egg production per unit of time in the lactophosphate females is nearly 5 times as great as in the controls.

A further point of interest is that if a very small dose of corpus luteum substance[2] be administered to the birds each day along with the calcium lactophosphate the stimulating effect of the latter upon the growth of the females is completely inhibited.

It has been known that the internal secretions of certain organs might have a different effect upon the growth of males and females, and indeed in the present series of experiments we have seen such a differential effect following the feeding of several different gland substances. It is another thing, however, to find inorganic salts exercising such a differential effect. It furnishes one more piece of evidence of the deep-seated biochemical differences which underlie sex differences, and at the same time is in line with the medical evidence as to the great importance of calcium in the physiology of the reproductive organs of the female.

Raymond Pearl

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THE PRESENT STATUS OF THE DOLOMITE PROBLEM[1]

The problem of the origin of the dolomites and dolomitic limestones has long occupied the minds of geologists and many theories have been advanced for their formation. But no one of these has been universally accepted. The chief theories which have been proposed are briefly as follows: First, the alteration theories which assume that dolomites have been formed by the partial replacement of limestones by magnesia either (1) before they emerged from the sea, through the agency of sea-water, or (2) subsequent to their emergence through the agency of ground-water. Second, the primary deposition theories which maintain that the dolomites were originally deposited in the form that they now appear, (1) by chemical precipitation from the sea, or (2) by the deposition of clastic grains of dolomite derived from the disintegration of older dolomitic limestones. Third, the leaching theories which are based on the well-known fact that during the weathering of a dolomitic limestone the lime is removed more rapidly than the magnesia, thereby causing an enrichment of the latter constituent. This leaching is supposed to take place either (1) through the agency of sea-water prior to emergence, or (2) through the agency of atmospheric water after the limestone has become a part of the land.

The marine alteration theory is by far the most widely held to-day, but the chemical precipitation theory has many champions.

The writer was led to suspect several years ago, that a careful field study of dolomitic formations would throw some light upon their origin and through the aid of the Iowa Geological Survey and an appropriation from the Esther Herrman Research Fund of the New York Academy of Sciences he has been able to examine nearly all of the important dolomites of the Mississippi Valley and the eastern United States.

These studies have furnished irrefutable evidence that the majority of the dolomites examined have resulted from the alteration of limestone. The following facts support this contention: (1) the lateral gradation of beds of dolomite into limestone, sometimes very abruptly; (2) the mottling of limestones on the border of dolomite masses by irregular patches of dolomite; (3) the existence of remnants of unaltered limestone in dolomite, and of nests of dolomite in limestone; (4) the irregular boundaries between certain beds of limestone and dolomite; (5) the presence of altered oolites in some dolomites; (6) the protective effect of shale beds; and (7) the partial obliteration of original structures and textures in many dolomites and dolomitic limestones.

Concerning the conditions under which the dolomitization took place there are many reasons for believing that the more extensive dolomites have all been formed beneath the sea prior to or contemporaneously with recrystallization and that the dolomitiza-

[2] A material which I have earlier shown (*Jour. Biol. Chem.*, Vol. XXIV., pp. 123–135, 1916) to have a retarding or inhibiting effect upon the growth of the chick.

[1] A more complete report on the origin of dolomite will appear in Vol. XXV. of the Iowa Geological Survey, which is now in press.

tion produced by ground-water is only local and very imperfect. Some of the features which lend weight to this view are as follows: (1) Recent dolomitized coral reefs are known to have been formed by the reaction of the magnesia of sea-water with the limestone. (2) The dolomite areas of mottled limestones are believed to have undergone recrystallization at the same time as the associated limestone areas, as suggested by the occasional development of zonal growths of calcite and dolomite. (3) In imperfectly altered limestones the dolomite is seen to follow original lines of weakness rather than secondary structures, such as joints or fractures. (4) In most cases of mottling the dolomitization appears to have progressed uniformly as we should expect it to do in an unrecrystallized rock, rather than to have progressed by forming veinlets and stringers in the early stages. (5) The existence of perfect rhombs of dolomite in many imperfectly altered limestones suggests that the latter had not yet solidified when the dolomite rhombs were formed. (6) The widespread extent and nearly uniform composition of many dolomites indicates that they must have been formed by an agent capable of operating uniformly over wide areas. (7) An adequate source of magnesia for transforming extensive limestone formations into dolomite is found only in the sea, which contains many times as much of the constituent as ordinary ground-water. (8) Many dolomites are directly and regularly overlain by pure limestone formations or by thick shale beds, proving that they must have been formed before these overlying beds were deposited and that descending ground-water has not been influential in their production.

The evidence of dolomitization beneath the sea then must be considered as positive, but the controlling factors of the process are very imperfectly understood, due chiefly to the lack of careful study of the phenomenon in the modern seas. A thorough investigation of the conditions which favor the transformation in the sea to-day would be invaluable in interpreting the history of the ancient dolomites. It is believed that very important data bearing on the problem could be obtained from a more careful study of the coral islands of the Southern Pacific.

As to whether dolomitization takes place in concentrated seas or not there has been considerable disagreement. Until recently the tendency has been to follow Dana, who believed that dolomitized portions of recent coral reefs were formed in concentrated lagoons and assumed that the ancient dolomites must have been formed under similar conditions, but Skeats pointed out in 1905[2] that the outer parts of certain fringing reefs of the South Sea Islands, which face the open ocean, are occasionally dolomitized and that the dolomitization of coral reefs is not confined to the lagoons; and Philippi[3] soon after presented evidence of recent dolomitization in the open sea. Still more recently, Blackwelder[4] has given it as his opinion that the Bighorn dolomite has resulted from the progressive alteration of limestone during deposition, the concentration of the magnesia being not more than two or three times as great as in the present ocean, since more than this amount would have been unfavorable to the life processes of the time. There are many commendable points to this theory of progressive dolomitization at low concentrations, but if dolomitization can go on under these conditions, why are not all of our limestones dolomitic? In answer to this query it might be said that the alteration takes place under unusual circumstances, possibly through the agency of certain bacteria which are not always present when limestone is deposited.[5] But much of the field evidence speaks against progressive dolomitization. The wavy boundaries sometimes exhibited between the dolomitic and non-dolomitic portions of formations; the lateral gradation of beds of dolomite into limestone; pseudo-interstratification effects of

[2] *Quart. Jour. Geol. Soc. London*, Vol. LXI., p. 97, 1905.

[3] *Neues Jahrb.*, Festband, Vol. I., 1907, p. 397.

[4] *Bull. Geol. Soc. America*, Vol. XXIV., p. 607, 1913.

[5] Both Nadson and Walther have suggested the possible influence of bacteria in dolomitization. See "Gesichte der Erde und des Lebens," p. 90.

dolomite and limestone; the presence of imperfectly dolomitized oolite beds in dolomites; the occurrence of mottled limestones grading gradually into dolomite, and many other features can only be accounted for by assuming that dolomitization took place after all of the beds involved were deposited, or at least in the closing stages of their deposition. When, however, a pure limestone member succeeds a dolomite member, known to be an alteration product, conformably, the contact line being regular and continuous over wide areas, it can not be assumed that this relationship has resulted from the alteration of the lower bed after both beds were deposited. The "Lower Buff beds" of northeastern Iowa, which consist of dolomite with occasional minute limestone remnants, are abruptly followed by the pure limestone of the "Lower Blue beds" over hundreds of square miles, the transition from one into the other taking place through only a few inches of imperfectly dolomitized limestone.

Moreover, the tendency of some limestones to be more highly dolomitic in their lower portions and to become progressively less dolomitic upwards, must also be regarded as lending support to the theory of progressive dolomitization. Orton and Peppel[6] state that the Delaware and Columbus limestones of Ohio are more dolomitic in their lower than in their upper portions.

But even if it should be positively shown that dolomitization can go on at low concentrations, all must agree that it would proceed not only much more rapidly, but also more completely at higher concentrations. With reference to the question whether the ancient seas which accomplished such extensive dolomitization were more concentrated than the modern ones or not, little can yet be said. On this point we must rely solely upon inference. Steidtmann[7] has presented evidence to show that the ancient seas were more highly magnesian than those of to-day. From independent lines of reasoning based upon paleogeographic evidence the writer is also led to believe that the magnesia content of the ancient seas may have been at least temporarily greater than at present. Let us consider the conditions obtaining in a constricted interior sea from which limestone is being deposited on a great scale. Fresh quantities of lime and magnesia and other salts are being introduced into this interior sea both by influx from the open ocean and from the streams draining the land. Now lime is constantly being depleted from this inland sea by lime-secreting organisms, while the magnesia and other salts tend to accumulate. It seems possible, then, that during a long period of limestone formation under these conditions magnesia might accumulate in considerable excess and that ere long extensive dolomitization might set in and continue until equilibrium was once more established.

Applying this theory now to the stratigraphic column, we actually find that many periods of extensive limestone formation in interior seas may be correlated with periods of extensive dolomitization. Witness the great dolomite masses of the Cambrian of the Appalachian province, and of the early Ordovician and of the Niagara.

As further evidence that the early seas which accomplished extensive dolomitization may have been temporarily concentrated, attention may be called to the fact that these seas in many instances were retreating and contracting towards the last, and that unless they were freely connected with the open ocean, evaporation under arid or semi-arid conditions might give rise to a considerable increase in salinity. Such a condition would seem to apply especially well to the Niagaran sea. Paleogeographic studies have shown that this sea became very much contracted towards the close of this epoch, and Clarke and Ruedemann[8] have concluded that the Guelph fauna must have inhabited a sea of abnormally high salinity. The latter fact considered in connection with the evidence of widespread dolomitization in the later stages of the Niagara seems significant.

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[6] Ohio Geol. Survey, 4th ser., Bull. 4, p. 165.

[7] *Jour. Geol.*, Vol. 19, pp. 323 and 392. 1911.

[8] *Mem. N. Y. State Museum*, No. 5, p. 117.