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WITH TWO PLATES.

NEW HAVEN, CONNECTICUT.

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ART. XXIX.—*On the Calcium Phosphate in Meteoric Stones;* by GEORGE P. MERRILL, Head Curator, Department of Geology, United States National Museum.

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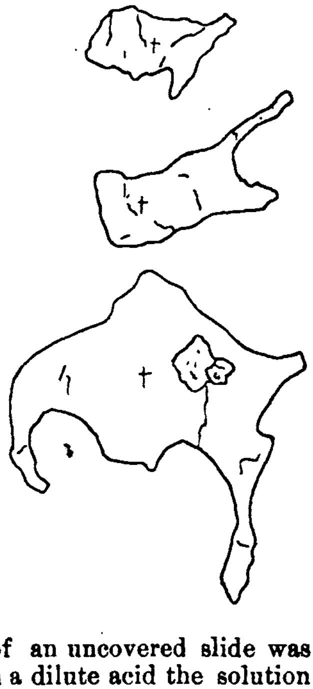
UNDER the caption *On the monticellite-like mineral in meteorites*, I have elsewhere* described a previously unrecognized form of calcium phosphate occurring among the silicate constituents of stony meteorites. Examination of a large number of thin sections of other stones than those there mentioned has shown the occurrence of this mineral to be so widespread as to warrant a brief note devoted exclusively to it.

The first noted occurrence of a mineral phosphate in a meteorite was that of C. U. Shepard, who in his description of the Richmond, Virginia, stone mentions the occurrence of a minute, but macroscopically visible, yellow mineral, particles of which reacted for phosphorus and calcium and which he interpreted as indicative of the mineral apatite. In this he was essentially right, but singularly enough the discovery remained unverified almost to the present time (see my paper), nor was apatite again reported until Berwerth† found it among the silicate constituents of the Kodaikanal iron, and Tschermak‡ in the stone of Angra dos Reis. Singularly enough, too, the phosphorus reported in chemical analyses of meteorites is in the majority of cases relegated to the metallic constituent, a matter to which attention was called in my paper on the minor constituents of meteorites published by the National Academy of Sciences.§ The cause of this is not difficult to determine, as noted in the following descriptions, in which I have repeated, in part, matter given in previous papers, adding the results of more recent observations, particularly in slides of the New Concord and Waconda stones.

The New Concord stone, a veined intermediate chondrite according to Brezina's classification, fell in 1860. It has been the subject of much study, and need be referred to here only in connection with its mineral and chemical composition. Dr. Smith's analyses‖ showed the stone to consist of 10·7 per cent nickel-iron and 89·37 per cent "earthy mineral," the nickel-iron yielding 0·012 per cent of phosphorus, but no mention is made of this same constituent in the "earthy" portion. An examination of the stone in thin sections, a method not available in Smith's time, reveals the presence of numerous areas of the phosphatic mineral I have elsewhere described and pro-

* Proc. Nat. Acad. Sci., vol. i, p. 302, 1915.
† Min. Petr. Mitt., vol. xxv, p. 188, 1906. ‡ Ibid. xxviii, 110, 1909.
§ Memoirs, vol. xiv, p. 27, 1916. In the 42 selected analyses there tabulated, the phosphorus is given as P in 24 cases and as P_2O_5 in the remaining 14.
‖ This Journal, vol. xxxi, 1861.

visionally referred to francolite. Three of these occurrences in a single slide (No. 62–a) are figured herewith, the actual diameters being from 0·5 to 1·5^{mm}. The mineral is in all cases colorless, without crystal outline (its form being controlled by that of the interstices in which it occurs), no definite cleavage, a complete lack of pleochroism, polarizing if at all only in light and dark colors, sometimes almost completely isotropic, and giving at best poor interference figures indicative of its biaxial nature. The isotropic sections are so colorless and lacking relief that on hasty inspection such might be mistaken for holes in the slide, a glass, or even the problematic maskelynite. Once seen, however, they are readily recognizable. In the three forms here figured the position of maximum extinction is shown by the small black cross. In the case of the larger form, the black brushes of the hyperbola emanating from a point outside the field of view, indicative of its biaxial character, are readily obtained. The phosphatic nature of the mineral has been determined beyond question by the usual microchemical method. An attempt at a quantitative determination was made, but with unsatisfactory results.



Studies of thin sections of the Waconda, Kansas, stone, a redescription of which is in process of preparation, reveal the presence of the phosphate even where it can not be determined microscopically. It was found that when the surface of an uncovered slide was treated for but a few minutes with a dilute acid the solution obtained would react for both calcium and phosphorus, and the slide when again placed under the microscope be found to contain numerous minute and irregular cavities left by the dissolving away of the mineral. A quantitative analysis shows the presence of 0·26% P_2O_5 in the stony portion, or 0·23% in the bulk or mass analysis.

Unmistakable evidences of the presence of the phosphate I have thus far found in the stones of Alfianello, Bath (South Dakota), Bluff, Dhurmsala, Estherville, Farmington, Felix, Homestead, Indarch, Knyahinya, Mocs, Plainview, Pultusk, Quenggouk, Rich Mountain, and Waconda.

These results agree in all respects with those given in my previous paper, and show with seeming conclusiveness that a calcium phosphate is a very general if not universal constituent of meteoric stones, and that, further, it differs from normal apatite in its optical and other physical characteristics, which may be summed up as below, a repetition in part of what I have previously stated:

Occurrence sporadic, without crystal form, very brittle, colorless; cleavage for the most part lacking though sometimes imperfect and interrupted, showing angles of 60° and 120°; optically biaxial and positive (?), birefringence weak, less than 0·005, refractive indices $\alpha = 1{\cdot}623 \pm 0{\cdot}002$ and $\gamma = 1{\cdot}627 \pm 0{\cdot}005$; no pleochroism and often undulatory extinction, polarizing in light and dark colors, sometimes almost isotropic; easily soluble in cold dilute nitric acid and less so in hydrochloric, giving solutions reacting for calcium and phosphorus. The mineral is further distinguished from normal apatite in that it is a product of the last rather than the first stages of consolidation.* Just what meaning and how much importance is to be attached to this different habit of the phosphate in the history of a meteorite it is yet too early to say. Obviously it bespeaks conditions governing crystallization unlike those which prevailed during the consolidation of terrestrial rocks.

For the present it would seem best to designate this member of the apatite group by the name *francolite*, with which it most nearly agrees,† as was done in the paper mentioned above. It may be added that its common presence in optically recognizable quantities suggests the advisability of exercising greater care in the determination of phosphorus and calcium in chemical analyses of meteoric stones.

* In his description of the meteorite of Angra dos Reis, Tschermak mentions the occurrence of abundant small colorless granules, without cleavage, weakly doubly refracting, *uniaxial* and *negative*. These he identified as apatite, a conclusion borne out by the chemical composition of the silicate portion of the stone. The mineral I have described, which apparently is quite similar, is, however, biaxial. The possibility of the apparent biaxial interference figures being those of a uniaxial mineral cut parallel with an optic axis was considered, but deemed wholly improbable from the fact that in not one of the many sections examined was I able to find a uniaxial figure. It seems improbable that among so large a number should not be found at least one, did such exist.

† See Schaller, Bull. 509, U. S. Geol. Surv., p. 91, 1912.