erosional features in general are very similar to, and probably were formed contemporaneous with, those in Las Vegas Valley, which are thought to be Pleistocene in age.''

In the course of completion of the present paper there appeared an important abstract by Mr. C. R. Longwell[4] of results obtained from a study of the geologic feature of southeastern Nevada in which particular attention is given to the region of the Muddy Mountains. In the description of the Tertiary formations, Longwell notes the presence of an older and younger series. The latter deposits occupy the intermontane valleys and are composed of silt, clay and sand to a thickness of nearly 2000 feet

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[3] U. S. Geol. Surv. Water Supply Paper 365, pp. 50, 58-59, 1915.
[4] This Journal, pp. 39-62, January, 1921.

FIG. 1.

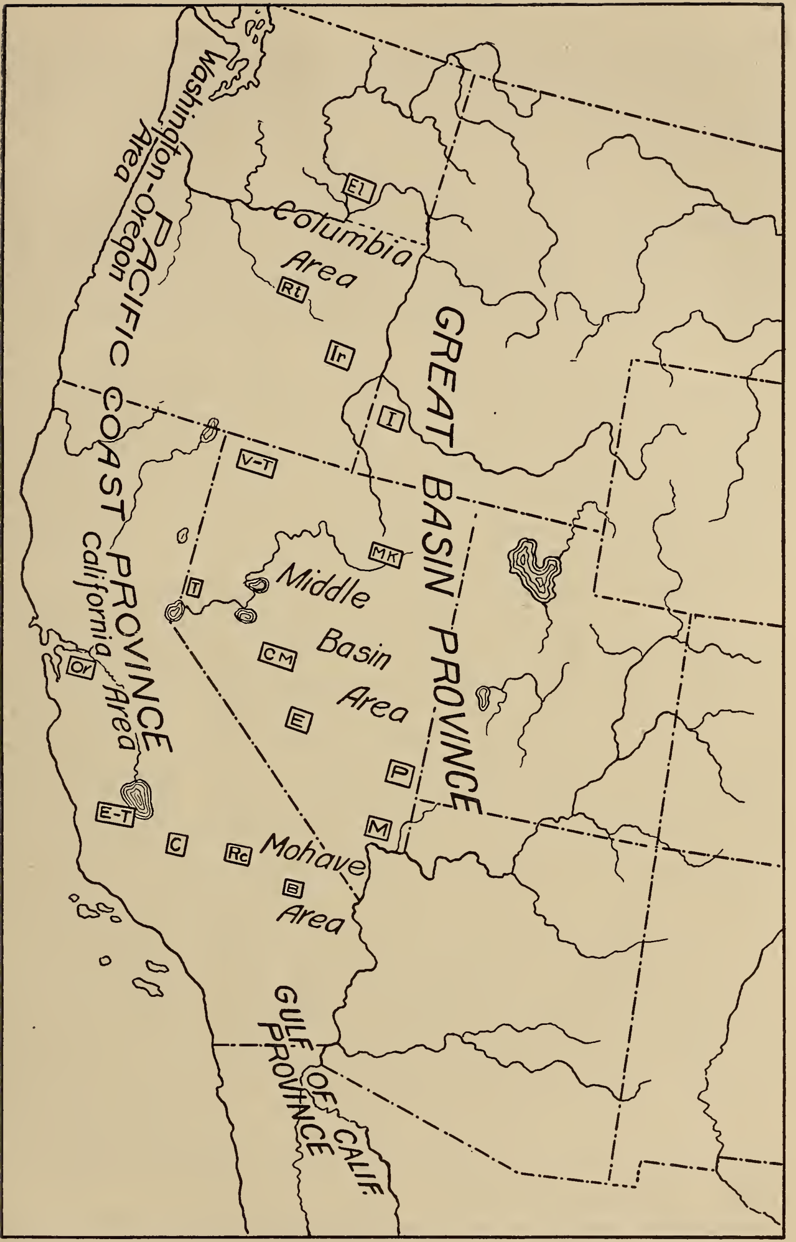


FIG. 1.—Outline map illustrating occurrences of Miocene and Pliocene faunas in Tertiary provinces of the United States west of the Wasatch Range. P, Panaca beds; M, Muddy Valley deposits; B, Barstow beds; Rc, Ricardo beds; C, Chanac formation E-T, Etchegoin-Tulare beds and Merychippus zone; Or, Orinda beds; E, Esmeralda beds; CM, Cedar Mountain beds, T, Truckee beds; MK, McKnight Miocene; V-T, Virgin Valley and Thousand Creek beds; I, Idaho beds; Ir, Ironside Pliocene; El, Ellensburg formation.

The beds rest unconformably upon the older series and are tentatively considered to be of Pliocene age. These are the deposits referred to below as the Muddy Valley Beds.

Occurrence.

Within the confines of the Meadow Valley region of southeastern Nevada at least two areas are known where well exposed sedimentary deposits, presumably of the later Cenozoic, have yielded mammalian remains. The northern area comprises Meadow Valley, an intermontane enclosure bounded on the west by the Highland Range, on the east and south by the Mormon Range, and on the north by the Pioche Range. Some 80 miles to the south of Meadow Valley, a second series of mammal-bearing beds flanks the southern extremity of the Mormon Range and is exposed in the valley of the Muddy River. Both areas lie within the drainage basin of the Colorado system.

Meadow Valley.—The later Cenozoic sedimentary deposits of Meadow Valley extend for approximately twenty miles north of the entrance to Meadow Valley Canyon and in a lateral extent reach perhaps a distance of ten miles or more. They are typically exposed near the village of Panaca. These beds rest unconformably upon older rocks of Paleozoic, Mesozoic, or early Tertiary age that form the borders of the valley. The deposits consist in part of red-brown and green colored sands and clays, not well indurated, exhibiting on their weathered slopes typical badland features. Cross-bedded sands and gravels as well as tuffaceous materials are also present. The sediments have either a horizontal position or show the effects of slight deformation. Meadow Valley presents striking physiographic features as a result of the terracing which the later Cenozoic beds have undergone. Fossil materials pertaining to a camel, a rhinoceros, and a horse were collected in exposures immediately southeast of Panaca. The designation Panaca beds may be conveniently applied to these mammal-bearing sedimentaries of Meadow Valley.

Muddy Valley.—Terraced sedimentary deposits extend along the Muddy River for some ten miles northeast of the confluence of this stream with the Virgin River. Southwest of Muddy River, between the villages of

Overton and Logan, Lincoln County, Nevada, where the beds were examined in detail, they consist of well indurated sands and clays, red and light brown in color, that overlie unconformably the early Tertiary deposits in this region. A small vertebrate fauna, including camels and a horse, was collected in the fine sandstone approximately three miles west of Overton. The sedimentary deposits of Muddy Valley, in which mammalian remains were found, may be known as the Muddy Valley beds as distinguished from the Panaca deposits of Meadow Valley.

Comparison of Faunas from the Meadow Valley Region.

Unfortunately few species are represented in the Cenozoic faunas from the Meadow Valley region, and much additional vertebrate material must be secured before satisfactory comparison can be made between the mammalian assemblages at present recognized by fossil remains in the Panaca beds of Meadow Valley and in the Muddy Valley deposits of Muddy Valley.

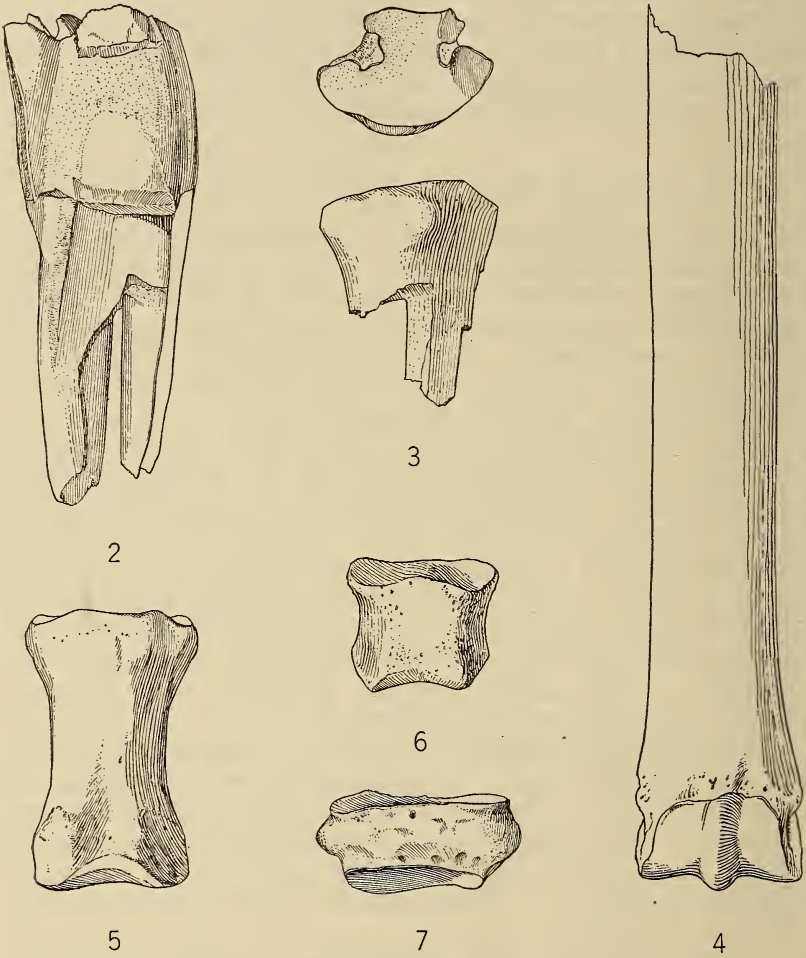
Remains of Equidæ found near Panaca, Nevada, belong to large types presumably related to species of *Pliohippus* or to early forms of *Equus*.. .In contrast to the species from the Panaca beds, that from the Overton deposits, so far as evidence is procurable from a single incisor tooth, seems to represent an earlier stage in the history of the horse group. The incisor from the Overton beds resembles closely in size comparable teeth of *Merychippus*. This genus occurs commonly in Miocene deposits of the Great Basin region.

Among the fragmentary rhinocerotid remains obtained in the Panaca beds is a phalangeal element similar in size and shape to phalanx 1, digit 3, manus of *Teleoceras fossiger*. Members of the Rhinocerotidae are known from the Tertiary deposits of western North America, but apparently are not found in deposits later in age than Lower Pliocene.

Camel remains from the Panaca beds apparently belong to a species of the *Pliauchenia* group, while materials from Muddy Valley are presumably referable to genera other than *Pliauchenia*. A fore-foot of an immature camel from the Muddy Valley deposits may belong to *Alticamelus* or to *Procamelus*, while a single astragalus from these beds, possibly pertains to the latter genus.

Such evidence as can be gathered at present from the

Figs. 2–7.



Figs. 2 to 6.—Pliohippus?, sp. Elements of the dentition and skeleton. Fig. 2, lower cheek tooth, No. 24094, outer view, × 1; fig. 3, proximal end of metacarpal 3, No. 24095, × ½; fig. 4, metapodial 3, No. 23931, × ½; fig. 5, first phalanx, digit 3, No. 24097, × ½; fig. 6, phalanx 2, digit 3, No. 24096, × ½. Panaca beds, Meadow Valley, Nevada.

Fig. 7.—Rhinocerotid, possibly Teleoceras, sp. Phalanx, No. 24093, posterior view, × ½. Panaca beds, Meadow Valley, Nevada.

very incomplete faunal representations occurring in the later Cenozoic sediments of the Meadow Valley region suggests that the Panaca beds and the Muddy Valley deposits are not of same age. Furthermore, the beds in Meadow Valley appear to be younger than those of Muddy Valley in which fossil vertebrates have been found. The occurrence of a large type of horse in the Panaca beds favors the belief that these deposits are not earlier in age than Pliocene, while the presence of a rhinoceros, possibly the genus *Teleoceras*, indicates a period antecedent to the Pleistocene. The collection of vertebrate remains from Muddy Valley is not large enough to permit definite assertion as to age of the Muddy Valley deposits. If the single incisor tooth belongs to a horse related to *Merychippus* or to a closely allied form the suggestion may be advanced that the Muddy Valley beds are Miocene in age. Information obtained from a study of the camel remains appears conformable to this view.

Description of Vertebrate Remains.

Panaca Beds, Meadow Valley, Nevada.

Pliohippus?, sp.

An unworn and fragmentary tooth, No. 24094,[5] fig. 2, locality 3548,[6] measures approximately 14mm. in transverse diameter across the hypoconid. This measurement does not include the thickness of the outer layer of cement.

Elements of the limbs secured at locality 3547 are shown in figs. 3 to 6. The limb materials indicate forms larger than species of *Pliohippus* from the Lower Pliocene of western North America. They approach in size comparable structures of the Pleistocene *Equus*. In specimens such as the median metapodial (fig. 4) and the phalanges of digit 3 (figs. 5 and 6) a size is shown which approximates closely that of limb elements of *Pliohippus proversus* from the Upper Etchegoin Pliocene of California.

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[5] Accession numbers refer to specimens in the collections of the Department of Palæontology, University of California.

[6] University of California collecting localities. See descriptive list of localities near the end of this paper.

Measurements of Limb Elements.

Metacarpal 3, No. 24095	
Transverse diameter of proximal end	45.6mm.
Anteroposterior diameter of proximal end	32.4
Metapodial, No. 23931	
Greatest transverse diameter of distal end	42.5
Greatest anteroposterior diameter of distal end	33.2
Phalanx 1, No. 24097	
Greatest length	71.3
Width of proximal end	44.7
Depth of proximal end	32.9
Width of distal end	38.8
Phalanx 2, No. 24096	
Greatest length	*a*36
Width of proximal end	*a*39

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a, approximate.

Rhinocerotid, possibly *Teleoceras,* sp.

Fragments of teeth of a rhinoceros were collected in the terraced sedimentary beds of Meadow Valley near Panaca, Nevada. Unfortunately the specimens are not preserved in sufficient completeness to permit satisfactory determination.

A single phalanx, No. 24093, fig. 7, found in association with fragments of teeth at locality 3546 resembles most closely in size and shape phalanx 1, digit III, manus of *Teleoceras fossiger*, from the Republican River beds of Kansas. No. 24093 differs from the specimen of *Teleoceras* available for comparison in possessing a proximal articulating surface relatively wider transversely. In this specimen, also, the proximal and distal articulating surfaces approach each other more closely on the posterior side, fig. 7, than in the corresponding phalanx of *T. fossiger* from Kansas.

Measurements of No. 24093

Greatest transverse width	52.4mm.
Distance between articulating facets measured across middle of posterior face	17.8
Greatest transverse diameter of distal facet	39

Pliauchenia?, sp.

A nearly complete fore-foot, No. 23916, fig. 8, collected at locality 3546, belongs to a rather large species of camel presumably of the *Pliauchenia* type. A single astragalus, fig. 9, from locality 3547, is perhaps also referable to this genus.

The individual represented by the fore-foot, No. 23916, approaches in size certain of the camel types known from the Ricardo Lower Pliocene of the Mohave Desert, California. The Meadow Valley species resembles in size the Camelops-like[7] form from the Upper Etchegoin Pliocene of California, but it does not approach in this character the genus *Camelops* from the Pleistocene of Rancho La Brea.

The camel from Meadow Valley differs from *Procamelus*[8] from the Barstow Miocene of the Mohave Desert in possessing a shorter and more robust cannon bone, larger and heavier phalanges. No. 23916 is decidedly larger and heavier than limb elements of *Procamelus* known from the Upper Miocene Cedar Mountain beds of Nevada.

The anterior cannon bone is badly crushed, particularly the posterior side. At the distal end the articulating surface for the inner digit is noticeably larger than that for digit 4.

Measurements of No. 23916.

Carpus.	
Greatest transverse width across proximal row of carpal elements	70.8 mm.
Depth measured from proximal surface of scaphoid to distal surface of magnum	53
Anterior cannon bone	
Length	336
Width of proximal end	*a*68
Width of distal end	*a*92.5
Digit 4, phalanx 1	
Greatest length	112.8
Width of proximal end	41.3

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[7] Merriam, J. C., Trans. Amer. Philos. Soc., n. s., vol. 22, pt. 3, p. 38, figs. 42*a* and 42*b*, 1915.

[8] Merriam, J. C., Tertiary mammalian faunas of the Mohave Desert, Univ. Calif. Publ. Bull. Dept. Geol., vol. 11, p. 513, fig. 91, 1919.

Depth of proximal end	35.2 mm.
Width of distal end	34
Digit 3, phalanx 2	
Greatest length	57.7
Width of proximal end	30
Depth of proximal end	25.7
Greatest width of distal end	29.5
Digit 3, phalanx 3	
Greatest length	29
Greatest width	19
Greatest depth	18

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a, approximate.

Muddy Valley Beds, Muddy Valley, Nevada.

Merychippus?, sp.

A single incisor tooth, no. 24099, fig. 12, from locality 3550, resembles closely comparable teeth of *Merychippus* in size. The specimen, apparently a lateral tooth, is worn and quite small. In no. 24099 the posterior or lingual enamel border is recurved slightly outward at the inner side.

Measurements of No. 24099

Transverse width measured along worn occlusal surface	10 mm.
Anteroposterior diameter measured along inner side	7.5

Alticamelus? or *Procamelus?*, sp.

Remains of camels from the Muddy Valley beds are also very incomplete. The principal specimen, no. 23917, fig. 10, from locality 3550, consists of an anterior cannon bone with associated carpal elements and phalanges of the digits. The materials unfortunately are badly crushed and belong to a young individual.

In no. 23917 the cannon bone is long and very slender, the latter character being especially noticeable when the specimen is contrasted with the corresponding element from the Panaca beds (compare figs. 8 and 11). The two specimens are nearly of same length, but their proportions are totally unlike. The differences noted in the proportions of the two forms certainly indicate generic separation.

FIGS. 8–12.

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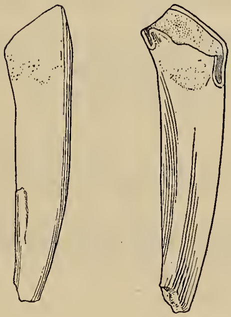

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FIGS. 8 and 9.—Pliauchenia?, sp. Skeletal elements. Fig. 8, carpus, metacarpus and phalanges, No. 23916, anterior view, × 1/4; fig. 9, astragalus, No. 23929, × ½. Panaca beds, Meadow Valley, Nevada.

FIGS. 10 and 11.—Alticamelus? or Procamelus?, sp. Limb elements. Fig. 10, astragalus, No. 23930, × ½; fig. 11, carpus, metacarpus and phalanges, anterior view, No. 23917, × 1/4. Muddy Valley beds, Muddy Valley, Nevada.

FIG. 12.—Merychippus?, sp. Incisor tooth, No. 24099, × 1. Muddy Valley beds, Muddy Valley, Nevada.

In the magnum of no. 23917 that portion of the articulating surface for the lunar, situated on the dorsal side of the posterior process, is continuous with the forward portion of the contact surface. In the magnum of no. 23916 from the Panaca beds the posterior articulation for the lunar forms a discrete surface. The articulating facet for the unciform on the outer side of the magnum is wider in no. 23917 than in no. 23916.

The cuneiform in no. 23917 exhibits the slenderness characteristic of the limb. It is distinctly less robust than the corresponding element in the camel from the Panaca beds. The posterior end is thin and quite different from that of the cuneiform of no. 23916.

The lunar in no. 23917 is very narrow transversely. On the ventral surface the posterior facet for the magnum is continuous with the forward articulating surface for this carpal element, not separated from it as in the lunar of the specimen from the Panaca beds.

Single artiodactyl astragalus, no. 23930, fig. 10, from locality 3550, approximates in size the smaller astragali of *Procamelus* from the Barstow Upper Miocene deposits of the Mohave Desert. The astragalus found near Overton, Nevada, differs from specimen 21554[9] from the Barstow in being larger and in lacking the narrow transverse diameter which is so prominent a feature in the latter element. No. 23930 approaches most closely in size the second astragalus of *Procamelus*[10] from the Barstow as figured by Merriam.

Measurements of No. 23917.

Carpus	
Depth measured from proximal surface of cuneiform to distal surface of unciform	33.3 mm.
Anterior cannon bone	
Length	323
Width of proximal end	*a*40.8
Width at middle of shaft	*a*20.7
Width of distal end	*a*40
Digit 4, phalanx 1	
Length	78.6
Width of distal end	16.8

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[9] Merriam, J. C., *op. cit.*, p. 512 and fig. 98, p. 515, 1919.

[10] Merriam, J. C., *op. cit.*, fig. 99, p. 515, 1919.

Digit 4, phalanx 2	
Length	33.2 mm.
Width of proximal end	16.4
Depth of proximal end	15.4
Width of distal end	12.8
Digit 3, phalanx 3	
Length	18.7
Width of proximal end	12
Depth of proximal end	10

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a, approximate.

Descriptive List of Collecting Localities.

Univ. of Calif. Coll. Loc.

No. 3546. Meadow Valley, ¾ mi. SE of Panaca, Lincoln County, Nevada. In deposits of reddish-brown color exposed on north side of terraced spur south of Panaca. Pioche Sheet, U. S. G. S.

No. 3547. Meadow Valley, Nevada, ¾ mi. SE of locality 3546. Strata exposed on south side of terraced spur south of Panaca. Pioche Sheet, U. S. G. S.

No. 3548. Meadow Valley, approximately 4 miles SE of Panaca, Lincoln County, Nevada. Massive beds of light brown sands and gravels showing cross-bedding and weathering to form pinnacles which often stand apart from the main exposures. South side of terraced spur south of Panaca. Pioche Sheet, U. S. G. S.

No. 3550. Muddy Valley, approximately 2½ miles NW of Overton, Lincoln Co., Nevada. Near base of exposed section of light brown sandstones and clays capped by conglomerate. Locality is west of the Muddy River and immediately west of the Weber Ranch. Saint Thomas Sheet, U. S. G. S.

No. 3551. Muddy Valley, Nevada, approximately 500 ft. west of locality 3550 and approximately 20 ft. higher in the section. Well consolidated chocolate colored clay beds. Saint Thomas Sheet, U. S. G. S.

Conclusions.

Two series of sedimentary deposits in the Meadow Valley region of southeastern Nevada have yielded mammalian remains of later Cenozoic age: (1) the Panaca beds exposed in Meadow Valley near the village of Panaca, and (2) the Muddy Valley beds as exposed between the villages of Overton and Logan in Muddy Valley.

The fauna from the Panaca beds includes horses, a rhinoceros, and a camel, while a horse and species of camels comprise the mammalian assemblage known by specimens collected in the Muddy Valley deposits.

Evidence derived from a study of the small mammalian faunas seems to suggest that the later Cenozoic beds of Meadow Valley and of Muddy Valley were not deposited during the same period of time. The Panaca beds are presumed to be Pliocene, while the Muddy Valley deposits are tentatively regarded as representing an earlier accumulation, possibly of the Miocene.

Berkeley, California.

Art. XIX.—*The Classification of Igneous Rocks—A Study for Students*; by L. V. Pirsson.

[Professor Pirsson was engaged during the last years of his life in preparing a text book of petrography, based on microscopical methods. This book was planned to consist of 15 chapters and to cover the igneous, sedimentary, and metamorphic rocks. Unfortunately, however, but five of the fifteen chapters had been completed at the time of his death: the four chapters of Part I that comprise the necessary introductory matter to the volume (methods of studying rocks, determination of rock minerals, rock minerals and textures, and classification of rocks), and a large part of Chapter V, describing the phanerocrystalline igneous rocks.

The following paper consists of the larger part of Chapter IV, with only minor verbal changes, and is presented here in the knowledge that Professor Pirsson's matured views on the classification of igneous rocks will be of wide interest. The subtitle, "A Study for Students," has been added in recognition of the obvious purpose of the author to present the subject matter primarily for the student.—Adolph Knopf.]

Igneous Rocks.

General Discussion.—There are probably few matters in the domain of natural science in which there is less general agreement than in the classification of igneous rocks. The reason for this is very simple, and it lies in the fact that there are no natural absolute division lines to be found among them, which are obvious to every one and which compel unquestioning assent from all as a basis for classification. Everywhere there are gradations among igneous rocks, geologically in the form and mode of occurrence of their masses, and petrographically in the kinds of material composing these masses. Thus, geologically, we divide them into intrusive and extrusive rocks, and yet in one rock-body we may observe a dike passing upward into a flow without break in the mass; indeed, every extrusive flow, unless separated by erosion, must in principle pass into an intrusive mass. Again in intrusive occurrences we find laccoliths grading into intrusive sheets, stocks running out in dikes, etc. This is true not only of the individual bodies, but of the masses grouped collectively; thus we may find occurrences in which it is arbitrary whether we shall call them intrusive sheets or laccoliths, dikes or stocks, stocks or batholiths. And so petrographically we may find one rock mass, like a stock, composed of different kinds of material sharply separated from one another, whereas in another mass one variety of rock substance passes most gradually into another variety, while collectively if the materials composing all igneous rock bodies are compared there will be found, mineralogically, and therefore chemically, whole series giving complete transitions from one kind into another.

It is therefore clear that any system of classification of the igneous rocks must be an arbitrary one, and an examination of those that have hitherto been attempted will prove the truth of this statement. Some which have been termed natural by their authors will be found to have divisions that seem natural only to the authors who made them. Others see no natural divisions in these places but would draw distinctions elsewhere. This is inevitable when one perceives that they are matters of opinion, and history teaches us that in matters of opinion men have always differed, and from this we infer that they are likely to continue to differ. The situation is similar to that of any continuous field which requires to be divided, like that of temperature or length for example, in which we see that one nation uses one scale and another nation uses a different scale. It will be profitable for us to consider briefly some of the more important attempts at classification and the principles upon which they are grounded.

Some Systems of Classification.—At the outset we must observe that it is possible to regard and classify igneous rocks from two different view-points. In one we may take account of the form, disposition, and relation of an igneous rock-mass and its relation to other rock-masses, in short its nature as a component unit in the architecture of the earth's outer shell. This is its mode of occurrence, whether intrusive or extrusive, whether a flow, dike, stock, etc., and is a *geologic* way of regarding it.

In the other we consider the kinds of material that make up such occurrences and the endeavor here is to classify the rocks according to those characters that would be inherent in representative masses selected from the rock-bodies. These characters would refer to the chemical composition of the mass, the kinds and relative proportions of the minerals composing it, if it is crystalline, and the sizes and arrangement of the mineral grains (texture), the specific gravity, etc. This we may term the *petrographic* way of viewing the rock. The geologic way considers its outward relations to other rocks, whereas the petrographic one regards its inward characters. The student will do well to bear these two viewpoints clearly in mind.[1]

We do not need to describe here the various systems of classification that have been suggested and more or less used in the past, but which are not now in vogue. Their interest is now historical and they have been clearly described and their merits and defects pointed out by Cross.[2] We shall consider briefly only those which are more or less in force to-day, and which consequently may be held to be of influence on the science of petrography.

Qualitative Classification—One of these is what may be called a purely petrographical classification and its chief exponent has, perhaps, been Zirkel.[3]

According to this the rocks are divided into classes dependent upon the kinds of minerals, the absence or presence and varieties of feldspars being given predominance, and then subdivided following the texture, that is whether granular, dense, glassy, etc. One other feature has been incorporated with this, especially in Germany, which demands notice, and this is a further subdivision of the fine, dense, and glassy rocks, which are often porphyritic, into two groups depending on their geologic age. Those that were older than the Tertiary received one set of names, whereas those that were of Tertiary age or younger were named differently, though

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[1] See Whitman Cross, Geological *versus* Petrographical Classification of Igneous Rocks; Jour. of Geol., Vol. 6, p. 79; 1898.

[2] Whitman Cross, Development of systematic Petrography in the Nineteenth Century; Jour. of Geol., Vol. 10, p. 331, 451; 1902. Also in Quantitative Classification of Igneous Rocks, by Cross, Iddings, Pirsson, and Washington; Chicago; 1903.

[3] F. Zirkel, Lehrbuch der Petrographie; Vol. I, p. 829, 1893.

of very similar composition and texture. This was based on historical grounds; the older rocks are more likely to have suffered various modifications which cause them to appear somewhat differently from fresh recent ones of similar nature. Such differences were thought to be fundamental in character, to belong to the period at which the rocks were formed, and to thus deserve recognition by giving such rocks an especial set of names. Since it has been perceived, however, that these characters have been superposed on the rocks, and are therefore secondary in nature, this distinction has lost its force and has practically been given up, even in Germany, though the names have been in large measure retained, as a matter of convenience, to denote rocks which present these characters, without regard to their geologic age. This historical usage, which never obtained much currency in America and Great Britain, the student should note, in order that he may understand the literature which he may consult, particularly the older part of it, and appreciate the meaning of these terms when he meets them. They will be mentioned in appropriate places. Returning now to our classification, we may illustrate its

TABLE No. 1. ILLUSTRATING QUALITATIVE CLASSIFICATION OF IGNEOUS ROCKS

Even-granular.	Predominant Alkalic Feldspar			Predominant Soda-lime Feldspar			No Feldspar
	With Quartz	No Quartz	With Nephelite	With Hornblende	With Pyroxene	With Nephelite	
	Granite	Syenite	Nephelite-Syenite	Diorite	Gabbro & Norite	Theralite	Peridotite
Porphyritic, dense, glassy	Pre-Tertiary						
	Granite-Porphyry Quartz-Porphyry	Syenite-Porphyry Keratophyre	Neph. Syen. Porphyry	Diorite-Porphyrite Quartz Porphyrite	Diabase. Augite-Porphyrite		
	Tertiary and Recent						
Dense, glassy, porphyritic	Rhyolite	Trachyte	Phonolite	Dacite & Andesite	Basalt	Basanite	Augitite

principles by grouping some of the more important rocks into a table, No. 1, which will show its practical application. It should be noted that the coarser granular, non-porphyritic rocks are not divided according to geologic age.

Remarks.—Aside from the question of age, which is now practically obsolete, it should be observed that the system is defective in that little or no account is taken of the relative *quantities* of the component minerals that may be present in a rock. Thus syenite may contain some pyroxene, but a rock composed mostly of pyroxene with a very little alkalic feldspar, although chemically it may differ widely from the former, is equally classed as a syenite. The chemical composition of a rock is, however, its most fundamental property. The defect runs through the whole scheme and it is for this reason spoken of as the *qualitative system.*

It is to be noted also that the system is arbitrary; thus in texture, whether a rock shall be classed as granular, porphyritic, or dense is purely a matter of opinion in many cases. Also what is meant by "predominant" may be very often an open question. It is customary to class rocks as syenites when they contain a little quartz, but not if they contain a little nephelite; they then pass into the next division. Such examples might be greatly multiplied, but these are sufficient to indicate that the division lines are largely artificial, or arbitrary. The valuable feature of the system is, from the petrographic point of view, that it is based on the inherent, inward properties of the rocks, and not upon outward geologic relations.

Geologic-Petrographic Classification.—In this system of classification, which has been given a wide circulation and usage by the writings of Rosenbusch,[4] the effort is made to combine the geologic outward relations with the inward petrographic characters of the rocks. They are divided into abyssal (deeply-formed intrusive or plutonic) rocks (Tiefengesteine), and the volcanic or extrusive lavas (Ergussgesteine), as the chief groups, with a smaller subordinate group of dike rocks (Ganggesteine), with intermediate characters. The effusive rocks, or lavas, were again divided according to their geologic age on the same basis as in the system previously mentioned, but in the last edition of Rosenbusch's work

[4] Mikro-physiographie der massigen Gesteine 1st, 2d, 3d, and 4th Eds. 1877-1908. Elemente der Gesteinslehre, 1st, 2d, and 3d Eds. 1898-1910.

this age distinction was laid aside. The groups of plutonic and effusive rocks thus formed on a geologic basis were subdivided according to their mineral composition on the same general lines as in the preceding classification. Texture in them is not used as a means of classification, except in so far that certain textures are held to accompany each group and to be characteristic of them; that is, the abyssal rocks are granular and the effusives are porphyritic. The dike rocks are subdivided

TABLE NO. 2, ROSENBUSCH CLASSIFICATION OF IGNEOUS ROCKS.

Characterized by	Plutonic Group Granular	Group of Dike Rocks Porphyritic and Panidiomorphic.			Volcanic Group Porphyritic.
		Granite-porph'ritic	Aplitic	Lamprophyric	
Alkalic feldsp's +Qtz.	Granite	Granite-porphyry	Aplite		Quartz-porphyry Rhyolite
Alkalic feldsp's —Qtz.	Syenite	Syen.-porph'y	Bostonite	Minette Vogesite	Orthophyre Trachyte
Alk. Feldspars and Nephelite, or Leucite	Nephelite-Syenite Leuc.Syen.	Neph.Syenite-porphyry Leu.Syen.por'y	Tinguaite Leuc. Ting.		Phonolite Leucitophyre
Feldspathoids Nephelite +Oliv.	Bekinkinite	----------	----------	----------	Neph. Basalt
Nephelite —Oliv.	Ijolite	----------	----------	----------	Nephelinite
Leucite +Oliv.	Missourite	----------	----------	----------	Leucite-Basalt
Leucite —Oliv.	Fergusite	----------	----------	----------	Leucitite
Melilite	----------	----------	----------	Alnöite	Melilite-Basalt
Alkalic or Lime-soda—Feldspars+Nephelite.	(Mafic) Theralite Shonkinite	----------	----------	Monchiquite? (glass-base.)	Basanite (+Oliv.) Tephrite (—Oliv.)
Lime-soda Feldspars+Alkalic minerals (Mafic)	Essexite	Essexite-porphyry	Gautéite	Camptonite	Trachydolerite
Lime-soda Feldspars (Andesine)	Diorite and Quartz-Diorite	Diorite-porphyrite	Malchite	Kersantite Spessartite	Porphyrite (+ or —quartz) Dacite (+qtz.) Andesite(—qtz)
Lime-soda Feldspar (Labradorite)+Pyroxenes.	Gabbro and Norite	Gabbro porphyrite	Beerbachite	Odinite	Diabase Basalt
No feldspar only Mafic mins.	Peridotite Pyroxenite				Picrite-porphyrite

into three groups; the first is identical with the abyssal plutonic, in chemical and mineral composition, but differs in texture, being distinguished as pronouncedly porphyritic; it is called the granite-porphyritic group. The second and third groups of dike-rocks are termed the aplitic and lamprophyric groups respectively, and they are formed on grounds of their chemical-genesis, a matter discussed more fully in a succeeding section; it is sufficient to say here that the aplitic group is felsic, the lamprophyres mafic in character, and they are held to be derived from the magmas which form the abyssal groups by the splitting process called differentiation. The two genetic groups are subdivided on mineralogical lines. The system may be seen summarized in Table No. 2.

Remarks.—In this table, No. 2, only a part of the many rocks named by Rosenbusch are given; they are, however, the most important ones defining the groups, and those omitted are mostly of the value of subordinate varieties. Anorthosite for example is treated as a variety under gabbro, though he is inclined to give it a group distinction on magmatic grounds. The table, however, will serve to illustrate the chief features of the system, though it is impossible in a set scheme of this kind to show the genetic relations of the aplitic and lamprophyric dike rocks to the plutonic groups that they accompany, and also some similar relations advanced for a small group of lavas that are held to be the effusive representatives of the lamprophyres.

Probably the most valuable feature of Rosenbusch's system is that in it was first clearly expressed the recognition of the genetic dependence of the so-called dike rocks upon the plutonic types, and the mutual derivation of aplites and lamprophyres from a single magma, though whether such relations furnish the best basis for a systematic classification which shall define the different varieties of igneous rocks is open to question. Aside from this point the chief defect of the system for petrographic purposes is the use of geologic relations to other masses in making definitions. The precise mode of occurrence of a rock-mass must be known before its component substance can be determined. This is of course a necessity in classifying occurrences geologically, but, as every one with any experience knows, it is often impossible in the field to determine the mode of occurrence of a rock-mass, and yet for description, mapping and other purposes it is necessary to state the kind of rock composing it. In a practical way the petrographer is constantly confronted with the problem of determining rocks of different kinds, for scientific and economic purposes, of whose mode of occurrence he knows little or nothing. In actual practice, since this difficulty must be met, those using this system in such cases fall back upon the texture of the rock, for Rosenbusch holds that the textures are characteristic of the modes of occurrence, and that from the former the latter can be told.[5] He confesses however that this determination of the geologic character from the texture (structure) is unsafe, but feels that this should have no influence on the naming of the rock, since a granite-porphyry is a granite porphyry, whether it occurs in the normal form of a dike, or the border facies of a stock of granite (plutonic), or, finally, as a central facies of a mass of quartz-porphyry (effusive).[6] One sees from this then, that, whereas in theory the mode of occurrence is the basis of classification, this must really be largely replaced by texture. Since the petrographic result is the same, it would seem more logical to adopt a uniform practice and use texture in all cases.

Another defect is that so little weight is placed on quantitative relations in the mineral groups. The value of this factor was felt by Rosenbusch and applied in places, as in the theralite-shonkinite group, which is stated to have a mafic character, but it finds no formal expression in the system. It obtains to some extent an underlying recognition in the division into groups of some of the rocks on the genetic-magmatic basis.

It is to be observed that in this system, as in others, the division lines must be arbitrarily drawn; thus, whereas a rock consisting of orthoclase with a little hornblende is a syenite, and one composed of andesine with hornblende is a diorite, a rock containing equal parts of orthoclase and andesine must leave the petrographer in doubt as to its classification. The same is true in divisions by texture, and even at times in the geologic mode of occurrence, as pointed out in a previous section.

Modifications of the Geologic-Petrographic System.—The Norwegian geologist Brögger has made some changes in the geologic-petrographic system, as presented in the foregoing section. He prefers first to divide the rocks into large families on chemical grounds (Granite family, Syenite family, etc.) and then to apply the method of geological occurrence to each family to form plutonic and effusive groups.[7] He adds a third group which he calls the *hypabyssal* as transitional between the other two. The idea is to include the minor intrusions, which in the form of dikes, sills, laccoliths, etc., appear above

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[5] Elemente der Gesteinslehre, 3d Ed. p. 74, 1910.

[6] Ibid.

[7] Grorudit-Tinguait-Serie. Eruptivgest. Kristiania-gebietes. Videnskap. Skrift. I Math-nat. KL. 1894. No. 4. p. 125.

the deep-seated stocks and batholiths, and thus at a higher level form an intermediate group with the surface lavas. These differences in the occurrences produce corresponding variations in the physical conditions attending the solidification of a magma, and this shows itself in the textures. Thus a suitable magma forms a plutonic granite, a hypabyssal granite porphyry, and a rhyolite lava. This group includes the dike rocks of Rosenbusch, but is obviously of greater scope. The division of these geologic groups into families (granite, syenite, etc.), although based in theory on chemical composition, in practice is mostly performed by considering the minerals, thus Brögger in the effort to solve the problem presented by rocks containing approximately equal quantities of orthoclase and plagioclase, mentioned in the foregoing section, proposed the recognition of a new family intermediate between granite and quartz diorite, when the rock contains quartz, and between syenite and diorite when quartz is absent, and of equal value with them in classification.[8] To this family he gives the name of *monzonite,* previously used by a few geologists to designate a rock of this character occurring at Monzoni in the Tyrol. This proposal has been generally accepted and the name widely used, especially by the geologists of the U. S. Geological Survey.

Brögger urges even more strongly than Rosenbusch the principle of the common genesis of groups of rocks from particular magmas distinguished by their chemical properties, as a means of classification. Thus he would not classify all aplites by themselves in one group and all lamprophyres in another group, but would assign to each plutonic mass, representing a magma (or family) the aplites and lamprophyres to which it has given rise by differentiative splitting. The mutual relation that the aplites and lamprophyres bear to another he designates under the term of *"complementary rocks."*[9] It will be seen from what has been stated that Brögger classifies the igneous rocks, partly on geological, partly on genetic, and partly on petrographic characters, the genetic predominating. He has applied his method very

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[8] Triadische Eruptionsfolge bei Predazzo, Erupt. Gest. Kristiania-gebietes; Videnskab. Skrift. M. N. KL. 1895; p. 21.

[9] Basic Eruptive Rocks of Gran; Quar. Jour. Geol. Soc. Vol. 50, p. 15, 1894.

strikingly to a group of the nephelite-syenite family occurring in the Christiania region.[10] These ideas of Rosenbusch and Brögger respecting the genetic origin of rock-groups, as well as the family relationships of rocks over particular areas, comprised by Iddings[11] under the term *consanguinity*, have had a wide influence, not only on classification, but on the development of petrology.[12]

The geologic-petrographic classification has also been used in England by Harker[13] who divides the rocks into plutonic, hypabyssal, and volcanic. They are then subdivided according to their petrographic characters. On the other hand Teall had earlier pronounced for a purely petrographic classification, based primarily on composition and texture.[14] In none of these systems is there any distinct recognition of the quantitative relation of variable minerals within a group.

Remarks on the Geologic-petrographic System.—Brögger evidently finds difficulty in using the geologic characters as a means of discriminating, classifying, and naming different *kinds* of rocks, since he remarks . . . "a rhombic porphyry (a variety of syenite porphyry) is to use a hypabyssal rock type, indifferently whether it occurs as a dike rock as border facies of augite syenite, or even as a lava flow."[15] He also says, relative to the dependence of texture on the rate of cooling—"But whether this slow cooling (which yet in comparison with the extremely slow cooling in the central part of a laccolith is relatively more rapid) has taken place along the border portion of an abyssal magma, in a very large dike fissure, or finally in the more central part of a very thick extension, must be regarded as quite irrelevant, if, eventually, the consolidation has furnished practically the same rock with essentially the same texture and composition."[16]

The student is desired to note this because it shows clearly the struggle to unite in one and the same classification very different features that relate to quite different things. As an instance of what happens when we use geologic position and petrographic characters in the same classification to determine a kind of rock

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[10] Das Ganggefolge des Laurdalits; Eruptiv. Gest. Kristiania-gebietes; Videnskab. Skrift. M. N. KL, 1897.

[11] Origin of Igneous Rocks. Bull. Phil. Soc. Washington, vol. 12, p. 128; 1892.

[12] See also Daly, R. A. Igneous Rocks and their Origin; p. 311; 1914.

[13] Petrology for Students, 3d Ed. 1902; p. 22.

[14] British Petrography, 1888, p. 69 et. seq.

[15] Grorudit-Tinguait-Serie, quoted ante, p. 123.

[16] Ibid. p. 124.

we may cite the fact that a granite stock is frequently cut by dikes of the lamprophyre called minette. Then the granite is called a plutonic rock, whereas the minette is referred to the hypabyssal group! The truth is that most petrographers who do this are using, unconsciously perhaps, *two* classifications; they first determine in their mind by petrographic characters, that is by texture and mineral composition, which is one sort of classification, what the kind of rock is with which they are dealing, and then place it in a geologic-genetic scheme. The bearing of this will be treated in a succeeding section.

Quantitative Classification. Several American petrographers, including the author, proposed in 1902 an exact classification of igneous rocks based on chemical composition, expressed, however, in terms of minerals of definite composition, called standard minerals.[17] For this purpose a chemical analysis of the rock is necessary, but where this cannot be obtained an approximately correct result may be achieved by measurement of the minerals under the microscope, computing from this their relative bulk and weight, and, their composition being known, reckoning from this the chemical composition of the rock as a whole.

The chemical composition is then computed, according to a set plan, into the relative amounts of standard minerals. These standard minerals are divided into two main groups: one characterized by the presence of alumina and silica, such as the feldspars, nephelite, corundum, and quartz, but without iron or magnesia; the second characterized by iron and magnesia, but without alumina, such as olivine, diopside, hypersthene, aegirite, and iron ores. The complex ferromagnesian minerals which contain alumina, such as hornblendes, biotite, augite, etc., are not treated as standard minerals because it is better to consider them as compounds of simpler molecules of two preceding groups. The first of these is called the *salic* (Si and Al) the second the *femic* (Fe and Mg) groups of standard minerals, and the composition of the rock computed in quantities of them is called its *norm*, which may thus, when hornblende or biotite are really present in it in notable quantities, differ considerably from its actual mineral composition or *mode*.

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[17] Cross, Iddings, Pirsson, and Washington; Quantitative Classification of Igneous Rocks; Chicago Univ. Press, 1903, pp. 286. See also, Jour. of Geol. Vol. 10, pp. 555-690, 1902.

All igneous rocks may be expressed in salic and femic minerals, and according to the relative amount of each group as compared with the other, they are divided into five classes, *persalane*, nearly or entirely composed of salic minerals:

$$(\text{sal} : \text{fem} > 7 : 1);$$

dosalane, mostly salic

$$(\text{sal} : \text{fem} < 7 : 1 > 5 : 3);$$

salfemane, equal or nearly equal quantities of each

$$(\text{sal} : \text{fem} < 5 : 3 > 3 : 5);$$

dofemane, mostly femic minerals

$$(\text{sal} : \text{fem} < 3 : 5 > 1 : 7);$$

and lastly *perfemane*, nearly or entirely femic

$$(\text{sal} : \text{fem} < 1 : 7).$$

The *classes* thus obtained are subdivided into *orders* on the relations of the salic minerals, quartz, feldspars, and feldspathoids (generally nephelite) to one another in the first three classes and on somewhat similar relations among the femic minerals in the last two. More minute consideration of the mineral oxides divides the orders into *rangs*, and the rangs into *grads*. The proportions by which they are thus divided are always the same as those by which classes are made.

Further details regarding this system will be found in the work referred to. It is the most exact system that has hitherto been proposed, and is based upon the fundamental property of the rock—its chemical composition. Aside from this, its most striking feature is the recognition of the quantitative relations among the component rock-minerals, the bearing of which we shall presently see. As must be the case in all petrographic systems the divisional lines of classification are arbitrarily drawn, but they are carried out logically on a consistent plan. It has been much used in careful and exact work, but the requirement of the knowledge of the chemical composition of a rock, and the difficulty in many cases of obtaining this, has doubtless prevented its wider extension.

General Remarks on Classification. From what has been stated in the foregoing discussions the student will have doubtless perceived that the chief difficulties in the systems described, excepting the last one, have been two; first, the attempt to introduce simultaneously into one scheme too many of the different properties and affinities of rocks that we must consider, with the result of making the system confused, and second, the failure to recognize quantitative relations among the minerals, with the result of making it inexact. When we observe that which is to entitle one kind of rock to recognition as an individual entity is based on geologic occurrence and mineral composition, whereas another kind is based on petrogenetic relations and texture combined with mineral composition, and a third is based on geologic occurrence, geologic age, and the minerals, it seems clear that there is an attempt to accomplish too many things at one time. Leaving aside the matter of geologic age, three systems of classification, each of which endeavors to express something different from the others, have been telescoped together, and the result is to the advantage of none of them.

It now seems clear that we need three systems of classification of igneous rocks in order to express our knowledge of their properties and relations and that we may put like things together; these are:

A. *A petrographic* classification based on those inherent characters of rocks, expressed by their minerals and textures, which shall define in a material way the *kind of rock* we are dealing with. This covers the idea, previously stated, that a granite porphyry is a granite porphyry, no matter where it occurs.

B. A *petrologic* classification based on petrogenesis which attempts to group the rocks according to their family relationships and co-magmatic origin, as expressed by their relative geologic positions, and the evidences of consanguinity that they may present. Here, for example, the dike rocks of Rosenbusch would find logical expression. This will be more fully explained later.

C. A *geologic* classification based on the method of occurrence that determines the form of the mass of an igneous rock and its outward space relations to other rocks. This states whether it is plutonic or volcanic, whether a stock, laccolith, sheet, dike, etc. This kind of classification is generally explained in more or less detail in the standard text books of geology, and, with reference to intrusive bodies, has been quite fully elaborated by Daly.[18]

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[18] Classification of Igneous Intrusive Bodies, Jour. of Geol., vol. 13, p. 485; 1905. Also, Igneous Rocks and their Origin, p. 61, 1914.

Each of these classifications has distinct aims of its own, which can only be properly expressed by separate treatment. The aims of each are legitimate and entitled to full recognition; the difficulty has been that in mixing them together and insisting on one compound classification there has naturally resulted wide divergence of views as to what the aims of the classification really are. We may find an analogy for these classifications in the stratified rocks; in one system they are arranged according to their geologic age; and we speak of them as Cambrian, Jurassic, etc.; in another, according to the nature of the materials composing them, and we have limestones, sandstones, etc.; again we divide them into series, stages, formations, etc.

The geologic classification, it is presumed, is already familiar to the student, and need not be further considered here. Petrologic classifications, with the meaning mentioned above, have not yet been definitely and clearly stated. The nearest approach to one is given by Rosenbusch, but mingled, as has been shown, with the petrographic system. Brögger has stated principles that must be essential in their formation and has offered an example with the rocks of the Christiania region, somewhat complicated with their geologic occurrence. Such a classification really belongs in the field of theoretic petrology, and should be given in a work treating of that subject.

This book is devoted to descriptive petrography, and obviously the rocks should be treated in it according to a petrographic system; until the student has mastered this he is not in a position to comprehend fully a petrologic one. For his benefit a preliminary attempt at a petrologic system is appended to that part of the book dealing with the igneous rocks.

Petrographic System of this Book. The petrographic system to be employed should be based on the inherent and fundamental properties that express the rock. The most important one is the chemical composition, but the ones that have generally been employed are the minerals and the texture, since these are the more obvious and readily determined. Moreover the chemical composition can to some extent be recognized, provided attention is given to the quantitative relations of the minerals. In a text book also the classification should be formed in such a manner as not to cut the student off from the historical aspect of the subject, or from current usages, and the volume of literature that has grown up based upon them. For these reasons a system has been adopted that is founded upon the older qualitative one, with modifications tending to greater definiteness in the statement of mineral composition, and at the same time a quantitative element has been introduced, and carried as far as seems advisable at present, in order not to introduce too great complexity into the scheme, and too great a departure from prevailing usages. The quantitative elements are derived in some degree from the quantitative chemical-mineralogical classification previously mentioned and the scheme is somewhat similar to that advanced by Iddings,[19] but with important modifications. It is shown in Table No. 3.

Explanation of Table No. 3. It should be understood at the outset that it is not intended in this table to present a scheme of classification that shall embrace all the different kinds of igneous rocks that have been described and named. Many of these differ from common well-known types in modifications of texture, or the proportions of the minerals, or the presence of some other mineral in relatively small quantity, and are to be regarded as having the value of varieties. For simplicity's sake only more common or important types are given for illustration in each division, and varieties are treated later in the descriptive part of the work.

The rocks are divided into five large groups, A, B, C, D and E, according to the nature of the feldspars that they contain. In A these are dominantly alkalic, orthoclase, albite, etc.; in B, alkalic and sodacalcic, that is to say, mixtures of alkalic feldspars with plagioclase, as for example orthoclase and andesine or oligoclase. Various types of mixtures may occur, but the essential thing is that lime is associated in the feldspars in notable quantities with the alkalies. In C on the contrary the soda-lime feldspars dominate over or replace the alkalic and may run through oligoclase and andesine to labradorite. In D the alkalic feldspars have practically disappeared

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[19] Igneous Rocks; vol. II, p. 347, 1909.

and the plagioclases are normally those rich in lime, from labradorite to anorthite. In E are the rocks that contain no feldspar, or only negligible quantities of it. In a chemical sense then we may say that the horizontal

TABLE NO 3, PETROGRAPHIC

DOMINANT	A Alkalic Feldspars		B Alkalic and Sodacalcic Feldspars	
Characterized by	1. Felsic	2. Mafic	3. Felsic	4. Mafic
Quartz and Feldspars	**Granite**	---------------	**Quartz Monzonite and Granodiorite**	
	Granite Porp'y	---------------	*Qtz. Mon. Porp'y*	---------------
	Rhyolite	---------------	Dellenite	---------------
Feldspars	10. **Syenite**	11. **Shonkinite**	12. **Monzonite**	13. **Kentallenite**
	Syenite Porp'y	*Minette* and *Vogesite*	*Monzon. porp'y*	*Camptonite*
(little or no quartz or lenad)	Trachyte and Bostonite		Latite	Trachydolerite
Feldspars and Lenads (feldspathoids)	Felenites 19 **Neph - Syenite** Group.	20. **Malignite**	21. **Theralite** (in part)	22 **Essexite** (in part)
	Neph. Syen. Porp'y	---------------	Tephrites	
	Phonolite and Tinguaite			
Lenads (little or no feldspar)	28. Lenites **Ijolite Urtite Fergusite** Group	29. **Bekinkinite Missourite** Gr.	30. ---------------	31. ---------------
	Nephelinite	Neph. Leuc—& Melilite Basalts.	---------------	---------------
	Leucitite (in part)	Nephelinite and Leucitite(inpart)	---------------	---------------
		Monchiquite		

arrangement represents a reciprocal relation between alkalies and lime.

In the vertical direction the chemical relation expressed is that of silica (SiO_2). When the silica is in excess over that amount required to form feldspars, etc., we have free quartz; as it diminishes quartz disappears; next, there is not enough to turn all the alkalies and alumina into feldspar, and a feldspathoid (*lenad*) appears; this increases with lowering silica until no feldspar is present.

The quantitative relation of the ferromagnesian (*mafic*) minerals to the quartz, feldspars, and feldspathoids (*felsic* minerals) in the A, B, C, D divisions is expressed under a felsic and mafic column in each. In one, felsic minerals dominate and form 50-100 per cent of the rock; in the mafic, the ferromagnesian ones dominate in like manner. Other quantitative relations, like those affecting the felsic minerals among themselves, will be discussed later in appropriate places.

CLASSIFICATION OF IGNEOUS ROCKS.

C Sodacalcic Feldspars		D Calcisodic Feldspars		E No Feldspar
5 Felsic	6 Mafic	7 Felsic	8 Mafic	9 Mafic
Quartz Diorite	----------	**Quartz Gabbro**	----------	----------
Qtz. Dior. Porp'y	----------	----------	----------	----------
Dacite	----------	----------	----------	----------
14 **Diorite** *Diorite Porphyry* *Kersantite* Andesite	15	16 **Anorthosite** **Gabbro and Norite Group** *Diabase* Basalt and Melaphyre	17	18 **Peridotite Group** **Hornblendite** **Pyroxenite** Picrite and Augitite
23 **Theralite** (in part)	24 **Essexite** (in part)	25 **Rouvillite**	26 **Teschenite**	27 **Jacupirangite** **Yamaskite**
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		Basanites		Limburgite
32	33	34	35	36
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Texture in Classification. The factor of texture has so far never been given any very precise definition in classification. Different varieties of texture themselves have been minutely described, and, since textures merge into one another gradually in various directions and division lines between them must be arbitrary, quantitative definitions and limits to textures have been suggested, as set forth in the preceding chapter. But so far as textures have been used in systematic classification this has been done in a purely megascopic manner, and mostly with very vague limitations. Only the broadest distinctions are employed; divisions of granular, dense, and glassy are used, and whether the rock is porphyritic in fabric or not. No quantitative values as to the use of these distinctions are suggested. The greatest stress is laid upon the character of whether a rock is porphyritic or not; this shows itself in the terminology in that the term, as one of texture, is embodied in the name, either complete, as in *syenite porphyry*, *rhombic porphyry*, etc., or in the contractional suffix *phyre*, as in *orthophyre*, *keratophyre*, etc.

All that Zirkel[20] remarks as to the relation between texture (structure) and classification is that he lays stress on the contrast between porphyritic and nonporphyritic rocks. He notes also that this gives rise to some inconsistencies, since some basalts are not porphyritic, but granular. Rosenbusch does not use texture as a primary factor in classification, but only in a secondary sense as connected with mode of occurrence; when the latter is unknown he then falls back on texture, and the porphyritic quality plays the chief role. Brögger essentially follows Rosenbusch but has only offered an outline of his suggested classification. Iddings[21] merely remarks that on the basis of texture the rocks are divided into the phanerocrystalline (grained) and aphanitic (dense) groups; the latter is subdivided into those with paleotypal, and cenotypal habits, this distinction being based on the appearance of the rock due to more or less alteration from, in general, greater age,[22] as suggested by Brögger. Harker[23] does not use texture in primary classification but, in general, follows Rosenbusch and Brögger in relegating it to a secondary position.

These examples will serve to show that no general agreement either as to the use of texture in classification, or if used, as to its limits, obtains among petrographers.

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[20] Lehrbuch der Petrographie, Vol. I, p. 837.

[21] Igneous Rocks, Vol. I, p. 350.

[22] Op. cit. p. 353.

[23] Petrology for Students, 3d Ed. 1902.

One reason for this is the feeling that as a character its importance is secondary to chemical-mineral composition, and another, that if all the various ramifications of texture, strictly defined, were introduced into a primary system of classification as divisions in one direction, and mineral groupings as divisions in another direction, the variety of rocks produced would be bewildering in number. Nevertheless the texture of a rock has always been held to be one of its most obvious features and the recognition of it, in the simple forms mentioned above, is seen in classifications, either directly or indirectly. We propose to employ it in a megascopic manner, but will attempt to give it a more precise definition than is usual, for the benefit of the student. The scheme is as follows:

Grained Rocks; mineral constituents megascopically determinable.

A. Apparently even-granular in fabric; fine to coarse; rarely subporphyritic.

B. Distinctly porphyritic in fabric.

1. Groundmass grained, constituents determinable.
2. Groundmass dense, but sempatic to presemic; phenocrysts determinable.

Dense and Glassy Rocks; constituents mostly or wholly indeterminable.

C. 1. Porphyritic, but sempatic to prepatic.
   2. Nonporphyritic.

This is probably as far, in preciseness of definition, as it is wise to go at present; to be more detailed would introduce such radical differences with the existing literature as would confuse the mind of the student, and greatly hinder his use of it. As it is, the scheme introduces a number of differences, not however of major importance, and these will be pointed out in proper places.

We have then three textural divisions, which may be summarized as A, granular; the names of these rocks are shown in the table in **bold-face** type; B, porphyritic, in *italics*, and C dense or glassy, printed in roman type.

The fragmental volcanic rocks, the tuffs and breccias composed of dust, ashes, bombs, etc., might well form a fourth textural division, but for the sake of simplicity of treatment they are not subdivided into groups in this book but are considered in a section by themselves, as will appear later.

It is obvious that the character of rocks, which texture affords, might be employed for classification at the very beginning, or after the rocks have been separated by mineral grouping. In either case the final result would be the same, so far as classifying and naming the rock is concerned. In the first case, if rocks are first divided into granular, porphyritic, and dense classes and then subdivided on mineral composition, we should have three such tables as No. 2 to refer to; whereas, if the texture is applied after the mineral grouping, the whole can be condensed into one table, as has been done, with greater convenience of reference.

It is not, however, a necessity that we should follow the latter plan in describing the rocks for the benefit of the student. It is very much easier and more logical for him to take up the coarser-grained rocks first; he can learn to make his determinations of the minerals, and their groupings and relative quantities and relations, which settle the classification, much more quickly and accurately, with them, and the knowledge thus gained can then be applied efficiently to the more difficult fine-grained and dense rocks. Moreover, in this one follows the usual mental course of procedure in determining a rock: we first examine the rock megascopically and notice whether it is sufficiently coarse-grained to permit us to recognize the component minerals; we study them and then assign the rock to its proper position in the scheme of classification we have in mind.

ART. XX.—*Studies in the Cyperaceæ;* by THEO. HOLM. XXXI. *Carices aeorastachyæ*: *Crinitæ* nob., *Apertæ* nob., and *Magnificæ* nob. (With 8 figures drawn from nature by the author.)

Crinitæ.

This section is a small one, comprising only *C. crinita* Lam., *C. gynandra* Schw., and *C. maritima* O. F. Muell. Characteristic of these is the light-green or yellowish color (*C. maritima*), and the aristate scales. *C. crinita* is widely distributed from Newfoundland, Quebec and Ontario south to Florida, Louisiana, west to Minnesota and Texas; *C. gynandra* is distributed from Newfoundland to Wisconsin, and in the mountains to Georgia; they inhabit swales and damp thickets. *C. maritima*, on the other hand, grows in brackish or saline shores from Labrador to Massachusetts, and in Europe along the coast of Sweden and Norway to the White Sea.

Carex crinita is a stately species reaching a height of about 1.5 m.; the rhizome is cæspitose, and develops several purely vegetative shoots, beside the floral, which are phyllopodic, flowering already in the first year, and surrounded by several green leaves at the base. The staminate spikes are generally two, the pistillate from three to six, remote and quite long, narrowly and evenly cylindric, dense-flowered, long-pedunculate and pendulous.

With regard to the distribution of the sexes, this is very variable; the terminal spike is not always purely staminate, but very frequently it is androgynous, i. e. staminate above, pistillate below; or, though seldom, gynæcandrous with pistillate flowers at the apex. In many specimens, collected near Clinton, Md. the terminal spike was only staminate in the middle, pistillate at the apex and base; in a few specimens from Quebec the terminal spike was purely pistillate. The pistillate spikes vary from purely pistillate, the most frequent, to androgynous; both types may occur on the same specimen. A somewhat peculiar structure was observed in a few specimens from Clinton, where there was a bract below the terminal, staminate spike subtending a single pistillate flower; sometimes the

Fig. 1. Inflorescence of *Carex aperta* Boott; specimen from Columbia River, Washington; natural size.

Fig. 2. Inflorescence of *C. aperta* forma *concinnula* nob.; specimen from Mt. Paddo, Washington; natural size.

Fig. 3. Inflorescence of *C. aperta* forma *hydroessa* nob.; specimen from Columbia River, Washington; natural size.

Fig. 4. Perigynium and squama of typical *C. aperta;* enlarged.

Fig. 5. Pistillate squama from near the base of the lowermost spike of *C. crinita* Lam.; enlarged.

Fig. 6. Perigynium of same; enlarged.

Fig. 7. Pistillate squama from near the base of the lowermost spike of *C. gynandra* Schw.; enlarged.

Fig. 8. Perigynium of same; enlarged.

rhachilla had grown out bearing a small staminate spike similar to the case we have described and figured in this journal (1896, p. 214, fig. 4).

The squamæ of both sexes vary from oblong ovate, acuminate to emarginate, and the midrib is extended into a thick, rough arista of variable length; the arista is always much longer in the scales of the basal flowers than in the apical, and much longer in the pistillate spikes than in the staminate. The small perigynium is thin, green, granular, inflated, ovate to obovate, with a short entire beak; only the two marginal nerves are present, and the perigynium is spreading at maturity, longer and broader than the body of the subtending scale. The very small caryopsis is deeply constricted at the middle.

Carex gynandra was first described by Lewis D. de Schweinitz[1] as a distinct species, but in his monograph of the North American species of *Carex*, edited by John Torrey,[2] it is enumerated as a variety of *C. crinita* with the remark, however, that "it may prove to be a distinct species." Its characters are pretty constant, but sometimes it appears to pass into the ordinary *C. crinita*. It has much the appearance of *C. miliacea*, but it is easily distinguished. By Boott[3] it was accepted as a species. It resembles *C. crinita* in habit and size, in the number and length of the spikes, but the perigynia are ascending, less inflated, more or less elliptic, and distinctly nerved, i. e. there are two marginal nerves, and three shorter, rather faint between these on both faces of utriculus; the arista of the scales is much shorter than in the former species, beside the body of the scale being entire instead of emarginate. The number of staminate spikes is mostly 2, and they are very seldom androgynous; the pistillate spikes are mostly four, and they are commonly androgynous. It represents undoubtedly a distinct species.

Carex maritima has a stoloniferous rhizome, and the culms are phyllopodic, but develop in the second year;

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[1] An analytical table to facilitate the determination of the hitherto observed North American species of the genus *Carex*. (Ann. New York Lyc. Nat. Hist., Vol. 1, p. 70, 1824).

[2] Ibidem Vol. 1, p. 360, 1825.

[3] Illustrations of the genus *Carex* Vol. 1, 1858, p. 18, t. 50.

thus they are at the base surrounded by long, withered leaves from the previous year. It is strange that Kükenthal[4] attributes an aphyllopodic culm to these species as well as to *C. salina, C. subspathacea,* etc., which certainly depends on an error. It is of lower stature than the two former, but of a similar, graceful habit with the oblong-cylindric to clavate, pistillate spikes drooping on very thin peducles. The scales resemble those of *C. crinita,* and the arista attains a considerable length; the perigynium is shorter, but broader than the body of the scale, mostly erect, membranaceous, ovate to obovate with a short, emarginate beak; the perigynium has several, but faint nerves; the nut is constricted at the middle.

Among twenty-three specimens from Europe and this country the distribution of the sexes was as follows:

14	specimens	had	2	staminate	spikes.
8	"	"	1	"	"
1	"	"	3	"	"
9	"	"	4	pistillate	"
9	"	"	3	"	"
5	"	"	2	"	"

In nineteen of these the pistillate spikes were androgynous, and in six of these all the spikes showed this structure. The terminal spike was androgynous in five specimens. Furthermore two pistillate spikes may be developed from the axil of the same bract, which, however, seems to be a rare occurrence.

Apertæ.

Carex aperta Boott and *C. pruinosa* Boott are the only members of this section.

C. aperta (Figs. 1. and 4).

The original diagnosis[5] reads as follows:

"Spica mascula 1-2 oblongo-cylindrica, acuta, foem. 2-4 oblongis superioribus approximatis sessilibus apice masculis inferiori remota pedicellata saepe toto foeminea, stigm. 2, perig. orbiculatis stipitatis enerviis pellucide punctatis abrupte brevi-rostratis ore

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[4] Cyperaceæ-Caricoideæ in Engler's Das Pflanzenreich Leipzig, 1909, p. 357.

[5] Flora Boreali-Americana, vol. 2, 1840, p. 218.

bidentato squama ferruginea lanceolata acuta latioribus brevioribusque. Hab. Columbia River. Dougl. Scouler.''

Howell[6] calls the species ''*bovina*'', and some points in his description deserve mention, viz. ''densely matted and forming extensive meadows of many acres''. ''Spikes all peduncled or the upper one sessile, lower more or less cernuous''. ''On lands that are overflown by the Columbia River''.

The species is aphyllopodic, and the rhizome is densely matted, slightly stoloniferous. With regard to the number of spikes and the distribution of the sexes, we observed in 54 specimens, kindly presented to the writer by Messrs. Louis F. Henderson, James M. Macoun and Wilhelm N. Suksdorf: they were collected in British Columbia, Vancouver Island, Idaho and Washington State:

36 specimens with 1 staminate spike.
15 '' '' 2 '' spikes.
3 '' '' 3 '' ''
39 '' '' 3 pistillate ''
12 '' '' 2 '' ''
2 '' '' 4 '' ''
1 '' '' 1 '' spike.

In fourteen of these some of the pistillate spikes were androgynous: six with two, and eight with one; in four specimens there were a few (1-3) pistillate flowers at the base of the terminal, staminate. The species is known to be abundant at several stations in British Columbia, Vancouver Island, Washington, Oregon and Idaho; it prefers low grounds, but occurs also in the mountains, for instance on Mt. Paddo, where Mr. Suksdorf collected it on borders of ponds at an elevation of 2,000 m.

Characteristic of the species are the turgid perigynia with the surface very prominently papillose, by Kükenthal (l. c. p. 319) interpreted as ''utriculi resinosi,'' which of course is not correct; all the cells of the epidermis are extended into obtuse, thick-walled papillæ. Only two nerves, the marginal, are present. The caryopsis is small, obovate, and not constricted. In the material, which has been examined, we have been able to distinguish the forms as follows:

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[6] A Flora of Northwest America. Portland, 1903, p. 702.

forma 1. *concinnula* nob. (fig. 2) Culmus tenuis, 50-80 cm. altus, inflorescentia brevis, 6-9 cm. longa. Spiculæ 2-3 cm. longæ, graciles, capillari-pedunculatæ, fere cernuæ. Washington: Mount Paddo, border of a pond; alt. c. 2,000 m.; collected by Mr. Suksdorf.

forma 2. *hydroessa* nob. (fig. 3.) Culmus 40-60 cm. altus, strictus, tenuis. Spiculæ ♀ minores, valde remotæ, sessiles vel ima pedunculata. Washington: Bottom-land, Columbia River, after high water; collected by Mr. Suksdorf.

forma 3. *mimetica* nob. Rhizoma stoloniferum, Culmus 50-60 cm. altus, scabberimus. Spiculæ ♀ breviores, ½-1½ cm. longæ, nigricantes, sessiles, erectæ ± remotatæ, brachteæ foliaceæ, ima spicam masculam valde superans. Habitum *Microrhyncharum* (e. g. *C. aquat.*) simulans. Washington: Among bowlders 5 km. west of Bingen; collected by Mr. Suksdorf.

C. pruinosa.

Boott's diagnosis[7] reads as follows:

"Spica mascula 1 subclavata; foemineis 4 cylindricis pedunculatis evaginatis erectis contiguis superioribus apice masculis inferioribus longissime bracteatis, stigmatibus 2, perigyniis ovatis rostellatis emarginatis obsolete nervosis albo-tuberculatis squama lanceolata mucronata longioribus latioribusque.

Hab. In Java, Dr. Horsfield.

Culmus tripedalis, glaber; pars spicas gerens biuncialis, scabra. Folia glauca, 1½-2 lin. lata, culmo breviora, superne serrato-scabra; ligula obtusa brunnea. Bracteae binae inferiores foliaceae 8-10 poll. longae; reliquae setaceae spicis suis breviores, evaginatae. Spica mascula 1 poll. longa, 1½ lin. lata, basi attenuata, subsessilis, squamis ferrugineis. Spicae foemineae 4, superiores plus minus apice masculae, contiguae, 8-14 lin. longae, 2-3 lin. latae; superior sessilis; squamis brevi-hispido-mucronatis. Perigynium 1 6/9 lin. latum, ovatum, rostellatum, emarginatum, obsolete 3-4 nervosum, tuberculis albis minimis conspersum, quasi pruinosum. Achenium orbiculatum, compressum, basi styli aequali terminatum.

C. glaucescenti Elliott (quae tamen stigmatibus 3 gaudet), habitu et aspectu similis."

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[7] Caricis species novæ, vel minus cognitæ. (Transact. Linn. Soc., vol. 20, p. 131, 1845-46).

In Ill. gen. *Carex* (l. c. vol. 1, 1858, p. 65) Boott regarded the species as being an ally of *C. crinita.* The species differs from *C. aperta* by the long-peduncled pistillate spikes, by the scales being distinctly mucronate and by the perigynium showing several nerves beside the marginal: but the peculiar, epidermal structure of utriculus is common to both.

A very different classification is proposed by Kükenthal (l. c. p. 345), who places *C. pruinosa* in a subsection *Praelongæ* Kükenth. of the *Acutæ* Fr., including Drejer's *Microrrhynchæ* and *Aeorastachyæ.* This author considers the affinity of *C. pruinosa* to be with such species as *C. torta* Boott, *C. Sitchensis* Prescott, *C. phacota* Spreng. etc. However, when this author cites Fries as the author of the section *Acutæ* we must remember that Fries established this section in the year 1835,[8] and only for C. *acuta* L., *C. stricta* Good. and *C. cæspitosa* L. In the year 1846[9] Fries classified the Scandinavian *Carices* in a more elaborate manner, and we see from this that he segregated *C. stricta, C. cæspitosa* and *C. turfosa* from "*Phyllopodæ: Prolixæ: C. acuta, C. prolixa,* etc."; according to Fries the *Aquatiles, Salinæ, Rigidæ* and *Bicolores* were sections distinct from the *Prolixæ* and the aphyllopodic *Spiculosæ* and *Cæspitosæ* (*C. stricta,* etc.). It is therefore absolutely incorrect to credit a section "*Acutæ*" to Fries, when this author had no intention whatever to make it include his other sections, viz. *Rigidæ, Bicolores,* etc. As this section *Acutæ* is outlined by Kükenthal it cannot possibly be credited to Elias Fries, but to Pastor Kükenthal himself. We have several years ago[10] suggested the advisability of independent classification rather than combining the systems proposed by Elias Fries, Kunth. and several other authors, which leads only to misinterpretations, as in the case stated above.

Magnificæ.

To this section we have referred *C. magnifica* Dew., *C. Schottii* Dew., and *C. lacunarum* nob.

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[8] Corpus florarum provinciarum Sueciæ, p. 191.

[9] Summa Vegetabilium Scandinaviæ, p. 71.

[10] Greges Caricum, this Journal, vol. 16, p. 449, 1903.

The history of Dewey's unpublished *C. magnifica* we have mentioned in some previously published papers,[11] stating that C. B. Clarke called our attention to the fact that the species had for many years passed for *C. Sitchensis* Prescott. *C. magnifica* is a robust species with the culm reaching a height of about 1.5 m.; the rhizome is stoloniferous, the culms phyllopodic; the latter character is seldom to be seen in herbarium-specimens, but an excellent specimen collected by Mr. E. P. Sheldon in Oregon shows this structure very plainly. The leaves are shorter than the culm, relatively broad, glaucous and thick. Spikes 3-8; the upper was staminate, seldom androgynous, the lower pistillate, mostly androgynous, cylindric, 3-15 cm. long., thick, dense-flowered, sessile or nearly so, contiguous, spreading or drooping, often curved. The bracts subtending the pistillate spikes are leaflike, much longer than the inflorescence; squamæ of pistillate flowers elliptic, acuminate, dark purple with midrib of lighter color; perigynium spreading, coriaceous, obovate, turgid, deep brown, scabrous along the upper margin, terminated by a short emarginate beak. The species is not very variable except with reference to the number of spikes, and, to some extent, the distribution of the sexes, as may be seen from the following table, drawn from 31 specimens:

15 specimens had 2 staminate spikes.
11 " " 3 " "
3 " " 1 " "
2 " " 4 " "
19 " " 3 pistillate "
8 " " 2 " "
4 " " 4 " "

Only in 5 specimens the pistillate spikes were all purely pistillate; in the remaining 26 some or all were androgynous; in 6 specimens one or two of the lateral male spikes were androgynous, and one specimen had a simple, terminal androgynous spike. Some specimens of gigantic size were collected by Professor Piper in Alaska (Astoria, June 21st, 1904); in these the entire inflorescence measured from 23 to 24 cm.; the staminate spikes varied from 5 to 10 cm. in length, and the pistillate from 10 to 15 cm.

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[11] This Journal, vol. 17, p. 316, 1904, and vol. 26, p. 486, 1908.

Carex magnifica is distributed from Alaska, following the coast, south to California.

Carex Schottii Dew.

Dewey's original diagnosis has been cited in our paper dealing with the structure and affinities of some of Dewey's Carices[12] and the species was accepted by C. B. Clarke as identical with *C. obnupta* Bailey, but distinct from *C. Barbaræ* Dew. Nevertheless Kükenthal (l. c. p. 305) refers the species, as a mere synonym, to *C. Barbaræ.* Mr. S. B. Parish.[13] however, holds the opinion that they are distinct.

Carex Schottii resembles *C. magnifica* in many respects, but the spikes are longer and more slender, drooping on long peduncles and remote.

Carex lacunarum nob.[14]

As may be seen from the diagnosis (l. c.) and the figures (l. c. p. 303) the species is very distinct from the others of this section, especially on account of the lighter color and structure of the perigynium and squama; as a matter of fact the squamæ of the basal pistillate flowers are very prominently aristate; moreover the perigynia are appressed, not spreading.

In these sections: *Crinitæ, Apertæ* and *Magnificæ* the distribution of the sexes thus shows a variation well marked. In *C. crinita* the terminal spike is sometimes gynæcandrous, or it consists of a pistillate portion above and below the staminate; or there may be a single pistillate flower subtended by a bract below the terminal, staminate spike; the pistillate are often androgynous. In *C. maritima* the terminal spike may be androgynous, and in some cases two pistillate spikes may be developed in the axil of the same bract. In *C. aperta* there may be from one to three pistillate flowers at the base of the terminal, staminate spike. Androgynous staminate spikes occur in *C. magnifica*; the pistillate are mostly androgynous; furthermore the terminal may also be

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[12] This Journal, vol. 26, p. 478, 1908.

[13] A preliminary synopsis of the Southern California Cyperaceæ. (Bull. South. Calif. Acad. Sc., 1904, p. 108.)

[14] This Journal, vol. 17, p. 316, 1904.

androgynous. In other words the species of these sections illustrate to some extent the inflorescential structure of the more evolute types of the grex: *Ternariæ.* In the *Salinæ* and *Cryptocarpæ*[15] the pistillate spikes are often androgynous, and in *C. Lyngbyei* the terminal, staminate spike is sometimes androgynous; otherwise the distribution of the sexes is more regular than the sections discussed in the present paper.

Clinton, Md., July, 1921.

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[15] This Journal, vol. 49, and 50, 1920.

Art. XXI.—*The Stratigraphy of Eastern New Mexico—a Correction;* by John L. Rich.

In a paper entitled "Contributions to the Stratigraphy of Eastern New Mexico" which appeared early in 1920,[1] there are certain statements and correlations which, if allowed to pass unchallenged, are likely to lead to much confusion.

During the summer of 1919, the writer spent four months studying the stratigraphy and structure of Guadalupe and adjacent counties. A number of detailed sections were measured, but, unfortunately, they are now in the files of an oil company and are inaccessible, so that only generalized descriptions of the sections can be given here.

The generalized section for Guadalupe and adjacent counties is:

Triassic.—Red and purple shales and sandstones	1500′ ±
Coarse gray sandstone, conglomeratic at base (Santa Rosa sandstone)	50-100′
Triassic or Permian.—Brick red sandstone and red shale, becoming more shaly toward the base	150-200′
Permian.—Red, brown and variegated shales and sandstones with much gypsum, anhydrite, and salt (Pecos Valley red beds of Baker and, probably, the Castile Gypsum of other writers). This formation occurs in the form of a wedge, thinning to the northwest, and thickening notably toward the southeast	0 to 1000′±
Blue-gray limestone with some gypsum (San Andreas limestone)	0 (?) to 300′+
Sandstone, coarse, gray, massive (Glorieta sandstone)	300-500′
Salmon pink sandstones and shales, with gypsum (Yeso formation)	700′ ±
Permian (or Pennsylvanian[2]).—Dark red sandstones and shales (Abo)	800′ ±

Baker has confused the Glorieta sandstone in parts of the area with the Santa Rosa sandstone. This has

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[1] Baker, C. L., this Journal (4), 49, pp. 99-126, 1920.

[2] Generally considered to be Permian, but thought by Böse to be Pennsylvanian, at least in the lower part. See Böse, Emil, On Ammonoids from the Abo Sandstone of New Mexico and the Age of the Beds which contain them, this Journal (4), 49, pp. 51-60, 1920.

led him to assign the Glorieta to the Upper Trias and to correlate the gypsiferous formation above the San Andreas with the Yeso formation whereas, in reality, it is entirely different and much higher. On page 118 he says:

> ''The basal member of the Upper Trias, the Glorieta sandstone, outcrops along the valley of the Pecos from the Glorieta Mesa downstream to somewhere between Puerto de Luna and Fort Sumner. It outcrops at Santa Rosa.''

This statement shows clearly that Baker thinks the Glorieta sandstone of Glorieta Mesa and the Santa Rosa sandstone are the same, whereas, as will be shown below, they are entirely different.

The Santa Rosa sandstone is a very definite unit exposed at Santa Rosa and Puerto de Luna and along the canyon of the Pecos for many miles both above and below those places. From Santa Rosa it may be traced up the valley of the Pecos as a continuous, unbroken, escarpment to the Estaritos Dome, east of Anton Chico, where it forms the rim-rock surrounding the dome. In the center of the dome, about 200 feet below the base of the Santa Rosa sandstone, the San Andreas limestone, 10 to 25 feet thick, is exposed. Beneath the San Andreas on the dome is the Glorieta sandstone in its proper relation and full thickness. The well drilled for oil near the top of the dome started on the top of the Glorieta and penetrated 490 feet of it before entering the salmon-colored sandstones of the Yeso below. On another dome 5 or 6 miles west of the village of Anton Chico, there are complete exposures of the series from the Glorieta to the Santa Rosa in such relations that there can be no question as to the relative positions of the various formations. Between the latter place and Glorieta Mesa there is a disturbed belt in which there has been some faulting. It is in this belt that Baker appears to have lost his bearings. East of this he apparently followed the Santa Rosa sandstone thinking it was the Glorieta.

There are many other places in the region between the Pecos and the Belen cut-off of the Santa Fe where the true relation between the Glorieta and the Santa Rosa sandstones can be seen. It may be observed, also, along the Santa Fe Railroad between Las Vegas and Bernal.

The confusion of the Santa Rosa with the Glorieta naturally led to the further confusion of the gypsiferous series between the Santa Rosa and the San Andreas with the Yeso.

Speaking of the Yeso formation Baker says (pp. 110-111):

> " . . . . and is exposed beneath Upper Trias in the anticlinal axes along the Pecos River from Ribera southwards to beyond Puerto de Luna and in Cañon Blanco, a tributary entering the Pecos a few miles below Anton Chico. It is also exposed for many miles in upper Pintada Cañon and forms the surface of a large area west of Fort Sumner. Altogether it covers or probably underlies fully half of New Mexico east of the Rio Grande."

In this paragraph it is plain that he has confused the gypsiferous series above the San Andreas with the Yeso. It is the former, not the latter, which "forms the surface of a large area west of Fort Sumner."

The gypsiferous series above the San Andreas wedges out completely in western Guadalupe Co. where the formations lap up over the buried granite mountain range which has been revealed by drilling for oil in that region. It appears a few miles to the southeast in Pintada Canyon. From there toward the southeast it thickens notably. The superficial resemblance of this formation to the gypsiferous part of the Yeso is doubtless partly responsible for Baker's miscorrelation.

On page 112, Baker says:

> "The San Andreas is not known north of the line of the Belen cut-off of the Santa Fe Railroad."

As a matter of fact it is well exposed at Vaughn, north of the railroad, from which it may be traced continuously northward for 10 or 12 miles to the foot of the high mesa visible from the railroad and it is at the surface in several places on the plain between the mesa and Pastura. It is also exposed on the Estaritos dome, already referred to, and in the tributaries of Pintada Canyon north and northeast of Encino.

Speaking of the Upper Triassic rocks, Baker says, p. 117:

> "West of the Pecos River they extend at least as far south as the Belen cut-off of the Santa Fe Railroad. . . . "

This statement, also, is evidently based upon the confusion of the Upper Triassic Santa Rosa sandstone with the Permian Glorieta, for, though the latter extends south to and beyond the railroad, the latter does not, except close to or east of the Pecos.

Baker's suggested correlation of the Glorieta with the Shinarump is also based on the erroneous supposition that the Glorieta sandstone of Glorieta Mesa is the same as the sandstone at Santa Rosa.

317 Railway Exchange Bldg.,
Denver, Colo.,
June 30, 1921.

SCIENTIFIC INTELLIGENCE

I. Chemistry and Physics.

1. *A New Reaction for Ammonia, and its Application for the Detection of Nitrogen in Organic Substances.*—C. D. Zenghelis has devised a very delicate test for ammonia. His reagent consists of a solution containing 20 per cent of silver nitrate and 3 per cent of commercial formaldehyde solution of 33 to 37 per cent strength. The reagent should be prepared immediately before use. When some drops of the reagent are placed upon a small watch-glass and this is exposed to the action of ammonia under a crystallizing disk a brilliant mirror of silver is formed upon the surface of the drops of the reagent, or in the case of very small quantities of ammonia, such as 0.000001 or 0.000002g. brilliant rings of silver are formed around the edges of the drops. In cases where the reagent begins to decompose spontaneously silver is deposited in the form of a powder, and this does not interfere with the reaction, provided that decomposition has not gone too far. The test may be applied to a solution by placing a small quantity of it in a rather short test-tube, adding a few drops of caustic soda or sodium carbonate solution, covering the mouth of the test-tube with a watch-glass, upon the lower, convex side of which is a drop of the reagent and upon the upper side is a drop of water for the purpose of cooling. Upon warming the liquid in the test-tube until water begins to condense upon the watch glass, around the drop of the reagent, then discontinuing the heating, the reaction soon appears in the form of a silver mirror if ammonia is present. It is stated that a distinct

reaction was thus obtained with as little as 0.0000004g. of gaseous ammonia, and the reaction is even more delicate than that of Nessler.

In order to apply the reaction for detecting nitrogen in organic compounds a small quantity of the substance is mixed in a porcelain crucible with a mixture of two parts of well-dried soda-lime and one part of finely divided metallic copper, prepared electrolytically. The copper facilitates the formation of ammonia from compounds in which the nitrogen is directly combined with oxygen. The crucible is then heated upon a hot plate and the resulting ammonia is detected by means of the reagent on a watch-glass covering the crucible according to the method already mentioned for testing the vapors from a test-tube. It seems probable that the ignition with soda-lime and copper could be carried out in the bottom of a test-tube and the tube satisfactorily made in this way.—*Comptes Rendus,* **175**, 153 and 308. H. L. W.

2. *The Quantitative Separation of Arsenic, Antimony and Tin.*—F. L. Hahn and P. Philippi have adopted for quantitative use a qualitative process that was described about six years ago by the former author. As the method is a simple one and as it varies essentially from the usual processes, it deserves attention. A mixture of the three sulphides is dissolved in the least possible measured quantity of 10 per cent sodium sulphide solution, the same volume of 20 per cent sodium hydroxide is added, the liquid is diluted to 50 or 100 c.c. and strong peroxide (10-30 per cent) is gradually added to complete decolorization. The liquid is then heated to boiling, cooled, 1/3 volume of 80 per cent alcohol is added, and after twenty-four hours the precipitated sodium pyroantimonate is filtered and washed with alcohol of increasing strength. The precipitate is dissolved in hydrochloric and tartaric acids in order that antimony may be determined by one of the usual methods, for instance, as Sb_2S_3 or volumetrically. The filtrate is evaporated in a porcelain or platinum dish until the alcohol has been removed, the liquid is diluted to about 300 c.c. and the same volume of 50 per cent ammonium nitrate as that of the 20 per cent sodium hydroxide previously used is added, the liquid is boiled until the odor of ammonia has disappeared and the tin precipitate is filtered off and washed with hot, dilute ammonium nitrate solution. The precipitate is ignited and SnO_2 is weighed. The filtrate is concentrated and ammonium magnesium arsenate is precipitated as usual. This should be dissolved in hydrochloric acid and re-precipitated with ammonia.

The authors have carried out as many as fifty-three test-analyses by this method. The results of many of these are given, including those that gave the least accurate results. The agreements with the amounts taken are astonishingly close.—*Zeitschr. anorgan. u. allgem. Chem.,* **116**, 201. H. L. W.

3. *Chemical Reactions and their Equations;* by Ingo W. D. Hackh. 12mo, pp. 138. Philadelphia, 1921 (P. Blakiston's Son & Co. Price $1.35 net).—This little book has been prepared for the use of students in connection with the writing of chemical equations. The fundamental ideas about symbols, atoms, molecules, ions, formulas, valency, valence numbers, oxidation and reduction, etc., are very clearly presented, and then the principles of chemical reactions and their equations are well discussed. The book presents no less than 446 consecutively numbered equations which cover the various types very fully. Considerable attention is paid to ionic equations, but a great many are given in the molecular form. The book may be regarded as a very useful and satisfactory one for its purpose, but it appears that it might be made still better if some discussion were given in regard to reversible reactions, and also if precipitates and volatile products were indicated in some way in the equations, and if reactions of gases or vapors and of fused or ignited substances were distinguished by parenthetical notes from those taking place in solutions. For instance, the equation of an important metallurgical reaction, $2PbO + PbS = 3Pb + SO_2$, which is given without note or comment, might lead the student to suppose incorrectly that this would happen at ordinary temperature. Again, it appears that the equation $2NaCl + H_2O = Na_2O + 2HCl$ of a reaction that is familiar in connection with the "salt-glazing" of pottery where the salt is volatilized, should be written with the sign of reversibility and that the high temperature required should be noted. H. L. W.

4. *Food Products, Their Source, Chemistry and Use;* by E. H. S. Bailey. 8vo, pp. 551. Philadelphia, 1921 (P. Blakiston's Son & Co. Price $2.50 net).—This is the second, revised edition of a useful book for students and general readers dealing with a subject of the greatest importance to mankind. A very extensive list of edible products is discussed in connection with their origin and production, their manufacture, composition, food-value, digestibility, adulteration, etc.

The book is supplied with ninety-two appropriate illustrations. It gives a vast amount of valuable and interesting information, not only about the foods commonly used in this country, but also concerning the important products of other parts of the world. The subject of beverages, including water, is well treated, but the discussion of alcoholic drinks has been considerably abbreviated, in comparison with the previous edition, because the manufacture of these liquors is now of much less importance than formerly. H. L. W.

5. *Discussion on Isotopes.*—A discussion participated in by Sir Joseph Thomson, Dr. Aston, Professors Soddy, Merton and Lindeman at the March meeting of the Royal Society is inter-

esting as showing how widely the new interpretations of atomic structure derived from physical experimentation have replaced the earlier conclusions obtained from chemical phenomena alone. The term isotype, i. e. same place (in the periodic table) was coined by Soddy in 1913 to designate two elements having different atomic weights but with chemical properties identical, or so closely resembling each other that they have not yet been separated by chemical methods. In contrast to isotypes, the term isobar is used to designate substances of the same atomic, or molecular weight, but having different chemical properties. Lindeman thinks it doubtful that the properties of isotypes, though indubitably very similar, are exactly identical and hopes to separate them electrolytically if, as seems likely, they have different migration velocities in solution.

On the electron theory the atoms of the isotopes of an element contain an equal number of electrons and the difference in the atomic weight is supposed to be due to the simultaneous entry into the core of the atom, of one or more positive charges and a corresponding number of electrons so that the charge on the core is not affected. Thus one can suppose that an elementary atom of mass m may be changed to one of mass $m + 1$ by the addition of a positive particle and an electron. If both enter the nucleus an isotope results, for the nuclear charge remains unaltered. If only the positive particle enters the nucleus an atom of the next higher atomic number results. In cases where both forms of addition give a stable configuration the new elements will be isobars, i. e. will possess the same atomic weights but have different chemical properties which are believed to depend upon the number of electrons in the outer layer and its general distance from the center.

The work of Aston upon the determination of isotopes by the positive ray spectrograph is characterized by Soddy as one of the most brilliant combinations of mathematical analysis and experimental skill this century has produced. The method of focusing positive rays of constant $\frac{m}{e}$ independently of their velocity and producing a "mass spectrum" has been explained in detail by the author in the Philosophical Magazine, **38**, 709, 1919, and **39**, 611, 1920. Briefly it consists in dispersing a ribbon-like beam of positive rays first by an electric field and then recombining a restricted portion of them by a magnetic field so that they produce a definite linear spot or image on a photographic plate. Where several carriers are present the separation of these lines permits their relative masses to be determined to an accuracy of one part of a thousand. The intensity of the lines also permits some estimate of the number of each kind to be made. In this way it has been possible to show that some elementary gases consist of a mixture of two or more isotopes. Neon, for example, which by chemical methods shows an atomic weight of 20.200 has been proved to contain two isotopes having respectively atomic weights of 20.00 and 22.00 in proportion of 90 per cent and 10 per cent with a faint possibility of a third of mass 21. Likewise chlorine which by the method of combining volumes is found to have an atomic weight of 35.46 shows no indication of a line corresponding to this mass but does give definite lines indicating masses 35 and 37. The unquestionable accuracy of its combining weight and the striking whole number masses given on its mass spectrum by its individual particles leaves little doubt that its chemical atomic weight is a statistical average. The investigation which has been extended to more than fifty atomic and molecular weights indicates the very interesting and important result that all these masses as determined by Mr. Aston are integers except in the case of hydrogen.

Isotopes have been of use to chemists in various ways as, e. g., the determination of sparingly soluble lead salts has been made with ease. Their use has afforded a test of the Nernst theory of E.M.F. at concentrations completely beyond the range of ordinary methods and has recently given a direct demonstration of the separated existence of ions in an electrolyte.—*Proc. Roy. Soc.*, **99**, 87, 1921. F. E. B.

6. *Wireless Telegraphy and Telephony;* by L. B. TURNER, pp. xii, 195. Cambridge, 1921 (Cambridge University Press).—The author is a fellow of King's College and has been connected with the Signals Experimental Establishment of the Royal Engineers at Woolwich. This book occupies a position intermediate between the requirement of the student for a treatise on radio-engineering and that of the wireless operator. The need for instance of the electrical engineer who had never studied this particular branch of the subject was in mind in the preparation of what is described as an outline of the frame work of a great and growing subject. It will be understood consequently that the treatment is distinctly topical, rather than compendious, with the discussion full in some cases and scant in others.

After a brief introductory chapter, electromagnetic radiation is taken up but not very satisfactorily presented. The mathematics of this and the following chapter is hardly more than the formulation of the physical conditions and a quotation of the results of their mathematical analysis. The reader is either presumed to be familiar with alternating current theory or must consult a treatise on the subject.

Chapter IV gives an interesting account of the production of high frequency currents by spark, alternator, arc, and vacuum tube methods and is followed by a chapter on the detection of these currents. The remainder of the book is occupied with the theory and applications of the thermionic vacuum tube, the new instrument of such boundless utility that the author compares it to some such fundamental device as the wheel or the lever in mechanics. Chapter VI is devoted to a description of the characteristics of the vacuum tube and is followed by a chapter each, occupied with a discussion of the triode, i. e. the three electrode tube, as amplifier, as rectifier, and as oscillation generator. Chapter X discusses the use in receiving circuits and amplifiers of the ''retroactive'' principle by which is meant the way in which the stimulation of the grid by an oscillatory current brings about an introduction of energy into the oscillatory circuit from the plate battery. Chapter XI gives a good account of wireless telephony. The final chapter is a miscellany touching on such topics as antennae, direction finding, and interference from atmospherics.

It should be remarked that the author deals almost exclusively with the British practice and, as was intimated above, the book for the serious student will be chiefly valuable as supplementary reading to other treatises giving interesting sidelights on principles differently enunciated elsewhere.

It seems possible to inundate any discussion of radio-communication with a flood of mathematics which does not always leave the topics any clearer than at the beginning. The author is not open to this criticism for he strives to bring to light some important fact from his analytical expressions and frequently compares different arrangements by means of numerical results. The typography of the book is most pleasing and in addition to the 119 figures in the text twenty-four half tone illustrations from photographs are introduced to show actual apparatus and installations. One erratum was noticed. The reference in the second equation of Chapter VII should be to p. 96. F. E. B.

II. GEOLOGY.

1. *The White River Badlands;* by CLEOPHAS C. O'HARRA. South Dakota School of Mines, Bull. **13**, 181 pp., 96 pls., 75 text figs., 1920.—The president of the South Dakota School of Mines here presents, in more popular form, a much improved re-publication of his ''Badland formations of the Black Hills region'' of 1910, noticed in this Journal for March, 1911, p. 237. The new edition opens with a glowing pen picture by one of our pioneer geologists, the great John Strong Newberry, who contrasts the present scenery and life of the great West with that of the Tertiary. The South Dakota badlands are wonder places for fantastic scenery, for visible stratigraphy of fresh-water formations, and above all, as a vast cemetery of antediluvian mammals which have been made known to the scientific fraternity by Hayden, Leidy, Marsh, Hatcher, Scott, and Osborn. The book teems with

illustrations of the scenery and animals of the White River badlands, and is written, according to the preface, "in order that the intellectually alert, the indifferent thinker, the old and the young, irrespective of educational advantage or technical training, may have opportunity to get a clearer and more comprehensive idea of this wonderful part of nature's handiwork." C. S.

2. *Some Anticlines of Routt County, Colorado;* by R. D. Crawford, K. M. Willson, and V. C. Perini. Colorado Geol. Survey, Bull. **23**, 61 pp., 10 figs., 1920.—In this little report is brought together the evidence in regard to the anticlines in Routt County—and there are a number of them—where oil seeps have long been known. The work was done to facilitate the prospecting of the petroleum geologists. C. S.

3. *Permian Salt Deposits of the South-central United States;* by N. H. Darton. U. S. Geol. Survey, Bull. **715-M**, pp. 205-230, pls. 21-24, text figs. 31-40, 1921.—This little publication is one of the most striking of the many economic papers issued by the U. S. Geological Survey in recent years. It is now established that the sodium chloride beds of central Kansas are a part of the greatest salt accumulation of the world. These deposits cover an area fully 650 by 150 miles, equalling 100,000 square miles, and up to 700 feet in thickness, in the states of Kansas, western Oklahoma and Texas, and eastern New Mexico. The total quantity of sodium chloride is estimated by Darton at over 30,000 billion tons. Much anhydrite and gypsum is associated, and the whole of this series of salts lies in the lower part of the red beds of the Permian. So far, potassium salts in commercial quantities are unknown in this little explored and deeply buried formation, but there is a possibility and even a probability that such will be discovered. C. S.

4. *Interrelations of the Fossil Fuels;* by John J. Stevenson. Pp. 458, 1921.—Professor Emeritus Stevenson here brings together in book form what he has published under the same title in the Proceedings of the American Philosophical Society during the years 1916-1918 and 1921. To this has been added a table of contents and a good index. He treats of peats and coals, and gives a geologic synopsis of the world's fossil fuels, the whole testifying to a tremendous amount of labor devoted to bringing together the data presented. We congratulate our distinguished colleague! C. S.

5. *Foraminifera of the Philippine and Adjacent Seas;* by Joseph A. Cushman. U. S. Nat. Mus., Bull. **100**, vol. 4, 608 pp., 100 pls., 52 text figs., 1921.—In this extensive work are described and figured about 640 species or varieties (47 new) of Foraminifera, distributed among 119 genera. They are the result of six hundred dredgings in the Philippine region by the Fisheries steamer "Albatross," from depths ranging down to 1,000

fathoms. The shallow waters down to 30 fathoms have tropical species in great abundance, and in the deep seas arenaceous forms like those of high latitudes predominate. In this we see that temperature controls their distribution, and not depth and pressure. A giant discoidal form is *Cycloclypeus carpenteri,* growing to 3 inches in diameter. C. S.

6. *The Direction of Human Evolution;* by Edwin Grant Conklin. Pp. 247, New York (Charles Scribner's Sons), 1921. —This is certainly a very interesting book on philosophical naturalism, and because of the easy-flowing language one is swept on through the evidence of what evolution has done for man morphologically to the consideration of what in all probability social evolution will do for him. The author first prepares the reader through a discussion of ''Paths and Possibilities of Human Evolution'' for a better understanding of his views of ''Evolution and Democracy,'' out of which he believes will eventually come the highest possible happiness for social man, indicated in the concluding section on ''Evolution and Religion.''

To the scientist, ''nature is everything that is,'' and he seeks through observation, experiment, and reason to prove all things and to hold fast to that which is true. Therefore ''the one thing to be desired by church and state, by society and individuals is not perfect truth nor a panacea for all human ills but open-mindedness, sincerity, and sanity.'' ''The new wine of science is fermenting powerfully in the old bottles of theology.''

The human body, including the nervous system and the brain, seems to have already attained its limits of evolution, but man, by his increasing power over nature, is actually taking into his evolution the control of his environment. On the other hand, the progressive development of intellectual human society has just begun, for ''in social evolution a new path of progress has been found the end of which no one can foresee.'' ''The great goal toward which the human race is moving is the rational organization of society . . . a Society of Nations, a Federation of the World.'' Personal liberty will give way to social organization, to ''the freedom of nations and races rather than of individuals, the self determination of peoples rather than of persons.''

''Everywhere the universe is a cosmos and not a chaos.'' Throughout there is design, but we shall never find the explanation, for it concerns the origin of things, and finite man, even though his comprehension now extends beyond the stars, can not explain the riddle of the infinite.

''The religion of evolution . . . looks forward to unnumbered ages of human progress upon the earth, to ages of better social organization, of increasing specialization and co-operation among individuals and races and nations, to ages of greater justice and peace and altruism. Indeed the religion of evolution is nothing new, but is the old religion of the world's greatest leaders and teachers, the religion of Confucius and Plato and Moses and especially of Christ which strives to develop a better and nobler human race and to establish the kingdom of God on the earth.''

C. S.

7. *Wissenschaftliche Forschungsberichte. Naturwissenschaftliche Reihe. Bd. II, Allgemeine Geologie und Stratigraphie;* by A. Born. Pp. 145. Dresden and Leipzig (Th. Steinkopff), 1921.—The object of this book is to acquaint the Germans with the essential geologic publications of the world issued during the war years of 1914-1918. The material is arranged according to subjects, each of which is preceded by a general presentation of the views and facts attained by the authors. C. S.

8. *Mineralogische Tabellen;* by P. Groth and K. Mieleitner. 176 pp. Published by R. Oldenbourg, Munich and Berlin, 1921.—The last edition of Groth's ''Tabellarische Uebersicht der Mineralien, nach ihren kristallographisch chemischen Beziehungen geordnet'' appeared in 1898. The notable increase in mineralogical knowledge that has come since that time has made a new edition of this important book very desirable. It has been published with the assistance of Dr. K. Mieleitner, the Curator of the Mineralogical collection in Munich. The form of the book has been changed in this edition but the manner of treatment has remained essentially the same. A table for the determination of the important minerals by means of their physical properties has been added. W. E. F.

9. *Lehrbuch der Mineralogie;* by Gustav Tschermak; 8th edition by Friedrich Becke. 751 pp., 977 figs. and 2 colored pls. Published by Alfred Hölder, Vienna and Leipzig, 1921. —The first edition of this well known text book was published in 1883, the sixth edition in 1905, the seventh by Dr. Becke in 1914, and after less than seven years this present edition in 1921. The present book differs only in minor details from its immediate predecessor and therefore needs no especial comment. The publication of such a book at the present time under the very great difficulties that must prevail in Austria is especially noteworthy.

W. E. F.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Elements of Map Projection with Applications to Map and Chart Construction;* by Charles H. Deetz, Cartographer, and Oscar S. Adams, Geodetic Computer. Special Publication No. 68, U. S. Coast and Geodetic Survey. Pp. 163, 74 illustrations, 8 plates, 1921.—This publication is most welcome at this time because of the recent increase in interest in, and the use of, maps for many purposes. The dependence of the armies in the great war upon accurate maps has led the map makers in and outside

of the government to give much consideration to the question of projections with a view to constructing maps that will better meet the needs of the public.

The present publication is designed to serve as a guide to anyone having a special problem for which accurate maps are necessary. It is needless to say that some may wish the projection used on the map to maintain equal areas, that is, that areas on the map will have a definite relation to the corresponding areas on the earth from which the map is projected; others may not be so much interested in the maintenance of a true relation between the area on the earth and the area on the map, but their problems may involve the question of having the shape of a geographical feature as shown on the maps conform to its shape on the earth's surface.

The first part of the book shows very clearly why the projection of a spherical surface on a plane involves some distortion. This distortion will be in scale or in shape or a combination of both. In the second part of the book are described the various projections in common use. The list includes the polyconic projection so largely used in the United States; the Bonne projection which has been used a great deal in France; the Lambert conformal conic projection, which was brought to great prominence because of its very extensive use in the war zone in Europe; and the Mercator projection which is so well known to navigators. Other projections which are somewhat less known than these are also touched upon. These include several projections used to show the whole sphere. There is also described the Grid System or the system of rectangular co-ordinates which is used for military maps in the United States.

The book is well illustrated, which makes the text very clear to the reader. This paper should be read and studied by every one who has to deal with matters in which accurate maps play an important part. The authors are to be commended for this important contribution to the literature of geographical science.

WILLIAM BOWIE.

2. *Secrets of Earth and Sea;* by SIR RAY LANKESTER. Pp. xvii, 243. New York, 1920 (The Macmillan Company).—For many years the distinguished English zoologist who is the author of this book has contributed popular articles on various scientific topics to the daily or periodical press. Most of them naturally deal with some branch of biology, but others discuss such subjects of chemistry, physics, or geology as may suggest themselves by the news interest of the day. Some twenty-two of these papers have been brought together with more or less extensive revision and additions to form another volume of the author's "Science from an Easy Chair" and "Diversions of a Naturalist."

Although widely diverse topics are included, several of the essays deal with early man and his art, and with the derivation of conventional emblems of ancient and modern peoples, while the other discuss species and hybridization, cross-breeding of races, and curious forms of animal life. The book is of real value not only because of the pleasure and inspiration which the reading of the essays will give, but also because the information contained in them has been subjected to the judicial consideration of one whose wide knowledge and experience enables him to set forth the various phases of the subjects in their true proportions.

W. R. C.

3. *Observations on the Living Gastropods of New England;* by Edward S. Morse. Pp. 1-29; plates 1-9. Peabody Museum. Salem, Mass., 1921.—In spite of the fact that the shells of so many of our mollusks were described a half century or more ago, but little information is as yet available as to the structure and habits of the animals themselves. The observations on the natural history of the species recorded in this paper and especially the life-like drawings of the living animals will therefore be warmly welcomed. They supplement a similar study of the lamellibranchs published a couple of years ago. (See this Journal, **48**, 477.) The author also touches a responsive chord in his continued vigorous protest against such needless multiplication of generic names as has been in vogue in recent years. W. R. C.

4. *Elements of Bond Investment;* by A. M. Sakolski. Pp. 158. New York, 1921 (The Ronald Press Company).—In "Elements of Bond Investment" Mr. Sakolski has covered in a small volume, easily carried in pocket, a range of topics of remarkable extent. All bear upon the subject of the work, but can only suggest the complexity of the factors that go to advise the reader just what are these elements of bond investment. The book describes clearly what a bond is and that is a question probably nine men out of ten could not answer. Everyone has an idea as to what a bond is, until he is asked to tell you and then he usually weakens. The book is valuable as a text book to the entirely ignorant; it can be read profitably by the man who has a hazy idea about bonds and investment; and going still farther, the book is full of orderly information that even the expert investor can cull facts from. It is the work of a practical bond man, not a theorist.

Of course to read this book is not to become a competent investor. Men specialize in different kinds of bonds: Government, State, County, Municipal, Railroad, Public Utility and Industrial, each with a literature of its own and full of complications. And so the wise investor, be he in some business outside of brokerage, must still advise with the experts before he can safely risk his money. But with "Elements of Bond Investment" in the back of his head, he is forewarned and, therefore, forearmed. The book is readable and covers a large subject with skill and good sound level-headedness. Dean B. Lyman.

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VOL. II DECEMBER, 1921

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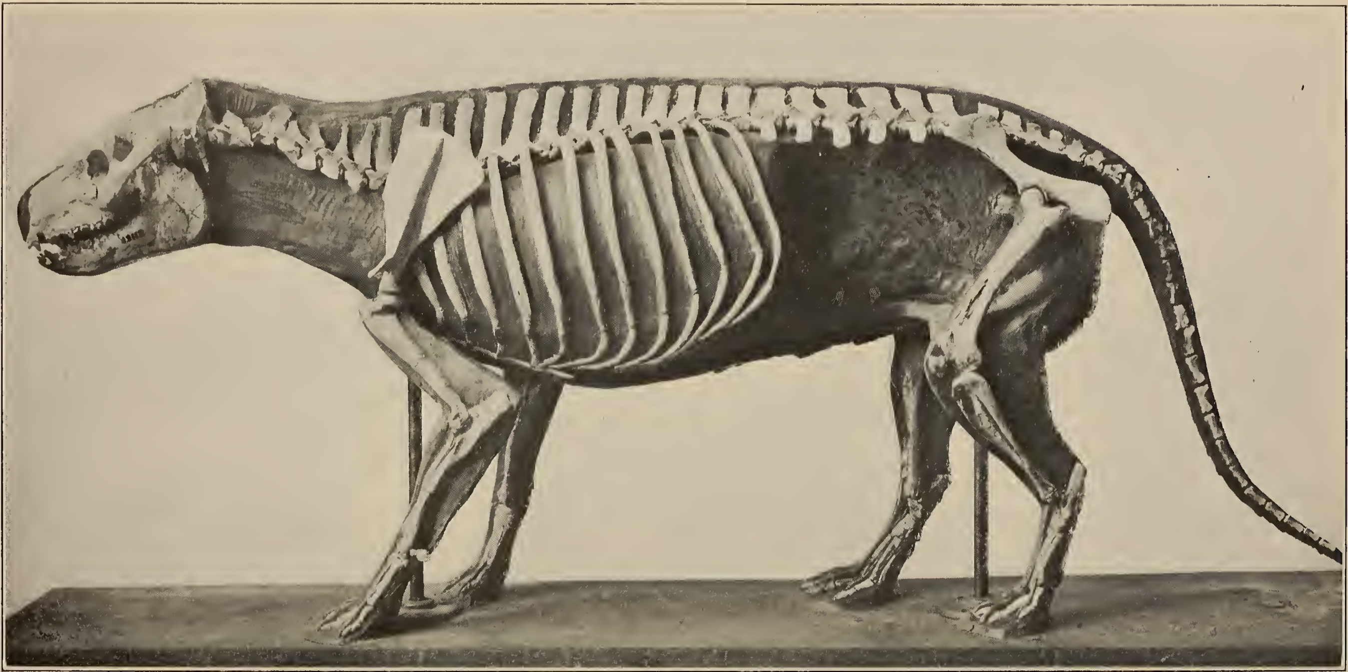

FIG 1.—Mounted skeleton of *Eporeodon socialis* Marsh.
Cotype, Cat. No. 13119, Y. P. M., with skull of cotype Cat. No. 13118, Y. P. M. × 1/7.

THE

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ART. XXII.—*A Newly Mounted Eporeodon;* by MALCOLM RUTHERFORD THORPE. With Plate I.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Connecticut.]

In the Marsh Collection are two nearly complete skeletons of *Eporeodon socialis,* one of which has been recently restored and mounted. The two specimens are cotypes, designated by Cat. Nos. 13118 and 13119, Y. P. M., and were collected at Scott's Bluff, Nebraska, by M. H. Clifford and A. S. Shelley on August 17, 1874. The skeletons were found very close together, in fact the skull of one was about 3 inches from that of the other and their vertebral columns were parallel. No. 13119 is now mounted (fig. 1). No. 13118 is a little smaller and of somewhat more slender proportions than the other skeleton. Both animals were fully adult, and while the detection of sex differentiation is extremely difficult if not impossible in this genus, yet it is not unreasonable to suppose that the larger (mounted) skeleton may have been a male and the other a female.

The bones, now freed from matrix, are of Upper Oligocene (Protoceras beds) age. The preparation and mounting were done by Mr. Hugh Gibb under the supervision of the author. After erecting the skeleton, the muscles of the right side of the body, head, and limbs were then modeled by Professor R. S. Lull over the actual bones. Viewed from the left (fig. 1), practically the entire skeleton is visible, while the right aspect (fig. 2) shows the complete animal in the flesh. Nearly all of the bones are removable and readily lend themselves to detailed study.

The osteology of this species has been worked out in detail and drawings made of the skull and various bones, for future publication.

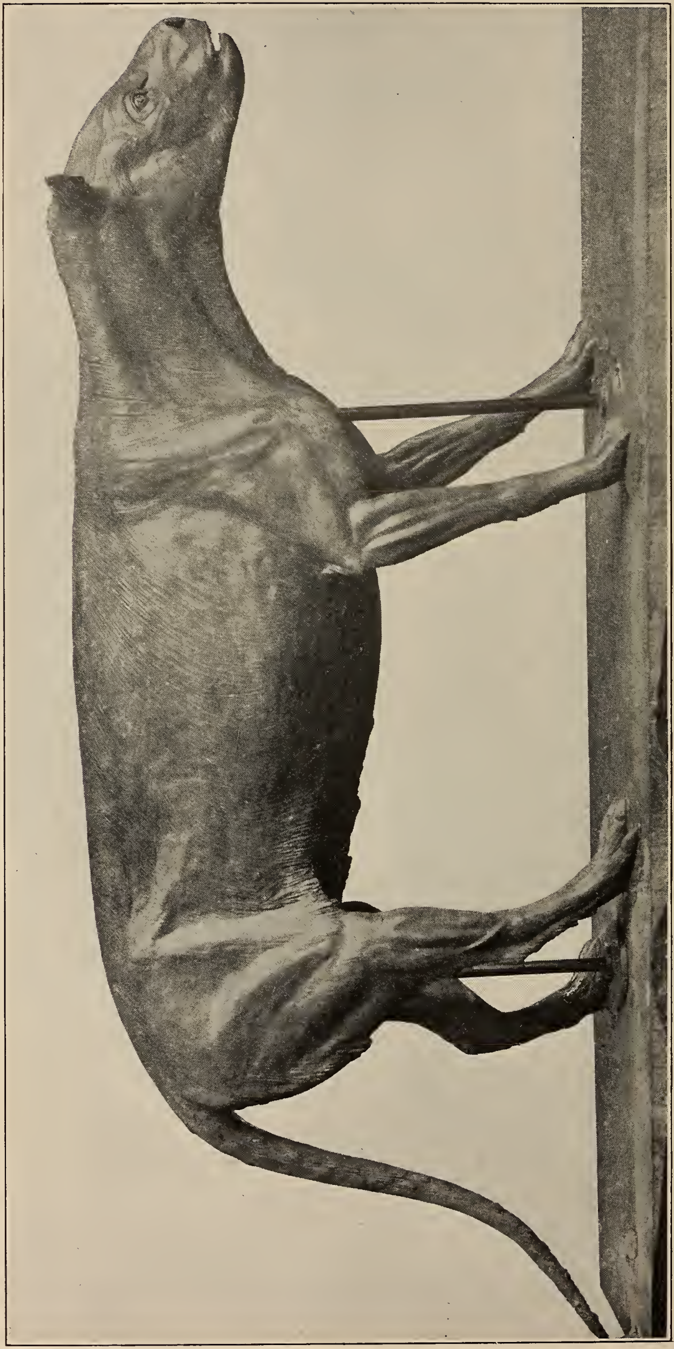

Fig. 2.—Restoration of *Eporeodon socialis* Marsh. Reverse of Fig. 1. Cotype. × 1/7.

Eporeodon socialis is known up to the present by only three drawings, with no text description. The first reference, in which the species was proposed, was in Professor Marsh's monograph on the Dinocerata, in 1884.[1] The only mention of the species in the text is a line on page 62 where the name *Eporeodon* alone is used, but this refers to figure 73, page 64, which shows a superior view of the skull of this species, with the brain cast in position. The skull, however, is incorrectly drawn. On page 187 of the same monograph are two woodcuts, the first, figure 162, of the left manus, and the other, figure 163, of the left pes of the same individual. Both of these latter figures are one third natural size and are reproduced in figures 3 and 4 of the present paper.

FIG. 3

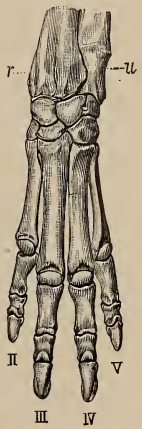

FIG. 4.

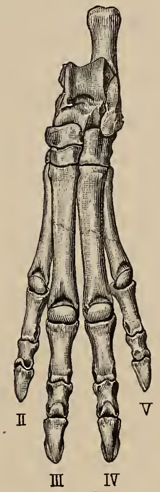

FIG. 3.—*Eporeodon socialis* Marsh. Left manus. Cotype. After Marsh. × ⅛.
FIG. 4.—*Eporeodon socialis* Marsh. Left pes. Cotype. After Marsh. × ⅛.

In the following year,[2] Professor Marsh again used the woodcuts of the left pes and manus as figures 128 and 129, without text reference. Until now, therefore, all knowledge of this species has been derived from the three above-mentioned woodcuts. Owing to this lack of exact information, it has been erroneously supposed that these cotypes were collected in the John Day basin of Oregon,

[1] O. C. Marsh, U. S. Geol. Survey, Mon. 10.
[2] O. C. Marsh, U. S. Geol. Survey, 5th Ann. Rept., 299, 1885.

and so stated in various faunal lists.[3] The less well preserved skull and jaws of No. 13119 were replaced in the present mount by the homologous parts of the more complete but somewhat smaller cotype, No. 13118. All of the remainder of the mount is of the one individual, the few missing parts being restored in plaster mainly from equivalent parts of the cotype.

The vertebral formula is C 7, T 13, L 6, S 4, and Cy 20+. This is not the typical formula found in *Merycoidodon,* but it would be very apt to vary as it does in *Sus.* Undoubtedly there were more than twenty caudals, but this number is all that were collected with the specimen. The four sacrals and the first sacro-caudal are ankylosed. No complete ribs now pertain to the skeleton, so these have been restored, as well as the superior part of both scapulæ, part of the pelvis, all of the sternum, and the right metacarpals and phalanges. Nearly all other parts of the skeleton are present in an exceedingly well preserved condition, even to the sesamoid and pisiform bones.

So far as the author is aware, this is the first specimen of the genus to be mounted. Skeletons of *Merycoidodon, Leptauchenia, Phenacocœlus, Promerycochœrus, Agriochœrus,* and other allied genera are on exhibition in various museums in the east, but up to the present none of *Eporeodon.* The skeleton as mounted is 47.5 inches (1.206 m.) in length and stands 17.75 inches (.452 m.) high at the shoulder.

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[3] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. **12**, 64, 1899; U. S. Geol. Survey, Bull. 361, 109, 1909. J. C. Merriam and W. J. Sinclair, Bull. Dept. Geology, Univ. Calif., vol. 5, 187, 1907.

Art. XXIII.—*A Note on the Wedge Work of Pebbles;*
by Chester K. Wentworth.

The phenomenon here described is one of those very simple processes which are so obvious as ordinarily to be considered unworthy of mention. But one reference to the process is known to the writer[1] and it is not so far as he is aware mentioned in any textbook of geology.

The wedge work of pebbles first came to the attention of the writer several years since at numerous localities along the gorge of the Potomac River below Great Falls. The action of pebbles in this fashion has since been noticed at other places where the conditions are similar and it will suffice to describe the Great Falls occurrence as typical. Below these falls the Potomac River flows between rock walls which range from 20 to 80 feet in height above low water level. The rock is gneiss which is extensively cut by joints. The rock walls are deeply fissured by differential weathering along lines controlled by the jointing and by the unequal resistance of different zones of the gneiss. On both sides of the present gorge of the river are the rock cut benches of the outer valley on which are strewn sands and gravels in thin, irregular patches. During flood the river rises 20 to 30 feet within the inner gorge and by occupying a number of channels which are dry at other times separates several rock islands from the mainland. In the vicinity of the river the surface of the gneiss is commonly fresh and the rock hard and compact. Within the wedge-shaped open joints are numerous rock fragments, some of which are angular blocks and others well rounded pebbles and cobbles from the gravel. These have lodged in their present positions in part by falling from the level of the rock bench above and in part by deposition during flood stages of the river. The notable feature is that a very large proportion of the pebbles and blocks are wedged tightly in place in the cracks which narrow downward. Pebbles of one or two inches in diameter are more commonly than otherwise held between comparatively smooth rock surfaces so

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[1] Wade, A., Some observations on the eastern desert of Egypt, Quart. Jour. Geol. Soc., vol. 67, p. 249.

tightly that it is impossible to remove them without the use of a hammer. In other words many of the pebbles are much more tightly wedged than would result from the impact of falling alone. In figures 1, 2, and 3 are shown several cracks in which pebbles were tightly lodged. None of the pebbles shown could be removed with the unaided hands.

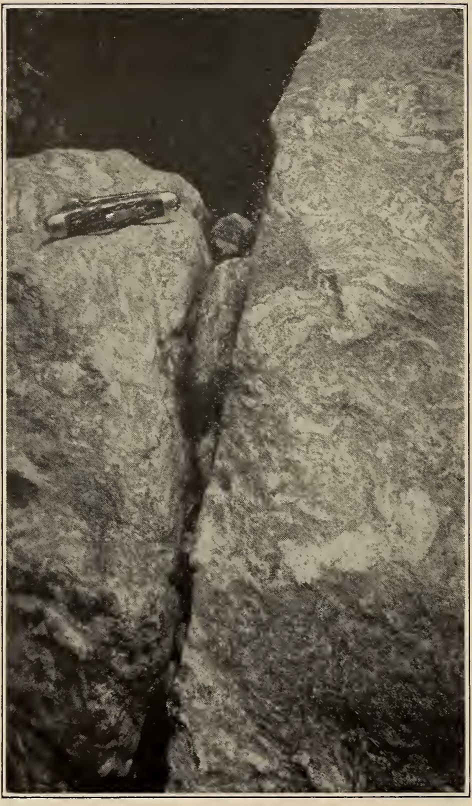

Fig. 1.

The explanation seems to be that the pebbles are wedged in place by the combined action of gravity and the expansion and contraction due to changes in temperature. In the case of a crack offering only moderate resistance to further spreading and which does not close again on removal of the force it is apparent that a single pebble would ultimately wedge the rock apart. When the pebble is cold and contracted it will fall until its weight is supported. When the air becomes warmer the pebble is heated more rapidly than the general mass of the rock and its expansion exerts pressure on the walls of the crack or fissure. If the pressure is completely met by an elastic yield of the rock mass and the rock recoils as the pebble becomes cooler again the latter will not fall and the process will merely be an alternate growth and relief of stress with little or no cumulative rupturing effects. If however the response to expansive stresses is only partially elastic the rock will not recoil completely and the pebble will fall on cooling to a new and more

Fig. 2.

effective position and the process will be cumulative in its results.

Assuming now a perfectly elastic rock mass but several pebbles in place of the one. Let these pebbles be of different rocks having different thermal constants and be differently exposed to the air and to the rays of the sun. When periodic temperature changes take place not all these pebbles will reach their maximum expansion at the same time. Recoil of the rock will follow the progress of the combined stresses rather than that of any one pebble and some pebbles will be free to fall ever so slightly while others hold the load. The pebbles thus act both at the time of greatest heat and similarly at the time of greatest cold to each other as pawls on a ratchet and the process becomes cumulative even with a strictly elastic

Fig. 3.

yield in the rock. If the rock yields in part by rupture the effect will be so much the more rapid. The foregoing analysis shows adequately that pebbles can exert cumulative stresses in widening cracks and disrupting the rocks. That the pebbles in cracks are usually tightly wedged is proof that they do exert pressure on the walls.

It remains to inquire what the quantitative importance of this process is. The factors involved include thermal expansion, thermal conductivity, thermal capacity or specific heat, elasticity, crushing strength, tensile strength and density. It is not essential nor possible here to treat the problem exhaustively and certain approximate assumptions will be made. The following values are taken as sufficiently typical for the common rocks:

Coefficient of expansion....	.0000025 per 1 degree F.
Compression elasticity.....	.00025 per 1000 lbs. to the sq. in.

Let a maximum diurnal change of 100 degrees F. be assumed and let it be considered that this temperature change penetrates only a foot or two. Considering temperature changes alone, then, two points on either side of a crack and each several feet within the rock mass will be separated by a distance which remains a constant. Let it further be assumed that the temperature gradients on either side of the crack and extending into the rock be such that the total thermal expansion on both sides is just equal to that wrought on a 4″ length by a change of 100 degrees F. If then a 4″ cobble be allowed to fall during the time of minimum temperature into the crack, the total expansion effect of an increase in temperature of 100 degrees will be twice that wrought on the cobble or

$$2(4'' \times 100)\ (.0000025) = .002''$$

The pressure required to produce a .002″ diminution of a 4″ length will be

$$\left(\frac{.002''}{4''} \times \frac{1}{.00025}\right) 1000 = 2000 \text{ lbs. per sq. in.}$$

It is valid to conclude that the pressure exerted by the cobble will equal 2000 times the mean or equivalent cross-sectional area in square inches. This conclusion is based on the assumption that the elastic yielding of the strongly supported regions of contact of the rock walls is negligible.

If the cobble is taken as a sphere and if the assumption is made that no shearing deformation takes place between successive zones of each segment of the sphere the equivalent elastic cylinder of the same height will have a diameter of approximately 2.4″. Inasmuch as there will be some deformation of this sort the diameter of the equivalent cylinder will be somewhat less and may be roughly taken as 2″ and its end area as 3.14 square inches. This gives a pressure of 6280 pounds exerted by a 4″ cobble under the conditions assumed. Such a pressure is likely to cause local rupturing of the cobble if concentrated on a very small area at the contact. This will tend to broaden the area of contact to a competent value. With an area of ½ square inch at the contact the pressure computed above is not likely to produce crushing in cobbles of the stronger rocks.

From the considerations set forth above it appears that the limit of pressure developed by any single pebble or cobble is that required to compress it by the amount of the thermal expansion caused by the maximum diurnal temperature range. This pressure may be reached only when the area of contact is sufficiently large to transmit it. Most commonly the position reached by the cobble in its fall will be such that there is considerable readjustment and local crushing while the first part of the expansion takes place. If it be assumed that one half of the expansion takes place before the cobble is adjusted to assume a full load there will remain expansive effect sufficient to produce a pressure on a 4″ cobble amounting to over 3000 pounds or 1½ tons.

It is apparent that the above computations are based on a number of assumptions which are only approximately correct but they serve to show that even after making ample allowance on the conservative side the pressure developed by the expansion of pebbles in cracks is sufficient to produce very considerable disruptive effects. When it is considered that this process is ever active at all temperature ranges it seems that in some situations even where there are freezing temperatures in winter it may be more potent in splitting the rocks than the ice which forms in the cracks, though the writer is by no means disposed to underestimate the effect of the latter.

Art. XXIV.—*On Concentric Drag-Folding in Alabama Marble;* by T. Nelson Dale.

While engaged in collecting material for a U. S. Geological Survey Bulletin on the marbles of the Southern States, the writer, on Oct. 23d, 1916, noticed in the storage yard of the Moretti-Harrah quarry near Sylacauga, in Talladega County, Alabama, several marble blocks containing lenses up to 2 ft. in diameter and 6-8 inches in thickness. These lenses were separated from the marble mass by a film of muscovite schist. Two of these blocks with lenses are shown in the reproduced photographs, figs. 1 and 2. Some blocks afforded two vertical sections of the same lens at right angles to one another, thus leaving no question as to their being really lenses.

No. 1.—Block of white marble (6 ft. by 4 ft. 6 inches) from the Moretti-Harrah quarry near Sylacauga, Ala., showing lenses bounded by films of muscovite schist. The drilled face is parallel to the strike of bedding.

Dr. William F. Prouty[1] refers to evidence of "drag-folding" in the marble at Gantts quarry about a mile S.W. of the Moretti-Harrah quarry. Drag-folding differs from plicated bedding in that it consists of the plication of the central part of a bed only, the upper and lower surfaces of which are not at all plicated. It has been explained by Reusch[2] as being the result of the unequal gliding of the upper and lowermost parts of a bed under lateral compression so as to drag the next adjacent parts of the bed in opposite directions and to fold them. Under accompanying pressure in a direction highly inclined to the bed this folding might easily pass into intense plication without affecting the upper and lower surfaces of the bed. The writer has figured such intra-bedding plications in quartzose marble and micaceous quartzite in Vermont.[3]

No. 2. Slab of white marble (12 by 1 ft.), from the same quarry as Fig. 1, showing on the sawn face, which is parallel to the dip direction, lenses bounded by films of muscovite schist and also plicated schist laminæ on either side of it.

Some of the marble blocks at the Moretti-Harrah quarry showed that the schist laminæ were not only

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[1] Prouty, Wm. F., Preliminary Report on the crystalline and other marbles of Alabama, Geol. Survey of Ala., Bull. 18, 1916, pp. 32, 35.

[2] Reusch, Hans R., Die fossilien-führenden krystallinischen Schiefer von Bergen in Norwegen. Authorized German translation by Richard Baldauf, Leipzig, 1883, p. 118, fig. 79.

[3] Structural details in the Green Mountain region and in Eastern New York, U. S. Geol. Survey XVIth Ann. Report, pt. I, 1896, p. 558, fig. 83; also in U. S. G. S. Bull. 589, The calcite marble and dolomite of Eastern Vermont, 1915, pp. 38, 39.

intensely plicated between the bedding planes but that this plication must have taken place both in the strike and the dip directions, and had resulted in the formation of marble lenses coated with a film of schist. Fig. 1 shows sections of such lenses on the strike face of a block and fig. 2 on the dip face. The latter shows intricate plications of the schist laminæ on both sides of the lenses which led up to the formation of the lenses.

In order to ascertain whether the micro-texture of the marble near these lenses showed anything abnormal, thin sections were made of pieces from two blocks, one section in the dip direction, the other in the strike direction. Only that in the dip direction from the block represented in fig. 1 showed grain elongation in the direction of the dip. This corroborates evidence from a thin section of the marble at Gantts quarry showing that during metamorphism there was a powerful pressure along the strike, i. e. about N. 10° E. which is implied in the occurrence of the lenses.

Conclusion: The formation of these schist-coated marble lenses involves not only extreme intra-bedding plication (drag-folding) but this must have occurred in rectangular and concentric directions in order to transmute plications with longitudinal axes into lenses.

Of course the schist laminæ are minute layers of clay particles of inorganic sedimentary origin metamorphosed into more or less fibrous muscovite, etc.

Sheffield, Mass., Oct. 13, 1921.

Art. XXV.—*Studies in the Cyperaceæ;* by Theo. Holm. XXXII. *Carices aeorastachyæ: Phacotæ* nob., and *Ternariæ* nob. (With 11 figures drawn from nature by the author.)

Phacotæ.

Characteristic of the species of this section is the terminal spike being gynaecandrous, even if not constantly so. The lateral spikes are single, not fasciculate; the squamae of the pistillate flowers are mucronate or aristate. The perigynium is membranaceous, ovate to obovate, with a generally short beak, entire to emarginate. The section is represented by *C. phacota* Spreng., *C. incisa* Boott, *C. cernua* Boott, *C. praelonga* C. B. Clarke, *C. Prescottiana* Boott, and *C. Kiotensis* Franch. et Sav.

They are natives of southern and eastern Asia; *C. praelonga* inhabits the Himalayas; *C. incisa* and *C. Kiotensis* Japan, while the remaining occur both in the Himalayas and Japan. The accompanying drawings illustrate the structure of the squama of the pistillate flower of *C. phacota* (fig. 6), and of *C. praelonga* (fig. 8), taken from about the middle of the spike; at the base of the same spike the mucro becomes an arista. The perigynia show only the two marginal nerves (figs. 7 and 9) except in C. *Prescottiana,* where several fine nerves traverse the perigynium.

Ternariæ.

In this section we meet with species in which the pistillate spikes are fasciculate: *Carex ternaria* Forst., *C. tuminensis* Kom., *C. suddola* Boott, *C. Darwinii* Boott, and *C. Arnottiana* Nees.

The geographical distribution of these species is very scattered: *C. ternaria* and *C. subdola* are indigenous to New Zealand; *C. tuminensis* is a native of Korea; *C. Arnottiana* of Ceylon, and finally *C. Darwinii* is known from Chile, Argentina and Straits of Magellan.

C. ternaria.

Boott[1] describes the species as follows:

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[1] Hooker's Flora Novae Zealandiæ, 1853, p. 282.

Fig. 1. *Carex ternaria* Forst. v. *pallida* Cheesem.; part of the inflorescence; natural size.

Fig. 2. Schematic drawing of a fascicle of spikes of same.

Fig. 3. Schematic drawing of a fascicle of spikes of *Carex cladostachya* Wahlenb. For explanation of letters see the text.

Fig. 4. Scale of pistillate flower of *C. ternaria* v. *pallida;* enlarged.

Fig. 5. Utriculus of same; enlarged.

Fig. 6. Scale of pistillate flower of *C. phacota* Spreng.; enlarged.

Fig. 7. Utriculus of same; enlarged.

Fig. 8. Scale of pistillate flower of *praelonga* C. B. Clarke; enlarged.

Fig. 9. Utriculus of same; enlarged.

Fig. 10. Scale of pistillate flower of *C. subdola* Boott; enlarged.

Fig. 11. Utriculus of same; enlarged.

"Spicis 15-24 sexu distinctis cylindraceis multifloris evaginatis, ♂ 1-6 inferioribus geminatis, ♀ 8-18 geminatis ternatisve raro quinatis, superioribus saepe apice ♂ inaequaliter longe pedunculatis pendulis longissime bracteatis, perigyniis subrotundo-ovatis v. ellipticis obovatisve ore integro v. emarginato nervosis ferrugineo-punctatis squama ovata v. lanceolata truncata v. emarginata rarius acuta longe hispido-aristata brevioribus, stigmatibus 2."

A specimen of the variety *pallida* from South Island, New Zealand, shows the inflorescence as follows. There are three staminate and ten pistillate spikes; the terminal and two uppermost lateral are purely staminate, somewhat remote. Then follow the pistillate in four remote whorls, subtended by long, foliaceous bracts; the uppermost whorl consists of two spikes, the second and third each of three, and the fourth, the basal, of two spikes; of these six of the upper ones are androgynous.

This peculiar ramification of the inflorescence may at a first glance look complicated, since the long peduncles proceed from the shallow axils of the bracts, two or three together. In the *Carices genuinae* we have generally only one pistillate spike in the axil of each bract, surrounded at the base by a small, more or less tubular leaf, the so-called ochrea or vagina (Gay and Roeper), which represents an organ homologous with *Utriculus*.[2]

Now if we examine the base of the peduncles in *C. ternaria* we notice two or three tubular, membranaceous leaves of exactly the same structure and adorsed position as an ochrea. When there are three spikes as in the present specimen, one is generally almost sessile, and stands before the two others; they actually occupy one row between the main axis of the inflorescence and the bract. The ochrea of the anterior, almost sessile, spike is extremely small and thin, while those of the two long-pedunculate spikes are larger, and quite distinct, somewhat distorted, however. How these axillary spikes are developed, and in what order is extremely difficult to decide from their position in *C. ternaria*. Because these three ochreae call for a system of axes belonging to the axil of a single bract. Nevertheless the arrangement of these three axes, their successive development, becomes

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[2] Compare this Journ., vol. 2, p. 215, 1896.

readily understood, when we compare the inflorescence with that of Tuckermann's section Vigneastra, for instance *C. cladostachya* Wahlenbg.[3]

The accompanying figures (2 and 3) show the ramification. In *C. cladostachya* (fig. 3) only a small part of the culm has been shown (St.); it bears a green leaf (L.), which subtends a rhachis (R.) bearing four androgynous spikes of which only the three have been shown; the rhacheola is terminated by an androgynous spike (S.). The racheola bears three long, leaf-like bracts 1^1 and 1^2 (the third one, the uppermost, is not marked). In the axils of these bracts are spikes, one in each, and they bear a distinct ochrea (P*). In *C. cladostachya* these ochreae (P*) are exposed to the light; they are of a dark brown color, and often hairy, while the basal ochrea (P) is membranaceous, hyaline, and partly hidden by the base of the leaf (L.). If we now compare the schematic drawing of *C. ternaria* (fig. 2) which represents a whorl of three spikes, we notice the striking accordance with the composition of the spikes in *C. cladostachya.*

We notice the small part of the culm (St.), bearing a green leaf (L.), which subtends a rhachilla (R.), bearing two lateral, androgynous spikes and a terminal (S.). At the base of the rhachilla is an ochrea (P), turning its back towards the mother-axis (St.). The two lateral spikes are also provided with ochreae (P*) but these are membranaceous, hyaline. Two bracts (1^1 and 1^2) are indicated with dotted lines, since they are not developed. By comparing this figure with *C. cladostachya*, the only difference depends on the very long rhachilla, the very short, lateral axes and the development of the bracts (1^1-1^2) in *C. cladostachya,* while in *C. ternaria* the rhachilla is very short, the bracts are suppressed, and the lateral axes are long. To render the position more distinct we have drawn the rhacheola in the latter species much longer than it is, and the uppermost lateral axis has been drawn much shorter than it is, in order to save space. As a matter of fact the length of the basal portion of the rhacheola in *C. ternaria,* between P and the uppermost P*, is only one mm.; thus the ochreae (P and P*) are situated almost at the same height. While these

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[3] Compare this Journal, vol. 10, p. 36, 1900.

ochreae are free, and exposed to the light in *C. cladostachyæ,* they are completely hidden within the base of the subtending leaf (L.) in *C. ternaria,* and are hyaline.

This structure of the inflorescence is characteristic of the species of Tuckermann's *Vigneastra,* but the number of lateral axes varies very much, nevertheless the fundamental composition is exactly the same. Among the *Carices genuinæ* we have shown that this structure is also characteristic of *C. Willdenowii, C. Steudellii* and *C. Barkii.*[4] Moreover several cases have been observed in various species of *Carices genuinæ* where a similar ramification may be developed, but only abnormally so.

The ramified secondary inflorescences in the *Vigneastra,* no doubt, indicate the most evolute type of *Carex.* However some of these species occur also with a more simplified structure, when the specimens are "depauperate." For instance, in *Carex Boyana* Schk., Boott mentions that this highly developed type may also be represented by individuals of less complicated structure. The typical plant[5] has about 20 spikes or even more, mostly fasciculate; but this species occurs also as forms much modified, in which the lateral branches may be fasciculate, but the spikes themselves simple, not branched; finally a much reduced form exists (Boott l. c. tab. 349), in which all the spikes are single in the leaf-axils, and more or less remote. In other words the lesser developed types of *Carex* may, sometimes, imitate the most evolute, either in cases defined as abnormal, or as normal and typical in *C. Willdenowii* and its allies. Conversely the highly evolute *Vigneastra* may occur as depauperate forms imitating the lesser developed *Carice genuinæ.* It will be evident to any one who examines these forms, that while they differ in the typical, they occasionally unite in some characters, in this case the structure of the inflorescence, exhibiting their descent through modification from a common type. And as we have stated before, we hold the opinion that the *Vigneastra* are referable to the greges of *Carices genuinæ*, and some evidently to the *Vigneæ.*

Figure 4 shows a squama of a pistillate flower, and the perigynium is drawn in fig. 5; we notice the scabrous arista in the scale, and the spinulose, upper margin of the

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[4] This Journal, vol. 10, p. 33, 1900.

[5] Boott: Ill. genus *Carex,* vol. 3, p. 111, tab. 345-549, 1862.

perigynium; the latter character is somewhat unusual in the grex *Aeorastachyæ,* but seems common to several of the New Zealand Carices, notably in the grex *Echinochlaenæ,* nob.[6]

C. tuminensis.

Meinshausen[7] credited *C. ternaria* to the island Sachalin, but according to Kükenthal's monograph (p. 369), the plant in question is Komarow's *C. tuminensis.* It is a near ally of *C. ternaria,* and the distinctive characters depend merely upon the pistillate scales being "lanceolatae subacutae cupreae nitidae," and "utriculi squamis breviores latiores, rostro subintegro" in *C. tuminensis.*

C. subdola.

This species shows the same habit as *C. ternaria,* and according to Boott[8] the squamae and the perigynia show the following structure:

> "Perigyniis ovalibus vel ovatis rostellatis, ore integro vel emarginato, stipitatis nervatis ferrigineo-punctatis, squama oblongo-emarginata aristata vel ovata acuta vel obtusa mutice purpureo-pellucida lineata nervo viridi longioribus vel subaequantibus."

Regarding its affinity Boott states, that it is intermediate between *C. Gaudichaudiana* and the small forms of *C. ternaria.* The accompanying figs. 10 and 11 show the squama and utriculus.

In some specimens kindly presented to the writer by Professor T. F. Cheeseman (Auckland, New Zealand) some of the pistillate spikes bore secondary spikes below the terminal ; these secondary spikes were purely pistillate, subtended by filiform bracts, and sessile in some distance from each other.

C. Darwinii.

Boott's diagnosis[9] reads as follows:

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[6] Greges Caricum, this Journal, vol. 16, p. 462, 1903.

[7] Die Cyperaceen der Flora Russlands. St. Petersburg, 1901, edited by J. Klinge and W. Komarow.

[8] Ill. gen. *Carex,* vol. iv, p. 201.

[9] l. c., vol. iv, p. 156, tab. 504-505, 1867.

"Spica elongata composita stramineo-ferruginea, e spiculis pluribus (15) cylindricis inaequalibus masculis 3 terminali longiore inferioribus geminatis una abbreviata sessili, reliquis ♀ inaequalibus remotis longe pedunculatis nutantibus vel pendulis, superioribus (2) geminatis vel infima solitaria. Stigm. 2; perigyniis ovalibus vel ovatis stipitatis sensim rostratis, ore integro utrinque 3-5 nervatis glabris tenuiter granulatis stramineis, punctis ferrugineis notatis squama lanceolata acuta cuspidata ferruginea nervo pallido latioribus brevioribus. In America meridionali."

C. Arnottiana.

A specimen of this species was preserved in the herbarium of Nees von Esenbeck, and Drejer[10] described and figured it:

"Spicis 10 pedunculatis, pendulis, densifloris, cylindricis, obtusis: superioribus geminatis, approximatis, duabus infimis solitariis, distantibus; bracteis inferioribus late foliaceis, culmum longe superantibus, evaginatis auriculatis; squamis ovato-lanceolatis acuminato-subcuspidatis; perigyniis (immaturis) ellipticis, laevibus; rostro breviusculo apice hyalino; stigmatibus binis. Habitat in Ceylona, ad altitudinem 6000 pedum Arnott."

Regarding its affinity Drejer writes:

"Quamquam ex specimine unico, florente, radice, foliis, culmique inferiore parte carente, certum judicium ferre non possum, tamen non dubito, quin affinitas huic speciei sit cum *Caricibus aeorastachyis,* minus tamen cum *C. glaucescente,* quam cum distigmaticis *C. salina* Whlb., *Lyngbyei* Hernem., *macrochaeta* C. A. Mey, reliquique."

Kükenthal (l. c. p. 350) describes the mature perigynia and squamæ:

"Utriculi squamis breviores latiores adpressi membranacei subobovati compressi 2½ mm. longi fusci superne granulosi enervii basi cuneati marginati, rostro brevi integro apiculati. Squamae ♀ lanceolatae acuminato-aristae (arista laevis) atrofuscae dorso viridi trinerves."

The *Ternariæ* constitute the last section of the *Aeorastachyæ* with two stigmata. We have seen the gradual evolution of this part of the grex from the *Salinæ* with the terminal spike being staminate, and the pistillate lateral and single in the axils of the bracts, to the *Phacotæ*

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[10] Symbolæ Caricologicæ Opus posthumum ab Academia scientiarum Danica editum, 1844.

with the terminal spike mostly gynaecandrous and the *Ternariæ* with the spikes fasciculate. And this progressive development of the species coincides, to some extent, with the geographical distribution: the simplest type being represented in the boreal, the most evolute in the southern regions. From the circumpolar *C. subspathacea* the development gradually advances towards south, culminating in the *Ternariæ*: Ceylon, New Zealand and Straits of Magellan.

A corresponding development of the species may be traced also to some of the sections themselves. For instance in the *Salinæ,* when we compare the inconspicuous, few-flowered *C. subspathacea* with the southern variety of *C. salina, Kattegattensis,* and with *C. halophila.* Among the *Cryptocarpæ* we pass from the boreal, slender forms of *C. cryptocarpa* to the more southern, very robust *C. cryptochlaena.* But regarding the *Crinitæ* there seems to be no transitional types between *C. maritima* from the northern coasts and the southern, sylvan types *C. crinita* and *C. gynandra;* nevertheless these three species are undoubtedly closely related, and as demonstrated above, they exhibit a remarkable variation in the distribution of the sexes as well as in the composition of the inflorescence, imitating the most evolute types of the genus.

While thus the distigmatic species of the *Aeorastachyæ* have reached the most evolute stage of the genus, exemplified by the *Ternariæ,* the tristigmatic do not extend beyond the so-called ordinary type of *Carices genuinæ,* except the peculiar *C. Magellanica* with the habit of the Limosæ, but with the spikes typically gynaecandrous.

Clinton, Md., August, 1921.

ART. XXVI.—*Native Antimony from Kern County, California*; by C. H. BEHRE, JR.

Metallic antimony in noteworthy amounts is of rare occurrence. It has been reported from Sweden, Germany, France, Bohemia, Borneo, Mexico, and Chile; in the United States it is known to occur at Warren, New Jersey, and in Canada at South Ham, as well as in York County, N. B. Casual references to its occurrence are to be found in the early reports of the California Geological Survey. Probably the best known deposits of that state are in Kern County along Erskine Creek. Specimens from this locality were received from Mr. A. Blanc[1] by the United States Geological Survey and were made available for the study here reported by Professor Edson S. Bastin of the University of Chicago, to whom the writer is also indebted for kindly criticism and many suggestions.

The specimens are kidney-like masses of the native metal covered with a thin layer of the various oxides mentioned below. On being broken, some of the larger nodules proved to be composed of several minor masses a cubic centimeter or so in volume, each having a nucleus of the metal coated with its afterproducts and massed together with other similar nodules to form aggregates measuring ten centimeters in maximum diameter. The individual smaller nodules are crossed by veinlets varying in width up to a half-centimeter.

The metallic antimony forming the core of the nodules is typical in appearance; it is of the granular type. It forms by far the greater part of the specimens. It is bordered marginally by a black mineral of resinous to dull luster, having a platy cleavage, but of indeterminate crystal form. This mineral defies all attempts at identification. It may be described as follows:

Color black to (locally) grayish-green (due to impurities?); streak white, opaque,—the color of shredded tallow; luster non-metallic,—dull or resinous; amorphous or crystalline; cleavage

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[2] Mr. Blanc, the discoverer of the deposit, furnishes the following brief description: The deposit has been worked through a trench about 150 feet long. The antimony is pockety in distribution. Stibnite appears with depth.

platy; surface frequently roughened by minute parallel laminae. Hardness 3.5 ± ; rather brittle. Specific gravity not determined. On charcoal gives white fumes and coat characteristic of antimony compounds; with Na_2CO_3 yields a brittle globule of metallic antimony. No color in beads of borax or salt of phosphorus. In open tube become yellow when hot; cools to whitish-gray slag, which, in early stages of fusion, often shows minute transparent crystals (senarmontite or, less probably, valentinite); forms very slight orange-colored sublimate (?) and much white sublimate of the usual antimony oxides. In closed tube yields slight amount of H_2O. In HNO_3 gives a white cloudy suspension (probably metantimonic acid). Dissolves slowly in hot HCl; from solution an excess of NH_4OH throws down a heavy, white, flocculent precipitate. Under the microscope, polished, it is dark gray with a faintly brownish tint and rough, etched surface. It reacts microchemically as follows: HNO_3,—fumes brown slightly, acid tarnishes brown or iridescent; HCl,—fumes brown slightly (?), acid tarnishes gray; KCN,—negative; $FeCl_3$,—tarnishes dark-gray to iridescent and rubs almost clean; $HgCl_2$,—negative; KOH,—roughens and tarnishes gray.

The greater part of the coating of the nodules is orange-brown and contains iron, probably in the form of limonite. Elsewhere dirty olive-green shades alternate with deep corn-yellow or opaque, porcellanous white; through these lighter colors undulatory lines of dark gray to black can be discerned and these are readily traced to veinlets that cross the nodule and native antimony core and are bordered by the black, dull-luster mineral already described. Scars or polished surfaces expose the tin-white antimony at no great depth beneath the coat of alteration products. The yellow and the white matter approximate in composition valentinite or senarmonite and are probably the former, as determined by qualitative chemical and pyrognostic tests.

Microscopic study reveals the following relations: Five minerals are distinguishable. Of these the most conspicuous is the native metal. Rarely this shows suggestions of radiate structure; far more commonly it is merely granular and massive. Neither stibnite nor kermesite are associated with it, nor are there any indications that it was derived from the former and tests for sulphur always yield negative results. The black unknown mineral replaces the native metal peripherally, and occupies replacement veinlets, sharing these with the apparently contemporaneous yellow or white mineral thought to be valentinite. These two minerals show sharp crystal faces toward each other, but ragged edges against the antimony. Like the black mineral, the valentinite also replaces the antimony peripherally. In veins it is generally central, the black mineral more nearly marginal; hence the latter is probably slightly earlier. Locally the valentinite forms fissure veinlets. When it and the unknown mineral are marginal in a nodule they show a cloudy suffusion, possibly representing a beginning alteration to a more hydrated form. When they are more nearly idiomorphic, the darker mineral appears to be hexagonal in sections, whereas the lighter one is more nearly tetragonal or may form acicular needles or ''barrel-shaped'' crystals like those of corundum.

Although the lighter-colored mineral yields some water in the closed tube, it is thought to be valentinite (Sb_2O_3) rather than stibiconite ($Sb_2O_3.H_2O$), because of its softness and its crystalline form. It reacts negatively to the standard reagents employed by Davy and Farnham for the identification of metallic minerals. In druses it is crystalline; the crystals are yellowish, translucent, prismatic, but poorly terminated, and lie side by side so that they form a ''stockade'', rather than the radiating sheaf so common in stibnite; the probability that these crystals are pseudomorphs after stibnite is therefore lessened.

Both the black mineral and the valentinite are crossed by veinlets which megascopically appear translucent, colorless or faintly yellow, and roughly paralleling the surface of the nodule. The mineral has a hardness of 5 and takes a good polish. Other than being slightly tarnished by HCl (?), it shows no microchemical reaction with the standard reagents of Davy and Farnham. With such limited amounts observable it cannot be positively identified, but it is thought to be stibiconite. In addition to crossing the valentinite and the black mineral and hence post-dating them in time of deposition, it may form the core of such larger veins as, toward their borders, show those minerals. Again, it appears to replace valentinite and the black mineral in their crystalline forms, exhibiting, however, a marked preference for the latter, so that the replacement veinlets frequently curve around areas of the lighter-colored valentinite. Closely spaced replacements of the black by this fissure-filling mineral are especially common.

This translucent, vein-forming mineral is locally bordered by a substance that is still lighter under the reflecting microscope but composes areas too small for microchemical or pyrognostic study. Frequently this lighter-colored mineral fills an entire veinlet and seems to be an intermediate product between the associated darker stibiconite and those more nearly anhydrous oxides that immediately border the vein. Possibly it may be crystalline, though generally amorphous, as a few similarly colored crystals have been observed microscopically in narrow veins.

Quartz is found here and there in the replacement veinlets, where it is apparently contemporaneous with valentinite and the black mineral, and in the coating of the nodules. It is nowhere of the same age as the native metal.

The general relations of these various compounds of antimony demonstrate that the pure metal has altered peripherally and along fissures, probably partially through the action of oxygenated waters, to valentinite and a distinct mineral of generally similar chemical composition but black in color and differing in microchemical reactions. This alteration has been slow enough to permit the formation of replacement and fissure veinlets of the same minerals, especially of valentinite, by circulating solutions. Subsequently valentinite and the black mineral have been replaced (altered) by another mineral and its intermediate, which are presumably more hydrated exides of antimony,—possibly stibiconite and "white antimony ocher." This last replacement and fissure filling are recorded by the veinlets of megascopically translucent, microscopically gray mineral. Of the origin of the native antimony itself, unfortunately no clue is afforded.

University of Chicago,
September 13, 1921.

ART. XXVII.—*A New Merycoidodon;* by MALCOLM RUTHERFORD THORPE.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

INTRODUCTION.

It is clearly apparent that the generic name *Merycoidodon* has priority over those of *Oreodon* and *Cotylops*, as previously pointed out by Gilmore and Hay. Yet Leidy preferred the name *Oreodon*, and this has been used by nearly all subsequent writers. When so great a group has been universally designated by a certain name for seventy years, and when this name is not a misnomer with regard to classification, it seems that its retention would be desirable, especially as both *Oreodon* and *Merycoidodon* were proposed by the same author.

Merycoidodon culbertsonii (1848), *Oreodon priscus* (1851), *O. robustus* (1851), and *Cotylops speciosa* (1851) are considered synonymous. The type of *Merycoidodon* possessed partly deciduous and partly permanent teeth; that of *Oreodon* had all permanent dentition; while the *Cotylops* type had all deciduous. *O. priscus* and *O. robustus* are the same.

This genus embraces five species and one subspecies, as now defined. They are all well marked and, with one exception, limited to the Middle Oligocene, the exception being *M. affinis* from the Lower Oligocene (Chadron). The majority of these forms have been well described and repetition will be avoided as much as possible in this paper. There are, however, a few factors which it is interesting to bring out.

Merycoidodon culbertsonii culbertsonii was exceedingly numerous, and must have roamed in droves. Of this one species alone, there are represented at least 400 individuals in the Marsh Collection in this Museum. This is, moreover, a very conservative estimate, as there are skulls and parts of skulls and jaws of some 340 individuals, together with a large quantity of skeletal parts belonging to these and many more of the same form.

This species was studied to some extent from a quantitative standpoint, and the determination of the relative age of the individuals at death is given below. The computations were made on a decimal basis of 0 to 10, as in the species of the genus *Eporeodon* of the John Day basin, Oregon. The same method of procedure was followed: 0-3, deciduous dentition; 4-6, average medium age with 5 considered as mid-life and fully adult; 7-8, those with the tooth pattern of the triturating surface of M^1 obliterated and that of M^2 much worn; and 8-10, those having the tooth pattern of all the true molars very much worn or completely obliterated. Of 210 individuals, 44, or 20.9 per cent, died between 1 and 3; 138, or 65.7 per cent, between 4 and 6; 21 or 10 per cent, between 7 and 8; and 7, or 3.3 per cent, between 8 and 10. This summary for *M. culbertsonii* is typical, in the main, for the other species, although they are not represented by so many individuals, and therefore the data derived from them are not so reliable.

In comparison with the figures resulting from a similar study of the John Day Eporeodons, we find a remarkable agreement in the percentage of those that died between 4 and 6, both groups showing 65 per cent. In the other age classes, the figures would seem to indicate that the infant mortality in the White River area was greater than in the John Day basin where it was seen to be 13.2 per cent, and that more individuals reached an older age in that basin, the classes showing 12.2 per cent for post-mature and 8.8 per cent for extreme old age.

These two groups are widely separated in time and geographic locality, and undoubtedly their environmental conditions were considerably different.

DESCRIPTION OF SPECIES.

Merycoidodon culbertsonii culbertsonii (Leidy) 1848.

Specimens of this form were collected in Colorado, South Dakota, Wyoming, and Nebraska, fully 50 per cent or more being obtained in the latter state. Nearly all parts of the skeleton are fully represented in the Yale collection, as well as several very excellent endocranial and endofacial casts.

A few specimens show peculiarities worthy of note. Cat. No. 12477, Y. P. M., from Scott's Bluff, Nebraska, consists of both rami, showing each P_4 placed obliquely forward, and the premolar series are unusually short.

These rami were collected by H. B. Sargent, former Yale Corporation member, on the Yale College Scientific Expedition of 1870; another specimen, Cat. No. 12586, Y. P. M., collected by Sargent at Gerry's ranch, Colorado, is a very robust individual with an unusually great bizygomatic diameter. It would seem to represent the male, but sex dimorphism is almost impossible to determine in this genus. Cat. No. 12471/2, Y. P. M., from Nebraska, shows a quite large style developed from the cingulum between the protocone and hypocone of both M^3; Cat. No. 12094, Y. P. M., is a skull with a well developed single-rooted accessory premolar between C and P^1 on both sides. The muzzle is elongated and both P^2 are set obliquely. This extra premolar is probably comparable to that found occasionally in the long-muzzled species of *Canis*. There is a certain degree of variation in the depth but not in the extent of the lacrymal fossa, which may be due to sex, those skulls having the more shallow fossa possibly being the females. The length of the superior molar-premolar series varies from 80 to 90 mm.; the molar series ranges from 45 to 50 mm., and the premolar from 37 to 42 mm.

Another specimen, Cat. No. 12101, Y. P. M., from the Middle Oligocene of White River, Nebraska, appears to be intermediate between *M. culbertsonii* and *Eporeodon hybridus* in its proportions. The cranium is broken away so that the presence or absence of the bullæ can not be determined. The muzzle is quite wide beneath the orbits and the infra-orbital foramen is above the middle of P^3. The length of the molar series is 49 mm., that of the premolars 45 mm., while the width beneath the orbits is 101 mm.

The Yale Expedition of 1914 collected several bones, including the skull and jaws, of an individual of this species (Cat. No. 12238, Y. P. M.), on the Warbonnet ranch, 12 miles north of Harrison, Nebraska. The enveloping matrix as typical Middle Oligocene. The various elements are normal, except possibly the pes, which is very excellently preserved and articulated. On the ventral surface of this, close to metatarsal II, was found in the matrix a small elongate bone which apparently represents the hallux. This bone is 17.5 mm. long, although the proximal end is somewhat damaged. The upper half of the inner side bears a distinct articular facet while the distal half of the bone is laterally compressed, ending in a blunt point. There is no indication of any phalanges accompanying this first metatarsal, if such it is, and the evidence certainly bears out the belief that it is the vestige of the hallux, present in the earliest forms of the Merycoidodontidæ, such as *Protoreodon*, but not previously noted as occurring in the Oligocene forms.

Specimen No. 12754, Y. P. M., consists of a skull and jaws from the upper nodular layer of the Middle Oligocene of South Dakota. It resembles *M. culbertsonii* in all essential respects, although it is considerably larger than the type. In fact, it probably represents a form intermediate, both structurally and stratigraphically, between *M. culbertsonii* and *Eporeodon major.* The bullæ are small and the lacrymal fossæ deep.

Measurements (Cat. No. 12754, Y. P. M.).	mm.
Total length, partly estimated	217
Postorbital constriction, diameter	29
Brain-case, maximum diameter	55
Superior molars, length	52
Superior premolars, length	46
Inferior molars, length	54.5
Inferior premolars, length	47.5

Merycoidodon culbertsonii periculorum (Cope) 1884.

This Middle Oligocene subspecies is represented by over fifty individuals in the collection, mainly from Colorado but a few from Nebraska and Wyoming. It differs but slightly from *M. culbertsonii* except in its smaller size. The length of the superior molar-premolar series varies from 72 to 77 mm.; the molar, from 40 to 42 mm.; and the premolar series has a length of 33 mm. The inferior molar-premolar length is 73 mm., with a molar length of 47 mm. The above measurements were derived from a considerable number of specimens. Cat. No. 12605, Y. P. M., has a bizygomatic diameter of 89 mm., a maximum brain-case diameter of 44 mm., and a postorbital constriction diameter of 30 mm.

The age classes, based on forty specimens, are as follows: 0-3, 6 individuals, or 15 per cent; 4-6, 26, or 65 per cent; 7-8, 6, or 15 per cent; and 8-10, 2, or 5 per cent.

Merycoidodon macrorhinus (Douglass) 1902.

M. macrorhinus is apparently not represented in this collection. It is a Middle Oligocene form from the nodular layer in Montana, collected near the Missouri River, southeast of Helena, and the holotype is Carnegie Museum Cat. No. 767. In nearly all respects it is close to *M. culbertsonii*, except that the face is one third higher above P^1 and the bone throughout is heavier. It may represent a male, showing an example of a considerable degree of dimorphism, but as I have not seen any comparable forms in the White River deposits, nor any examples of marked sex dimorphism in this group, it seems that the species is valid. The length of the superior molar series is 45 mm. and the length of the superior premolar series is the same.

Merycoidodon gracilis (Leidy) 1851.

This Middle Oligocene form has more than sixty representatives in the Marsh Collection from Colorado, Nebraska, Wyoming, and South Dakota. There seems to be such close resemblance between this species and *M. coloradoensis* (Cope) that they should be considered synonymous. The main distinctions of the latter were stated to be a little larger size, about 5 mm. longer in total length, and a different geographic locality, Colorado, to which Cope considered the species confined.

Another species is mentioned by Cope, and defined as follows (1888, p. 1094): "During the White River epoch droves of *Oreodon culbertsonii* inhabited the swamps, and the small *O. minor* was abundant. Several forms, perhaps species, coexisted with these two." Since this form is defined only to the extent of being smaller than *M. culbertsonii,* it is my opinion that *O. minor* should be considered a nomen nudum.

The amount of variation within this species seems not to be sufficient for subdivision into varieties. The young forms with deciduous dentition are usually more dolichocephalic and the posterior nasal bones are somewhat more acute than in the adult. There are likewise variations in the adult forms, but after a careful study of the specimens in this Museum, I am led to the conclusion that these differences are not greater than we should expect to find, due to sexual, individual, and local variations of minor importance.

Using a considerable series of specimens, it was found that the length of the superior dental series ranged from 57 to 60 mm.; that of the molars, from 33 to 37 mm.; and of the premolars, from 27 to 30 mm.

On a basis of thirty-four individuals, the age classes show: 1-3, 10 individuals, or 29 per cent; 4-6, 17, or 50 per cent; 7-8, 4, or 11.7 per cent; and 8-10, 3, or 8.8 per cent. This series does not represent as great a number of individuals as might be desired, but it shows a variation in the first two classes, while the latter two are more nearly normal.

Merycoidodon affinis (Leidy) 1869.

The genus *Merycoidodon* is characterized mainly by dolichocephalic forms, but *M. affinis* is mesaticephalic. The muzzle is short and the diameter across the frontals at the orbits is as great as in *M. culbertsonii.* The total length is but slightly greater than that of a robust *M. gracilis.* The length of the superior dental series averages 67.5 mm.; that of the molars, 38 mm.; and of the premolars, 32 mm.

There are some twenty or more skulls and parts of skulls here, together with much skeletal material, collected in Colorado and Nebraska. *M. affinis* differs from the other species of the genus in that it is Lower Oligocene (Chadron) in age.

Merycoidodon platycephalus, sp. nov.

(Figs. 1, 2.)

Holotype, Cat. No. 12752, Y. P. M. Middle Oligocene (lower Brule), near Scott's Bluff, Nebraska. Skull and some skeletal parts.

Distinctive characters.—Very low, wide cranium; long sagittal crest; nuchal crests wide apart and having less overhang than in other species of this genus; posterior part of nasal bones obtuse; infra-orbital foramen above interval between P^3 and P^4; lacrymal fossa small and shallow; orbits look forward and outward only, and their outline is quite different from that of any other species in the genus (see fig. 1); orbital opening smaller than in *M. gracilis*; supra-orbital groove a well defined depression leading forward from the supra-orbital foramen, and extending ventro-laterally to the infra-orbital foramen (this is probably a variable character); malar below orbit as robust as in *M. culbertsonii;* sagittal crest and postorbital processes of frontals very rugose.

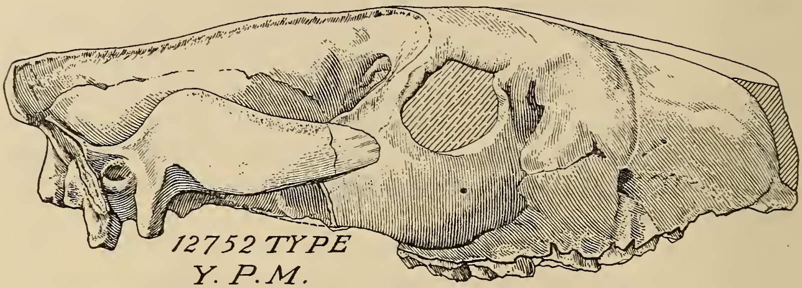

FIG. 1.—*Merycoidodon platycephalus,* sp. nov. Holotype. Lateral view of skull. × 2/3. Drawings by Rudolf Weber.

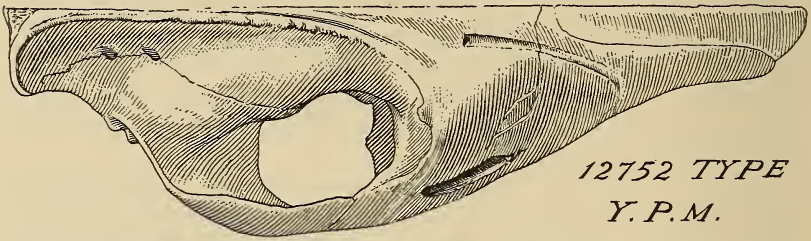

FIG. 2.—*Merycoidodon platycephalus,* sp. nov. Holotype. One half superior view of skull. × 2/3.

The skull is fully adult and not crushed, although the teeth are damaged. The distal end of the radius shows that the facets for the scaphoid and lunar bones were separated by a space of a little over 1 mm., which is an unusually large interval in this genus.

Measurements of Holotype.

	mm.
Total length	155
Maximum diameter of brain-case	46
Diameter of postorbital constriction	30.3
Bizygomatic diameter	89.5
Superior dental series, with C, length	75.2
Superior molar series	36
Superior premolar series	33.7

SYNOPSIS OF SPECIES.

1. Posterior part of nasal bones acute.

Infra-orbital foramen above interval between P^2 and P^3; frontals produced considerably forward of lacrymal bone; orbits nearly circular; short sagittal crest; length 190-210 mm. ....*M. culbertsonii culbertsonii*

Infra-orbital foramen above extreme posterior part of P^3; frontals produced a little forward of lacrymal bone; short sagittal crest; length, 150-160 mm. *M. culbertsonii periculorum*

Infra-orbital foramen above posterior part of P^3; same as *M. culbertsonii culbertsonii* in general, except much more robust and face one-third higher above P^1; length, 192 mm..............................*M. macrorhinus*

2. Posterior part of nasal bones obtuse.

Infra-orbital foramen above interval between P^2 and P^3; frontals produced only slightly forward of lacrymal bone; short sagittal crest; length, 123-133 mm. *M. gracilis*

Infra-orbital foramen above middle of P^3; frontals produced slightly farther forward of lacrymal bone than in above; long sagittal crest; much greater breadth at posterior margin of orbits than in *M. gracilis;* length, 136 mm....................................*M. affinis*

Infra-orbital foramen above interval between P^3 and P^4; frontal and lacrymal bones coëxtensive forward; long sagittal crest; length, 155 mm..*M. platycephalus,* sp. nov.

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Art. XXVIII.—*The History of Corals and the "Limeless" Oceans;* by Percy E. Raymond.

One swallow may not make a summer, but in the realms of Paleontology one discovery may let a flood of light into provinces previously most obscure. Perhaps the most remarkable single "find" which ever rewarded the fossil hunter was that made by Dr. Walcott at Burgess Pass, British Columbia. No such aggregation of soft-bodied animals had ever been seen in the rocks before, not even at Solenhofen. The fossils are so unusual, and so different in their preservation from those usually studied, that even now, ten years after the first of them was described, their significance is not fully appreciated.

Among these fossils there is one which has given rise to certain suggestions which I wish to bring forward, as to a possible interpretation of the somewhat obscure history of the corals.

Mackenzia costalis Walcott[1] (fig. 3) was described as a holothurian, but H. L. Clark[2] in a review of the original paper, and after a study of the specimens, considered it an Actinian, in which determination Austin H. Clark has concurred.[3] An extract from the article by the latter may be quoted:

> "The type specimen of *Mackenzia costalis* shows a pleated structure which can only be interpreted as due to longitudinal mesenteries, probably eight in number; there appear to have been sixteen processes around the mouth, which probably indicate sixteen tentacles retracted before preservation; the distal portion of the body resembles closely the distal portion of the body in the genus Edwardsia. Thus, as *Mackenzia costalis* presents characters not found outside of the Zoantharia, and in that group peculiar to the family Edwardsiidæ, it seems necessary to assign it to a position in the family Edwardsiidæ, near the genus Edwardsia." (loc. cit. p. 507.)

This determination of the fossil is of peculiar interest, since the Edwardsiidæ are considered the most primitive of the Zoantharia, and in their ontogeny, modern Hexacoralla pass through an Edwardsia stage. There is, fur-

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[1] Smithson. Miscl. Colls., vol. 57, p. 55, pl. 13, figs. 2, 3, 1911.
[2] Science, vol. 35, p. 275, Feb. 16, 1912.
[3] Am. Naturalist, vol. 47, p. 503, 1913.

thermore, a possibility that Mackenzia is even more primitive than is suggested by Dr. Clark. Although his interpretation of the ring about the mouth as a series of contracted tentacles is a very probable one, still their small size suggests that they are simple "out-pushings," and that the actinian of the Middle Cambrian retained in the adult a structure like that of the larva of the modern actinian just before fixation (fig. 2). If further discoveries sustain this opinion, then Mackenzia can be added to the list of "ancestors" whose recognition has been brought about by the aid of the doctrine of "recapitulation."

Figs. 1-3.

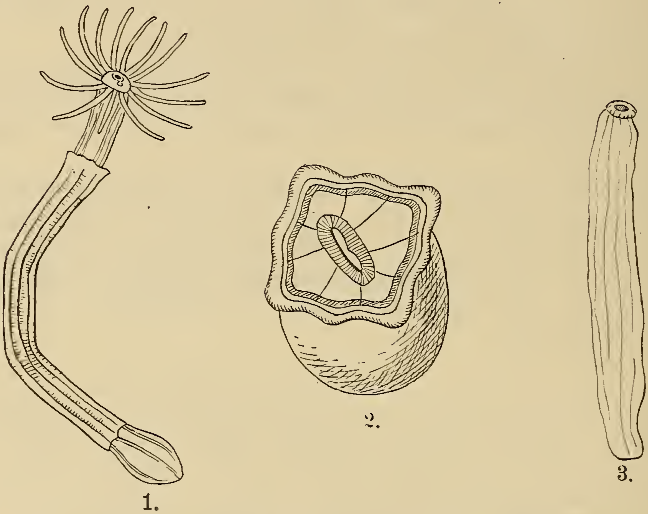

Fig. 1. *Edwardsia beautempsi.* After de Quatrefages. Two-thirds natural size.

Fig. 2. *Urticina crassicornis.* Larva just before fixation. After Appelöf. Much enlarged.

Fig. 3. *Mackensia costalis.* Somewhat restored. After Walcott. Two-thirds natural size.

The chief interest in Mackenzia lies, however, in the fact that it is a limeless Zoantharian which can be placed in a primitive position in relation to modern corals. Hexacoralla pass through a Mackenzia-Edwardsia stage, and it is very probable that the Tetracoralla did also.

One of the puzzles in the history of the corals has been the abrupt replacement of the Tetracoralla by the Hexacoralla in the early Mesozoic. No one of the former survived the Paleozoic; none of the latter is represented by a calcareous fossil in that system, Robinson having shown that the supposed Paleozoic hexacorals really do not belong to that group.[4] What caused the extinction of the Tetracoralla, and whence did the Hexacoralla come? Arguments that the latter were derived from the former have been put forward repeatedly, but do not seem convincing. That they had a common ancestry seems practically demonstrated by studies in ontogeny.

It seems possible that the answer to these questions may be connected with physical changes at the end of the Paleozoic. The waters of the oceans were doubtless greatly chilled at the time of the Permian glaciation, and this may have caused the killing of the Tetracoralla. That these animals had, like modern reef-building corals, become adapted to life in warm seas is shown by the fact that they are almost confined to limestone, and that practically all are of reef-building or reef-inhabiting nature. Even the simple unbranched corals are found in great numbers when found at all, and there is every indication that before the end of the Paleozoic they had become fully adapted to life in clear, shallow, warm waters. Many tribes did not, of course, survive even to the end of the Paleozoic, and in eastern North America perished during the uplift which followed the deposition of the Middle Devonian limestones.

Tetracoralla appear first in the Middle Ordovician, and although the earliest representatives now known are simple, it is very probable that further collecting will reveal them in the Lower Ordovician and perhaps in somewhat older formations. Mackenzia is a form which could have been ancestral to either of the groups mentioned and it is possible that they diverged as early as the Upper Cambian. Edwardsia, with which Mackenzia is comparable, is today an inhabitant of the sand, and does not secrete a skeleton. Members of the family occur in shallow, cool waters about the British Isles. It might seem that Mackenzia and its descendants remained, during the Paleozoic, in the cooler waters along sandy and rocky shores, and living thus in places where calcium carbonate remains readily in solution, they did not get the lime

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[4] Trans. Conn. Acad. Arts and Sci., vol. 21, p. 145, 1917.

habit. Being accustomed to cool water they survived the Permian glaciation, but due to geographic and climatic changes, were perhaps driven from their original homes, and, the temperature of ocean waters being universally lowered, attained a wide distribution. They found the geographical and ecological positions of the Tetracoralla uninhabited, and so began to thrive and to change.

Writers have repeatedly commented on the fact that corals are exceedingly rare in the older Triassic deposits, and reefs of Hexacoralla first appear after the middle of Triassic time. It may be inferred from this that the oceanic temperatures did not become favorable for corals for some time after the melting of the Permian ice, and by this time the limeless corals had become established in many regions previously unoccupied by them. With the warming of the waters there came a surplus of calcium, and the animals no longer being able to fully eliminate it, began to build skeletons. By this time the larval form had been sufficiently changed so that septa were deposited in cycles of six instead of four, and a new era in the history of corals was inaugurated.

It does not appear that the question of temperature, and inferentially of climate, has been given sufficient attention in connection with the discussion of the origin of the "lime habit" in animals. The first great development of calcareous skeletons was in the Ordovician, and was coincident with the first appearance of great masses of non-clastic limestone, and with the first relatively complete world-wide peneplanation. The almost universal Pre-Cambrian mountain building indicates that the Cambrian sedimentation began with differentiated but probably cool climates, and while small deposits of limestone formed during the Lower Cambrian testify to local, warm basins, the universal rise in temperature came later.

A second factor connected with the secretion of calcareous skeletons is that of the habits of the animal, whether active or sedentary. Although there are exceptions to the rule, active animals usually have less thick shells or bones, not because they have less need for them, but probably because they eliminate lime more readily. If one surveys the Cambrian fauna, he finds there few sedentary animals. Those which are present are sponges, a few cystids, some protrematous and a few atrematous brachiopods, and the anomalous Archaeocyathinæ. The sponges are all of the siliceous types, and only the Archaeocyathinæ secrete calcium carbonate in any quantity; they are also, aside from the sponges, the only animals which are firmly fixed in one spot. Reproduction by budding in colonial fashion was also in its infancy in Cambrian times, showing incidentally that the sexual preceded the asexual method, and this indicates clearly that animals had but recently "discovered the ocean bottom." Colonial life really developed first in Ordovician times, when sedentary animals like the Hydrozoa, Bryozoa and Anthozoa first became abundant.

Throughout geological history the times of great expanse of shallow, warm seas have been the times of great development of animals with thick shells. Once the lime-secreting habit had been acquired, animals persisted in it. The chief factors in its origin, however, would appear to be excess of salts, due to warming of the waters, and decrease in power of elimination, due to sedentary habits.

Museum of Comparative Zoology,
Cambridge, Mass.

SCIENTIFIC INTELLIGENCE

I. Chemistry and Physics.

1. *A Rapid Process for the Determination of Phosphoric Acid.*—H. Copeau has described a new method for this determination which deserves notice on account of its unusual features, and because it is very simple and rapid in its execution. It is based upon the fact that when phosphoric acid in the presence of another acid, such as sulphuric, is shaken with ether and an alkaline molybdate phosphomolybdic acid is formed which combines with ether and water to form a dense yellow liquid which is immiscible with the mother liquor. When equilibrium is established there are three liquid phases, an excess of ether, an aqueous solution and the yellow phosphomolybdic acid liquid. A reaction of this kind was first observed by Marignac in connection with silicotungstic acid, while the phosphomolybdic reaction was employed by Drechsel in 1887 in connection with the preparation of complex acids, but not for analytical purposes.

The yellow liquid was found to be practically constant in composition and to contain 1.73 percent of P_2O_5, with about 44 percent of phosphomolybdic acid, the 1:24 compound, 33 percent of ether and 22 of water, and its specific gravity was found to be 1.23. With as little as 1 mg. of phosphoric acid a distinct globule of the yellow liquid was obtained amounting to about $\frac{1}{20}$ cc. Reference to the original article must be made for the full details in regard to the reagents and the method, but it may be stated that the process is carried out in special flasks of about 60 cc. capacity which are provided with slender, graduated prolongations at the bottom for measuring the yellow liquid, and that the latter is collected by whirling the flasks in a centrifuge.

It was found that after the solution of phosphate was ready the time required for a determination was only about 15 minutes. A few test analyses were made showing excellent results. The only interfering substance mentioned is citric acid.—*Comptes Rendus,* **175**, 656 (1921). H. L. W.

2. *The Existence of Tetrahydrated Sodium Sulphate in Mix-Crystals with Sodium Chromate.*—Theodore W. Richards and W. Buell Meldrum have shown that in addition to the well-known isomorphic crystalization of $Na_2SO_4.10H_2O$ and $Na_2CrO_4.10H_2O$ in all or almost all proportions, the tetrahydrate of sodium chromate is also capable of isomorphously dissolving sodium sulphate, in spite of the fact that $Na_2SO_4.4H_2O$ does not exist by itself.

This induced crystallization of one salt by another in an otherwise non-existing form is well known in several other cases; as, for instance, $CaSO_4.7H_2O$, otherwise unknown, with $FeSO_4.7H_2O$.

The authors have examined a considerable number of crops of the mixed crystals, and by the determinations of water and of sodium sulphate in the carefully prepared and dried substances have shown beyond doubt that the sodium sulphate is in the form of the tetrahydrate. They have found, further, that the amount of sodium sulphate in the crystals is somewhat less than one-half of the quantity corresponding to the same weight of sodium chromate in the mother liquor.—*Jour. Amer. Chem. Soc.*, **43**, 1543.
H. L. W.

3. *A Text-book of Organic Chemistry;* by JOSEPH SCUDDER CHAMBERLAIN. 8vo, pp. 959. Philadelphia, 1921 (P. Blakiston's Son & Co. Price, $4.00 net).—In the preparation of this book the author has endeavored to make it sufficiently elementary for the purpose of a first course in the subject and at the same time to make it comprehensive by taking up practically all the important groups of compounds, and presenting an unusually large number of them.

A striking feature of the book is the clear and excellent discussion of the structures of organic compounds in connection with their syntheses and other reactions. The very numerous developed formulas and equations of reactions are very satisfactorily given.

The book appears to be a very good one for a first course and also for more advanced students. On account of its large scope it may appear somewhat formidable to the beginner, but the magnitude and complexity of the subject seem to warrant the avoidance of texts that are too much abbreviated and simplified.
H. L. W.

4. *Quantitative Chemical Analysis;* by HENRY P. TALBOT. 8vo, pp. 203. New York, 1921 (The Macmillan Company).—This is the sixth edition, completely rewritten, of a book which presents a well-selected course of laboratory work for students. The directions given are very clear and satisfactory, while the numerous explanatory notes are excellent.

Contrary to the usual custom the volumetric course in this edition precedes the gravimetric one, because the author has found by experience that this order of work appears to furnish the better approach to the subject. More than 100 well chosen and instructive problems with answers, make a valuable feature of the book.

In connection with weighing the author says, "The correct weight is that which causes the pointer to swing an equal number of divisions to the right and left of the zero-point, when the pointer traverses not less than five divisions on either side." The long swing thus recommended deserves strong adverse criticism, for although fairly good weighing can perhaps be done in this way in spite of the appreciable retardation of each single swing of such length, it is undoubtedly much easier and quicker as well as more accurate to employ short swings of from about ¼ to one or two divisions on each side of the center, such as the balance gives very easily. H. L. W.

5. *Volumetric Analysis for Students of Pharmaceutical and General Chemistry;* by CHARLES H. HAMPSHIRE. 12mo, pp. 124. Philadelphia, 1921 (P. Blakiston's Son & Co. Price, $1.45 net).—This little book, which is of British origin, now appears in a third edition. It presents a very good general introductory course including the principal standard methods. The exercises for practice are numerous, systematically arranged and clearly presented. More than a single method is frequently applied for a determination; for instance, three methods are given for finding the strength of bleaching-powder. Sections of the book in small type give a large number of determinations based on the requirements of the British Pharmacopœia. H. L. W.

6. *Étalon Interferometer.*—The homogeneity and reproducibility of the lines in the spectra of argon, krypton, and xenon make them useful as secondary standards of wave lengths. Scientific Paper 414 of the Bureau of Standards contains the most recent measurement of the stronger lines of these spectra which are probably correct to one part in several million. The elegance and precision of the interferometer methods for wave length comparisons are demonstrated by the close agreement between values obtained by different observers and also by the constant frequency differences of many of the lines belonging to combination series.

This publication is now ready for distribution by the Department of Commerce as is also the table of contents to Vol. 16 of the above mentioned series of papers. F. E. B.

7. *The Wehnelt Interrupter.*—The form of electrolytic interrupter using sulphuric acid as described by Wehnelt is subject to several faults which seriously impair its operation as a current break for an induction coil. The liquid often reaches the boiling point when the current ceases entirely. The platinum wire slowly disintegrates when used as anode and is likely to melt when it functions as cathode. Also the fumes and spraying of the acid are very objectionable.

A new form devised by F. H. NEWMAN gives much more satisfactory results. For the electrolyte he uses ammonium phosphate in an aluminum vessel which serves as cathode. The anode as usual is a platinum rod which may be protruded from a porcelain sheath. On account of the lower current density the cumulative heating does not reach a point where it stops the operation of the break. The latter functions steadily even at 90° C. The current passes practically only in one direction so that the apparatus may be introduced into an alternating current circuit.

An intimate knowledge of the characteristics of the interrupter was obtained by taking simultaneous observations on the current and the potential difference by the aid of a Duddell oscillograph and a falling plate camera. With a direct primary current the peak value of the potential difference at the platinum point was about six times the mean applied potential difference and the time of the break was small compared to the make. With higher frequencies not all the current was interrupted but there were no oscillations so that the secondary current was unidirectional.

With an alternating primary current, and the interrupter alone in the circuit, the negative half of the wave was suppressed. When the primary of an induction coil is introduced the frequency of interruption is much greater and only a fraction of the current is interrupted. When a current passes through the secondary spark gap the peak value of this current is great but it is unidirectional. Similar observations on the old form of the Wehnelt interrupter containing acid showed that the secondary current there was oscillatory.

A photograph of the curve of a secondary current through an X-ray bulb when operated with the new form of interrupter shows a very brief current rising to 180 milliamperes, where the mean value was only 5 milliamperes, which for ordinary uses gives a satisfactory performance.—*Proc. Roy. Soc.* **99**, 324, 1921.

F. E. B.

8. *Within the Atom;* by JOHN MILLS. Pp. XIII, 215. New York, 1921 (D. Van Nostrand Company).—The purpose of the author is to present to the lay reader our knowledge and current theories concerning the structure of matter and the phenomena of electricity. As he is himself a trained scientist and has been both a college teacher and a research physicist, he speaks, if not with authority, with a comprehension not possessed by the mere popularizer of scientific knowledge.

The standpoint chosen by the writer is a little unusual as he neither presumes any previous knowledge of electricity, mechanics, or chemistry, nor does he devote any space to the exposition of science in the conventional, i. e., the text-book manner. He is even so careful lest he make the book look mathematical and thus inhibit the general reader that all use of formulas is avoided. The usual historical order of discovery is reversed and all phenomena are explained from the two postulates of the electron, or negative particle of electricity, and the proton, or positive particle, together with the fundamental concepts of time, space and energy. The question for which an answer is sought is rather "the how" than "the how much." Terms with animistic connotation are freely used where they help us to clearer thinking, though it is hard to see how "satisfaction in configuration" is any better than "stability of equilibrium" or that the uninstructed reader would react more placidly to "pellate" and "tractate" than he would to "repel" and "attract." However the tenderness of the author to the reader's prejudices is happily shown by the inclusion, at the end, of a glossary of most of the terms which connote scientific ideas or exact definitions.

Coming to the contents of the book the success of the author's presentation is most commendable. The four chapters devoted to atomic structure give an excellent idea of how the modern theories account for both chemically active and inert atoms, the periodic system, and atomic weights. The discussion passes then to radioactive disintegration, conduction of electricity through gases, conduction through solids and liquids, electromagnetic induction and electrodynamics. A chapter for each is devoted to the proof for the existence of the electron, to the isolation of the proton, and to X-rays and atomic numbers.

The author now introduces a *jeu d'esprit* in the form of a dialogue between the dramatis personae of the book, to wit, the proton, the electron, the author, the scientific reader, the general reader, and the voice of energy, the purpose of which appears to be to prepare the peruser of the book for a serious discussion of further phenomena. The next chapter is given to photoelectricity, then one to light radiation, one to the quantum hypothesis and the last to energy and its availability. An illuminating discussion of the numerical magnitudes of electrons and some other quantities is reserved for an appendix.

The author's style is clear and the material highly informing. Indeed one can hardly read the book through without being profoundly impressed by the things that have been revealed in our microcosmic world during the past twenty years. It is a book that may be commended to the attention of anyone who reads this notice. F. E. B.

9. *Mathematics for Students of Agriculture;* by SAMUEL EUGENE RASOR. Pp. VIII, 290. New York, 1921 (The Macmillan Company).—The present volume is a reflection of the fact that students choosing agricultural courses in technical schools and colleges have not had sufficient or proper preparation in mathematics for successful completion of their work. The book may be described as an abridged hand book treating of drawing, arithmetic, algebra, geometry, trigonometry, surveying, and simple machines, with the materials so selected that they may function with the student's special interest and point of view. The various topics are illustrated by special examples and a great supply of problems for the student's exercise. The book should prove of value to teachers in agricultural colleges and also to students who have but limited opportunity for mathematical instruction. F. E. B.

II. GEOLOGY.

1. *The Rift Valleys and Geology of East Africa;* by J. W. GREGORY. An account of the origin and history of the rift valleys of East Africa and their relation to the contemporary earth-movements which transformed the geography of the world. Pp. 479, 20 pls., 44 diagrams, 5 maps. London (Seeley, Service & Co., Ltd.), 1921.—The author first became acquainted with the geology of British East Africa in 1892-3, and published his conclusions in a work entitled "The Great Rift Valley" (1896). In 1919 he returned to the region, and after a study of about five hundred papers and books on the geography and geology of the Great Rift Valley, now presents this interesting book. The Great Rift Valley extends more than one sixth the circumference of the earth, "from Lebanon to the Sabi River, with branches eastward to the Gulf of Aden and possibly to the Pangani Valley, and westward to Tanganyika, the Upper Nile and the rift valleys of Lakes Moero and Upemba in the Central Congo" (p. 359). The rifts are long and narrow sunken blocks between parallel faults. In Palestine the downthrow is as much as 5,000 feet. The Red Sea lies in a rift formed by repeated faulting, having a total downthrow of 11,000 feet. Lake Tanganyika also lies in a rift, its waters having a depth of 4,190 feet, and its floor being 1,664 feet below sea-level. These fault-formed valleys are continuous from Palestine to south of the Zambezi, except for 80 miles in southern German East Africa. The rifting "has broken through an especially stable part of the earth's crust, which consisted of a pre-Paleozoic mountain chain that extended from Asia Minor to Natal."

It is commonly held that this rifting took place during Pleistocene time, but it is evident that Gregory is much nearer the truth in his conclusion that these valleys "had a long and broken history." In fact, their geologic history dates from the Oligocene to modern times, with an earlier preparatory stage in the Upper Cretaceous. The author says that the first stage was the formation, with much outpouring of lava, "of a long, low arch with the axis trending N. and S. . . . . The second stage in the formation of the Rift Valley was the rupture of the sides of the arch as the lateral supports gave way. The top sank as the keystone of a bridge sinks if its buttresses slip or settle. The sinking of the keystone of the East African arch into the plastic layer below forced some of it up the adjacent cracks, through which the material was discharged in volcanic eruptions. Each renewal of the subsidence was followed by fresh eruptions" (pp. 361-2).

"The geographical features in Eastern Africa are arranged along three main directions—E. to W., N. to S., and diagonally,

N. W. to S. W. and N. E. to S. W. Of these series the earliest, the E.-W., features were caused by the buckling of the earth's crust in Mesozoic times. The diagonal series are the peripheral fractures around the sinking Indian Ocean between the end of the Cretaceous and the Oligocene. The last series, the N.-S. fractures, . . . were results of the world-wide mountain-forming disturbances which culminated in the Miocene, but lasted from the Oligocene to the Pliocene'' (p. 375).

''Africa, as a whole, remained throughout the Kainozoic Era as a raised and, judging from its river system, as a still rising plateau. But, since the crust on both sides sank during the formation of the Indian and South Atlantic Oceans, Africa was left unsupported laterally. Instead of its main highland axis being laterally compressed like the coastlands of the Pacific, Africa was in tension and torn by N. and S. fractures, along which the sinking of a strip of the crust formed the longest meridional land valley on earth. The Great Rift Valley is, therefore, due to a long series of earth-movements which began in the Cretaceous, and to faults formed at intervals between the Oligocene and the Pliocene. It owes its unique character to its position antipodal to the Pacific, and its course to the wrench in the crust of the Eastern Hemisphere between the segment pressing northward against Europe and that pressing southward in Asia toward the deepening basin of the Indian Ocean'' (pp. 378-9).

C. S.

2. *The Fish Fauna of the California Tertiary;* by DAVID STARR JORDAN. Stanford Univ. Pub., Biological Sciences, vol. 1, No. 4, pp. 235-300, 57 pls., 1921.—Chancellor Emeritus JORDAN in this memoir makes ''old bones live again'' through restorations in the flesh of nearly all the bony fishes, predatory or otherwise, known from the California Tertiary. The restorations, which are the work of W. S. Atkinson, are the first presented of American Tertiary fishes. The work treats of seventy-eight species, of which fifty-seven are pictured in the flesh; most of them are from the Middle Miocene.

The present fish fauna of California ''is derived from that of the Miocene period with a certain admixture from the north and from Japan. . . . . The Miocene temperature differed little from that which obtains at present . . . . The climate was arid.''

In the same diatom deposits which have so many fishes there are almost no other kinds of fossils except an occasional radiolarian and sponge spicules. Albert Mann reports provisionally on the diatoms, listing about fifty species at each of two horizons, while the great Lompoc zone has yielded far over a hundred species, and these ''appear to be only a small fraction of the diatom wealth'' of this zone. C. S.

3. *The Jurassic Ammonite Fauna of Cuba;* by MARJORIE

O'Connell. Bull. Amer. Mus. Nat. Hist., vol. **42**, pp. 643-692, pls. 34-38, 8 text figs., 1920.—In this paper are described at great length seven forms of ammonites (four are new) of the genera *Perisphinctes, Ochetoceras,* and *Ataxioceras,* from the Upper Oxfordian of western Cuba. C. S.

4. *A Text-book of Geology;* by Amadeus W. Grabau. Part I, General Geology, pp. 864, text figs. 1-734; Part II, Historical Geology, pp. 976, text figs. 735-1980. Boston (D. C. Heath & Co.), 1921.—This is a large two-volume work of 1840 pages, over 90 of which are in the two indexes. It is not provincial either in spirit or in scope, but is probably too comprehensive for undergraduates in geology; all geologists and postgraduate students in this science will, however, want to use the book. The text is often discursive, but reads easily, and, as is to be expected of the author, bristles with unusual terms and with original interpretations. It is loaded with illustrations, many of them original, but the majority taken directly from many sources and done in all styles of reproduction, with the consequence that the appearance of the volumes is not as good as might be desired. It is unfortunate that the pagination does not run continuously through the two volumes, as do the chapter numbers and the figures.

The subject matter of the twenty-three chapters of Part I is arranged as in no other book. The earth is first viewed as a whole; then the subdivisions of geology are discussed; followed by the rise of geologic observations and interpretations; the literature; materials of the earth's crust; classification of rocks; igneous and volcanic phenomena; the water-laid strata; the organic rocks, with a great mass of detail about the organisms precipitating lime; the work of ice; destruction, transportation and consolidation of rocks; and finally deformation, metamorphism, and erosion forms.

Part II begins with the units and history of classification, followed by mapping and correlation; the uses of fossils; classification and morphology of plants and animals (over 100 pages); and then by twenty-one chapters on the geologic history of the earth and its inhabitants, done in the usual way, with the addition of a discussion of the life of each era from the viewpoint of evolution. The book abounds in paleogeographic maps, many of which are decidedly original, with highly hypothetic and deeply embayed shore-lines; the lands are drawn as drowned, in consequence of which the drainage flows into the heads of deep bays, and not into projecting deltas as is so common at present.

5. *Het Idjen-Hoogland. Monographie II. De Geologie en Geomorphologie van den Idjen, door* Dr. G. L. L. Kemmerling. Batavia (no date). 4to, 162 pages with LVIII plates and a folded geological map, 1:250,000,—The Idjen highland consists

of a group of volcanoes at the east end of Java. Kemmerling's study of it was made in 1916 and 1917, and has been recently published by the "Koninklijke Natuurkundige Vereeniging" in Batavia. The highland includes a great variety of volcanic forms, of which the chief appears to be a hugh caldera, some 10 miles in diameter, with a simple rim on the north from 1,300 to 1,600 met. in altitude, but elsewhere buried by younger volcanoes, up to 3,000 met. altitude, by many small cones and by abundant lava fields and mud flows. The highland is surrounded by descending slopes, strongly incised by consequent valleys, 10 or 15 miles in length, which reach the sea on the north and east. The report opens with a general description of the district, then treats its structure, and finally its erosion. Supplementary chapters are devoted to petrography by the author, and to analyses of spring, lake and stream waters by Woudstra. It is a valuable and comprehensive volume, highly creditable to Dutch scientific enterprise in East Indian possessions. W. M. D.

6. *Het Gouvernement Celebes, Proeve eener Monographie door* L. VAN VUUREN. Encyclopaedisch-Bureau, Weltevreden (Batavia), Java, Dec. 1, 1920 (Large 8vo, XXV + 535 pages. 51 plates, 99 figures, and an Atlas of 25 maps).—The author of the comprehensive work, of which the first part has been completed, is the chief of the Encyclopedic Bureau by which it is published. It appears to be an extended undertaking as the large volume now issued is devoted to the coast and the offshore sea bottom, descriptions of which are gathered from many sources and only in smaller measure from the author's own observations. A great amount of information is thus brought together, far more than can be found in any other single volume on Celebes; but it is of diverse treatment and unequal value, some parts being purely empirical while others are gratifyingly explanatory; and it suffers by reason of being approached from the sea, instead of from the land as it should be; for coastal forms are only the marginal parts of other forms, and such marginal parts are best apprehended after the whole to which they belong has been described. It is however possible that an approach from the sea may be most advantageous in a region where the land is imperfectly known; and in any case, readers who are curious about this most remarkable East Indian island will here find much instruction. W. M. D.

7. *Moseundersögelser i det Nordöstlige Sjaelland.* Med Bemærkninger om Træers og Buskes Indvandring og Vegetationens Historie; by KNUD JESSEN. [Bog-investigations in North East Sjaelland, with remarks on the immigration of trees and shrubs and the history of the vegetation] Danmarks geol. Undersgelse. 2^{34}: 1-269, 1920.—This importnat work contains a summary of previous results in the study and interpretation of

the late glacial and post glacial bogs; detailed accounts, both geologic and ecologic, of the Danish bogs; lists of animals and plants found; and an account of the time of immigration and the subsequent history in Denmark of a large number of trees and shrubs.

The pollen-statistical method is largely used, and frequency curves are constructed for the different species. The results appear to point to the validity of the so-called Blytt-Sernander hypothesis of past alternations of climate. This study starts with late glacial times, considered, on the basis of the geological work of de Geer and Lidén, to have been about 11,000 B. C. or slightly earlier. This was the time of the Older Dryas flora of *Dryas octopetala, Salix polaris, Salix reticulata, Betula nana,* etc., indicating a subarctic climate in Denmark with July temperatures of 8°-12° c. This was followed by the Allerod period marked by the introduction of *Betula intermedia, Betula pubescens, Juniperus communis, Pinus silvestris, Populus tremula,* etc. indicating a temperate continental climate with July temperatures of 12°-15° C. The Allerod period was followed by the Younger Dryas period with a recurrence of the climate and flora of the Older Dryas period. Following this was a long warm period estimated as having lasted for about 7,000 years, commencing about 7500 B. C., during which the climate was warmer than it is at the present time. This warm period, which corresponds to the Ancylus Lake and the Litorina sea in the history of the Baltic, is divided into 1. An older Mullerup, Pine, or Boreal period, during which the climate was dry and rather warm, with such plants as *Alnus glutinosa, Tilia cordata, Ulmus glabra, Cornus sanguinea, Corylus avellana, Prunus padus, Pinus silvestris,* etc.: and 2. A mixed oak forest or Atlantic period at which time the climate was warm and humid, with July temperatures of about 17° C., and with *Acer platanoides, Fraxius excelsior, Humulus lupulus, Trapa natans* and, toward its close, *Fogus silvatica.* Then followed 3: The beginning of the Beech period, about contemporaneous with the Bronze age, when July temperatures reached 18° C. and the climate was again dry and warm. At about 400 B. C. the temperature lessened and the climate became more humid. This corresponds to the Limnaea Sea stage of the Baltic, or the Iron Age in Denmark, and is known as the sub-Atlantic period. This continued to the beginning of the Historic period which in Denmark was about 800 A. D. E. W. B.

8. *The Study of Geological Maps;* by GERTRUDE L. ELLES. Pp. 74, with 7 plates, 1 map, and 64 figures. Cambridge Geological Series, Cambridge University Press, 1921.—The subject matter of this book was assembled by the author to make it available to students of geology. One of the chief aims of the book is to train students to think in three dimensions, and for this purpose

it is admirably adapted. The subjects covered include the uses of topographic maps in geology, the relation of topography to outcrop, the effect of folds and faults on the outcrops of beds, and the interpretation of geologic maps. The illustrations are specially noteworthy, and are unsurpassed in any work of similar scope. The book should serve as an excellent text in structural geology. A handicap on its wide use outside of Great Britain, however, is that the topographic and geologic maps employed in illustration are exclusively British. ADOLPH KNOPF.

10. *Geological Explorations in Africa.*—An important series of investigations of the igneous rocks of South Africa and elsewhere is being undertaken by a force of American geologists essentially financed by the Shaler fund of Harvard University. Professor R. A. DALY, the chief mover in the enterprise, has gone on in advance and after a month on Ascension Island will work on St. Helena. Dr. F. E. Wright sailed for England early in November. On December 30 with Professors Charles Palache and Molengraaf of Holland, he will sail for Cape Town where the party will be joined by Dr. Daly. The field-work will be chiefly in the Transvaal.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The autumn meeting of the National Academy was held in Chicago on Monday and Tuesday, November 14-15, at the University of Chicago. The attendance was large and a notable series of papers were presented. The Academy dinner took place on Tuesday evening. Members of the Academy had the opportunity to visit the Yerkes Observatory at Williams Bay, Wisconsin, on Wednesday, November 16.

2. *American Association for the Advancement of Science.*—The winter meeting of the American Association, the seventy-fourth in its history, will be held in Toronto on December 27 to 31. This is the second Toronto meeting, the first having been in 1889. Two other meetings in Canada were those of Montreal in 1857 and 1882. All of these meetings have been marked by their international character which has been an important element in their success. It may be added that the membership of the Association, which was nearly 2,000 in 1889, is now about 12,000.

Professor Eliakim H. Moore of the University of Chicago is president of the Association.

3. *The Zoological Record,* 1915-1920.—The Zoological Society of London announces the publication of the volumes of the Zoological Record for 1915, 1916, 1917, 1918, 1919, 1920 (vols. 52 to 57). These correspond with what would have been the 15th to 20th issues (N. Zoology) of the International Catalogue of the Royal Society. The Zoological Society is able to supply

these volumes, bound in paper covers, at the net cash price of £12 for the six volumes. Volumes 1915, 1916, 1917, 1918 can be delivered at once; volume 1919 is in the press and volume 1920 is in preparation. The general charge of this work has been assumed by Dr. DAVID SHARP, assisted by H. M. WOODCOCK, A. K. TOTTON, F. W. EDWARDS, H. B. PRESTON, W. T. CALMAN, C. T. REGAN, W. L. SCLATER, AND M. HINTON.

The Zoological Record has had an intermittent career since it was started in 1864. The International Catalogue, carried by the Royal Society from 1900, and one of the volumes of which covered the ground of the Zoological Record, was suspended in 1914. The new enterprise above stated will be continued if it has, as should be the case, adequate financial support.

4. *The Echinoderm Fauna of Torres Strait: Its Composition and Its Origin;* by HUBERT LYMAN CLARK. Department Marine Biology of the Carnegie Institution of Washington, Vol. 10, quarto, pp. viii, 223, with 38 plates, of which 19 are in color. Washington, 1921 (Carnegie Institution).—This is primarily a contribution to zoogeography, although all of the species included have been critically examined and many supplementary characters described for those that are less well known. The region covered by the report is of unusual interest both from a physiographical and zoological standpoint, for it is considered a region of relatively recent subsidence. The distribution of the marine life may well serve as evidence for or against this theory, and at the same time indicate the route taken by a given group of animals in the course of its dispersal. The echinoderms are particularly suitable in this respect, for in no other region of similar extent anywhere in the world have so many species been discovered, no less than 240 species being recorded in this monograph, 146 or which are reported for the first time. They show distinct evidence of a divergent origin, for some of the forms are closely related with groups distributed in the Pacific, while others show a close affinity with species found in the Indian Ocean. Hence the author concludes that his studies indicate that subsidence of this region since Mesozoic times first brought in a great number of echinoderms from the Pacific, while a later and further subsidence then opened up the Strait to the tide of East Indian forms which are now mingled with the earlier arrivals from the Pacific to form the heterogeneous fauna of the present day.

The work is also a most important contribution to the biology and taxonomy of the echinoderms, for the habits of many of the new and little known species are described at length and their anatomical peculiarities and systematic relations fully discussed. In beauty of coloration and grace of form, as indicated by the superbly colored plates, these animals rank high among all of nature's creations. W. R. C.

5. *Readings in Evolution, Genetics and Eugenics;* by HORATIO HACKETT NEWMAN. Pp. xviii, 523, with 101 figures. Chicago, 1921 (University of Chicago Press).—For supplementary reading in the more general biological sciences, as genetics and organic evolution, it is customary in college courses to assign chapters from a considerable number of standard books. If a sufficient number of copies of the books required could be made available this is without doubt the best way to make the student acquainted with the work of recognized authorities on the subject. But, as a matter of fact, this is feasible only in the case of very small classes. For this reason the author has compiled a book, suitable for a college text, which is composed largely of excerpts from the works to which reference is made. Quotations from some fifty books and papers by forty-four different writers have been cleverly pieced together with the necessary introductory and explanatory notes to make a very readable book covering the entire field of genetics, evolution, and eugenics.

The excerpts are usually sufficiently extensive to give the student a fair example of the best work of the foremost classical and modern biologists as well as of their points of view. The selections appear to be well chosen and the book promises to fill a real need not only in the teaching of biology, but also in stimulating the reader to a further acquaintance with the books and writers so auspiciously introduced. W. R. C.

6. *Philosophie des Organischen;* von HANS DRIESCH. Zweite, verbesserte und teilweise umaufgearbeitete Auflage. Pp. xvi, 608. Leipzig, 1921 (Wilhelm Engelmann). This work is based on the author's studies in experimental embryology, by which he was led to believe that the living organism is more than an aggregate of its parts—that it embraces something that is neither substance nor energy, but a factor peculiar to life which the author terms "entelechy." This conception of vitalism is invoked in a critical analysis of the processes of development and reproduction and is applied in a discussion of the theories of heredity and evolution, as well as in an examination of the human personality.

The first five hundred pages, which deal particularly with the science of the organism, have been little changed from the first German edition, which followed the English edition in 1908. But the last hundred pages, bearing on pure philosophy, have been entirely rewritten to accord with the progress of logic and metaphysics during the past decade. W. R. C.

7. *A New Alaska Base Map.*—The U. S. Coast and Geodetic Survey of the Department of Commerce reports the completion of a new outline map of Alaska on the Lambert conformal conic projection. Scale 1/5,000,000; dimensions 17 x 26½ in., price 25 cents. The map extends from the Arctic Ocean in the north to the State of Washington in the south, and includes all of the

Aleutian Islands and a part of Eastern Siberia. It is intended merely as a base map to which may be added any kind of special information that may be desired. For this reason, only national boundaries, the adjacent Canadian provinces, and the names of a few of the important towns are given. The shoreline is compiled from the most recent Coast and Geodetic Survey charts and in respect to southeast Alaska and westward to Kodiak Island, the coastline is better represented than heretofore. The accumulation of the yearly surveys in the extensive and largely unsurveyed waters of Alaska as here embodied, presents a delineation of the coastline in a more really true shape than heretofore and in this respect the map is more reliable than other existing maps of similar scale.

8. *The Geography of Illinois;* by DOUGLAS C. RIDGLEY. Pp. xvii, 385, 16mo; with nearly 250 illustrations including a general map of the state. Chicago, 1921 (University of Chicago Press; price $2.50 or $2.65 postpaid).—This is the first of a series of volumes, to be issued by the University of Chicago Press and devoted to Regional Geographies, that is to the geographic study of a state or other limited region; Dr. J. Paul Goode is the editor of the series.

Illinois is a notable state: the twenty-first to be admitted to the Union (1818). It ranked in 1910 *first* in the value of farm property; *second* in mineral products and number of hogs; *third* in population, manufactures, etc.; *seventh* in wheat and cattle; *eighth* in hay and forage, and *twenty-third* in area. In 1920 the population was nearly 6,500,000, an increase of 15 percent since 1910.

This volume covers all the appropriate topics with a thoroughness remarkable in one of small size. It thus contains a wealth of material valuable alike to intelligent citizens as to teachers and pupils. The bibliography (pp. 363-370) is full as is the index which follows. The illustrations are very numerous, well selected and faultlessly reproduced.

9. *La Géographie.* Vol. **36**, No. 2, July-August, 1921. *Centenaire de la Société de Géographie.*—A scientific Society which has carried on an uninterrupted existence for one hundred years is a notable institution and has few rivals in the world. This honor belongs to the Geographical Society of France which celebrated its Centenary on July 4-6, 1921. The present number of *La Géographie* gives a very interesting account of the history of the Society and the formal proceedings at its one-hundredth anniversary. Some forty-four foundations are mentioned from the funds of which medals and money prizes have been bestowed upon those who have accomplished important work in geography. It is particularly interesting to note that the "Grande Médaille d'Or" was presented in 1829 to Captain

John Franklin for his polar voyages while recent awards of the medal have been made to Sven Hedin (1904), Sir E. Shackleton (1910), Dr. J. B. Charcot (1912), Capt. R. Amundsen (1913), Admiral R. E. Peary (1914), Comm. J. Tilho (1918). What these explorers accomplished is too well-known to require mention. An excellent portrait is given of Prince Bonaparte, the president of the Society, to whom a gold medal (here figured) was presented by the Belgian Society of Geography. The frontispiece of this number is a portrait of the first president, Marquis de Laplace, 1821-22. The reproduction of the cover of the first number (of June, 1822) of the Society's Bulletin (opposite p. 152) bears an interesting resemblance to that of the first number of this Journal, published just four years earlier (July, 1818); this last is reproduced on p. 14 of the centennial number, July, 1918 (vol. **46**).

The *Société de Géographie* is to be congratulated upon its long and honorable career and for the important contributions it has made to geographical science.

10. *A new map of the North Pacific.*—Dr. R. L. Faris, acting director of the U. S. Coast and Geodetic Survey, announces the completion of a new base map of the North Pacific Ocean on the transverse polyconic projection, prepared by W. E. Johnson, cartographer of the Survey; it is now available for distribution. It is published in clear form and convenient size (dimensions 14 by 41 inches) for desk use. (Map No. 3080, North Pacific Ocean, scale 1:20,000,000, price 25 cents.) The method of projection employed was devised by Dr. Ferdinand Hassler, first superintendent of the Survey, and was computed by C. H. Deetz, the Survey cartographer.

This map is designed primarily as a base on which statistical data of various special kinds may be shown. In consequence of this purpose only features of major importance are shown on it and these features are emphasized to an extent not possible on a map which contains the vast amount of detail usually included. In addition to the foregoing specific value this map is of general interest at present as showing the relation between the United States, its possessions, and the Far East and as including those areas around which present problems in the North Pacific Ocean are centered. It represents the acme of scientific precision combined with simple practical utility. It extends from New York and Panama to Singapore and Calcutta, from Alaska and Siberia to the Hawaiian Islands and includes a part of South America and a portion of Australia. Through its lateral center it extends over 180°, or more than half-way around the earth.

The distinctive feature of the map is that the localities mentioned are pictured in practically their true relation as to distances, areas, and comparative angular direction of coast line.

It will thus serve to correct the erroneous impression that we have all received from the usual representation of this region on Mercator charts (so useful in navigation) and on maps which greatly exaggerate areas and distances toward the poles when compared with their equatorial equivalents, and to the eye, present the general continental coast lines out of their proper angular relation to one another.

The problem of representing any considerable portion of the ellipsoidal form of the earth on a plane surface is not readily dealt with, or in other words is intractable. Always some desirable features must be sacrificed in order to incorporate those of primary value to the problem or area at hand. In the present instance the property of true scale along a great circle, tangent to the forty-fifth parallel of north latitude at the central meridian of the map, was chosen. This great circle is approximately the shortest distance between San Francisco and Manila, and in close proximity to it lie practically all the important points of interest, such as the Panama Canal, Mexico, our Pacific Coast, Alaska, the Philippine Islands, Japan, and the coast of China. This is accomplished through the use of the transverse polyconic projection, which is the regular polyconic, or American, projection turned from its normal vertical axis to a lateral great circle axis. This is an involved and laborious operation but the resulting advantages are well worth while where areas of this nature are presented and accuracy is desired. Both the vertical and lateral axes are straight lines, true to scale and represent the shortest distance (great circle) between their extreme points.

The new Alaska base map of the U. S. Coast and Geodetic Survey is mentioned on an earlier page of this number (p. 360).

OBITUARY.

JOSEPH WINTHROP SPENCER, the well known geologist, died the 9th of October in Toronto after an illness of four weeks. He was born in Dundas, Ontario, and was a graduate of the Faculty of Science, McGill University, then professor of geology at King's College, Windsor, N. S., and later at Columbia University, Missouri, and State Geologist of Georgia. He was widely known through his investigations of the Great Lakes, and in 1907 was asked to do extensive research work at Niagara Falls on behalf of the Geological Survey of Ottawa. His reports and publications on this subject are the standard authority on the Falls.

Dr. Spencer's work covers a great field; his main interest was concentrated in "Niagara," and he has offered a magnificent contribution to the knowledge of the evolution of the Falls, their relation to the Great Lakes, the origin and history of these, beside the age of the Ontario shore and modern St. Lawrence River; among the Niagara fossils he studied especially graptolites. Moreover, he wrote valuable papers dealing with the geological development of the West Indies and Central America, the geography of submarine valleys, and great changes of level of land and sea.

Three years ago Dr. Spencer presented to the University of Manitoba his comprehensive and valuable collection of minerals and fossils. He resided in Washington, D. C., from 1900 until a year ago, when he returned to Toronto. His death is a great loss to science, and to his numerous friends, for his character as a man, and his work as a naturalist gained for him the admiration and gratitude of the scientific world. THEO. HOLM.

Clinton, Md.

DR. JOEL ASAPH ALLEN, the veteran zoologist, died on August 29 in his eighty-fourth year. Born in Springfield, Mass., on July 19, 1838, he was one of the well-known group of pupils of Louis Agassiz whom he accompanied to Brazil in 1865. He was early connected with the Museum of Comparative Zoology in Cambridge, as also in a special capacity with the U. S. Geological Survey. In 1885 he accepted the curatorship of mammalogy and ornithology in the American Museum of Natural History; this position he held for thirty-six years until he was made honorary curator in 1921. His original papers on natural history were very numerous; in addition to these he did important editorial work, conspicuously with the *Auk* (1884-1911) and the *Bulletin* of the American Museum (1886-1918).

PROFESSOR VICTOR VON LANG, the distinguished Austrian mineralogist and physicist, died in Vienna, at the age of eighty-one years. The end came after a lingering illness, aggravated by the unfortunate conditions existing since the war.

PROFESSOR JULIUS VON HANN, the well-known meteorologist, director of the "Zentralanstalt für Meteorologie und Geodynamik" in Vienna, died recently in his eighty-third year.

M. ALFRED GRANDIDIER, eminent as a geographer, and explorer, died on September 12 at the age of eighty-four years.

DR. A. S. F. LEYTON, the English pathologist, died on September 21, at the age of fifty-two years.

SAMUEL STOCKTON VOORHEES, engineer chemist of the Bureau of Standards, died on September 23 in the fifty-fifth year of his age.

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*This Index contains the general heads, BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY; under each the title of Articles referring thereto are included.

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