plied physics, your readers may be interested in the following letter, which I have just unearthed, in one of those single-handed combats in the perennial struggle against dirt, in which an armistice has just been declared. (Pardon the lack of unity in the preceding sentence. It at least does not contain the word "due," nor the adverbial phrase "back of," meaning behind).

I had written an article, the first in English, describing the Physikalisch-technische Reichsanstalt in Charlottenburg, which I had seen in its initial stages, and urging to the best of my ability the establishment of such an institution in this country. This article I had sent to the *Popular Science Monthly,* from whence it was returned with a note from the editor, Dr. Youmans, saying he did not believe that such things were the function of the government. What to do with it I did not know, but finally Dr. G. Stanley Hall took pity on the little wanderer, and published it in his *Pedagogical Seminary,* and the U. S. post-office did the rest. I sent copies to Sir Oliver Lodge, who read an article on the same matter at the meeting of the British Association, but I never heard whether he got them. It was probably as a result of his paper that the National Physical Laboratory was founded. The United States, as usual, brought up the rear. It was not until eight years after my article that the first step was taken leading to the establishment of the Bureau of Standards, which now, in size and expenditure at least, leads all the rest. This is due to the extraordinary tact and skill in management of its able director, Dr. Stratton, whose name is now a household word. May the bureau long continue to have success under his wise direction. The letter follows:

Cambridge, 1892, Jan. 13.

My dear Sir:

Your article on a National Physical Laboratory came duly, and I thank you for sending it to me. By this mail it goes back to you.

I have read it with care and much pleasure, and trust that you may soon publish it, for it can not fail to be useful. What may be the best way to bring it before the public I do not know; but, from my limited means of judgment, it seems to me that some one of the great New York magazines might afford a good opportunity —say the *Century,* or *Scribner's.* I should select a periodical of large circulation—and not a "popular scientific" one, where the public reached is one which would in general require no education on the subject, or else not to be of the influential class of people.

And when it is printed, I hope you will take steps to insure that members of Congress and professors of physics in our leading universities shall have opportunity to read it. Possibly some of the engineering journals might have the sort of circulation which is desirable.

Wishing you all success, and with cordial sympathy with such a movement, I am,

Very sincerely yours,

B. A. GOULD

Dr. Arthur G. Webster,
Worcester.

A. G. WEBSTER

WORCESTER,
JULY 8, 1922

SPECIAL ARTICLES

BASAL GLAUCONITE AND PHOSPHATE BEDS

As a result of lithologic studies of carboniferous formations in Texas I showed last year[2] that glauconite beds characterized by certain peculiarities occur at breaks in a sedimentary series. Although I pointed out that this observation was merely an extension of Cayeux's observation[3] that phosphate beds occur in similar positions, I thought at the time that the relation of typical glauconite beds to these breaks had not been noted. I was therefore much interested to learn in conversation re-

[1] Published with the permission of the director of the U. S. Geological Survey.

[2] Goldman, Marcus I.: "Lithologic Subsurface Correlation in the 'Bend Series' of North-central Texas," *U. S. Geol. Survey Prof. Paper* 129-A, pp. 1-22 (especially pp. 3-4), 1921. "Association of Glauconite with Unconformities," *Bull. Geol. Soc. America,* 32, p. 25, 1921 (abstract).

[3] Cayeux, L.: *Contribution à l'étude micrographique des terrains sédimentaires, Mém. de la Soc. géol. du Nord.* 4 pt. 2, pp. 427-432, 1897. *Genèse des gisements de phosphates de chaux sédimentaires, Bull. Soc. géol. de France,* 4e ser., *5,* pp. 750-753, 1905.

cently with Professor W. G. Fearnsides, of Sheffield, England, that the association was familiar to him and had been described by him in print. He mentioned a number of other occurrences and gave in addition several references to British publications which discuss the relation of phosphate beds to stratigraphic breaks. As all this evidence serves to establish the principle on a solid basis it seems worth while to bring it to the attention of American stratigraphers.

The deposit of basal glauconite described by Fearnsides[4] and Anderson[5] is at the boundary between the Cambrian and Ordovician of Sweden and is very extensive. Another deposit of wide extent, described by Hayes,[6] is at the boundary between the black Chattanooga shale and the overlying carboniferous in Tennessee. Both of these are associated with phosphate. The association of glauconite and phosphate is, in fact, so generally referred to in the literature relating to either of them, especially in that relating to nodular phosphate, that it may be regarded as established. Anderson[7] not only recognized it but interpreted the relative abundance of one or the other. He formulated the principle that in deposits of the two constituents phosphate predominates in the littoral facies and glauconite in the offshore shallow-water facies (essentially the continental shelf). If this practical equivalence in mode of occurrence of glauconite and phosphate is recognized, then the papers referred to in this note, although most of them deal with phosphate deposits, serve to establish beyond reasonable doubt the association of certain types of glauconite as well as of phosphate deposits with breaks in a stratigraphic succession. As early as 1874 Tawney[8] stated that the fossils in a phosphate bed represent a long time range, indicating a dearth of sedimentation. The development of the conception with various modifications may be followed in the references given. In a very recent paper Vaughan[9] points out the possible bearing of a glauconite bed in solving the problem of the position and character of the Mesozoic-Cenozoic boundary in New Zealand.

Two conclusions seem to have impressed themselves on most students of these basal deposits of phosphate and glauconite: One is that the surfaces on which they occur had not emerged, the other that they represent a long-time interval.

The reasons for supposing that there has been no emergence are not always very clearly formulated. The principal ones seem to be: (1) The usual absence of any *recognizable* erosion surfaces underlying the deposits; (2) The absence of an underlying weathering surface; (3) The absence of fragments of the underlying bed; (4) Lack of evidence of transportation of constituents of the beds; (5) The fact that similar modern deposits form under purely submarine conditions.

There seems to be room for many fallacies in these assumptions, and at best the demonstration of the fact they are called upon to prove—that during the interval between the formation of the underlying and overlying bed there was no emergence—does not appear very essential. A long period during which the sea bottom was at or near marine base-level seems to be implied in any case, and that, so far as I can see, implies also an approximation to subaerial base-level of the adjacent land. Slight oscillations of base-level may safely be assumed and are indicated by some of the evidence. Whether these fluctuations have at times brought part of

[4] Fearnsides, Wm. G.: "The Lower Ordovician Rocks of Scandinavia," etc., *Geol. Mag.*, n. s., Dec. 5, 4, pp. 257-267, 295-304 (especially pp. 264-267), 1907.

[5] Anderson, J. G.: *Über Cambrische und Silurische phosphoritführende gesteine aus Schweden, Bull. Geol. Inst. Univ. Upsala*, 2, pp. 133-236 (especially pp. 178-200, 220-229), 1895.

[6] Hayes, C. W.: "The Tennessee Phosphates," *Sixteenth Ann. Rept., U. S. Geol. Survey*, pt. 4, pp. 611-612, 1895; *Seventeenth Ann. Rept., U. S. Geol. Survey*, pt. 2, p. 523, 1896.

[7] Anderson, J. G.: *loc. cit.*, p. 221.

[8] Tawney, E. B.: "Notes on the Lias in the Neighborhood of Radstock," *Proc. Bristol Nat. Soc.*, n. s., 1, p. 174, 1874.

[9] Vaughan, T. Wayland: "Correlation of the later Mesozoic and Cenozoic Formations of New Zealand," *Proc. First Pan-Pacific Scientific Conference*, Pt. 3, Bernice P. Bishop Special Publication, pp. 734-737, Honolulu, 1921.

the area, in which phosphate is found, above water makes little difference. The essential fact is that the phosphate nodules and most of the materials associated with them probably accumulated mainly in place and not as a result of transportation.

The length of the period during which the deposits accumulated is deduced from the following facts: (1) The wide range of the fossils they contain; (2) The great thickness of the "equivalent" section in other areas. Without the fossils this has no bearing; (3) In modern deposits of similar character the decomposition of associated detrital minerals and evidence of prolonged submarine exposure of other constituents; (4) The abundance in the deposits of bore holes made by submarine animals; (5) The evidence of different stages in the formation of the nodules; (6) Differences in the amount of wear on different nodules, indicating formation at different times; (7) The fact that the sand included in the concretions is finer than that in the matrix, indicating a range of conditions; (8) The abundance in the deposits of the teeth of fish without their bones, the bones having been dissolved.

One of the most convincing arguments involves a consideration of the origin of the deposits and the reason for their association with stratigraphic breaks. This is not the place for attempting a complete discussion of the problem, but one explanation formulated or implied by several of the papers cited is so convincing in its simplicity that I wish to state it briefly as superseding the one which, following Cayeux, I proposed in my previous papers. This new explanation is based on the peculiar composition of the glauconite and phosphate beds at stratigraphic breaks. A definition of these peculiarities is almost an explanation of them—they are essentially concentrations. The materials concentrated as I have described them and as they are described in part by Fearnsides and others include the glauconite and phosphate grains and nodules themselves, shells or coarse fragments of shells of marine animals, sulphide concretions, etc. These same constituents are found in the overlying bed and in some localities also in the underlying bed. The reason they are concentrated here is apparently that no detrital material accumulated to separate them. In Teall's picturesque words,[10] "The deposition of sediment acts on the zonal succession [of ammonites] and on the distribution of phosphatic matter very much as a prism acts on the rays of light. It supplies a kind of dispersive power." So far as my reading goes, Hayes[11] is the only one who has made the important deduction from this interpretation that the scarcity of calcareous shells must then be accounted for. He attributed it to solution, which accounts also for the dominance of phosphatic skeletons, the lime phosphate being less soluble than the carbonate. Otherwise the abundance of living phosphatic organisms such as the brachiopods, which usually characterizes these areas of phosphate deposition, would be hard to explain, seeming to imply a puzzling selective action of the environment on the fauna. Murray and Renard[12] noted on the one hand the occurrence of glauconite and phosphate deposits in areas of slow sedimentation, and on the other hand the presence of glauconite, though in much smaller relative amount, in many types of more rapidly accumulating deposits, such as the Blue Muds. But apparently they did not associate the abundance of the glauconite and phosphate with the mere scarcity of the sediment.

It is perhaps surprising that a fact so long and frequently recognized as this association of phosphate and glauconite with stratigraphic breaks should have failed almost completely to penetrate the text-books. I have found it touched on only in Grabau's "Geology of the Non-metallic Minerals."[13] Nevertheless, though it still requires a great deal of interpretation and qualification, it seems to be established well enough to receive general consideration from stratigraphers as a criterion of great possible value in the analysis of stratigraphic sections.

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[10] Teall, J. J. H.: "The Natural History of Phosphatic Deposits," *Proc. Geologists' Assoc.*, London, 16, p. 379, 1900 (bibliography of 45 titles).

[11] Hayes, C. W., *loc. cit.*, 1895, pp. 621-622.

[12] Murray, John, and Renard, A. F.: "Deep-sea Deposits," Report on the Scientific Results of the Voyage of H.M.S. *Challenger*, pp. 382 and 411, 1891.

[13] Vol. 1, p. 306, McGraw-Hill, New York, 1920.