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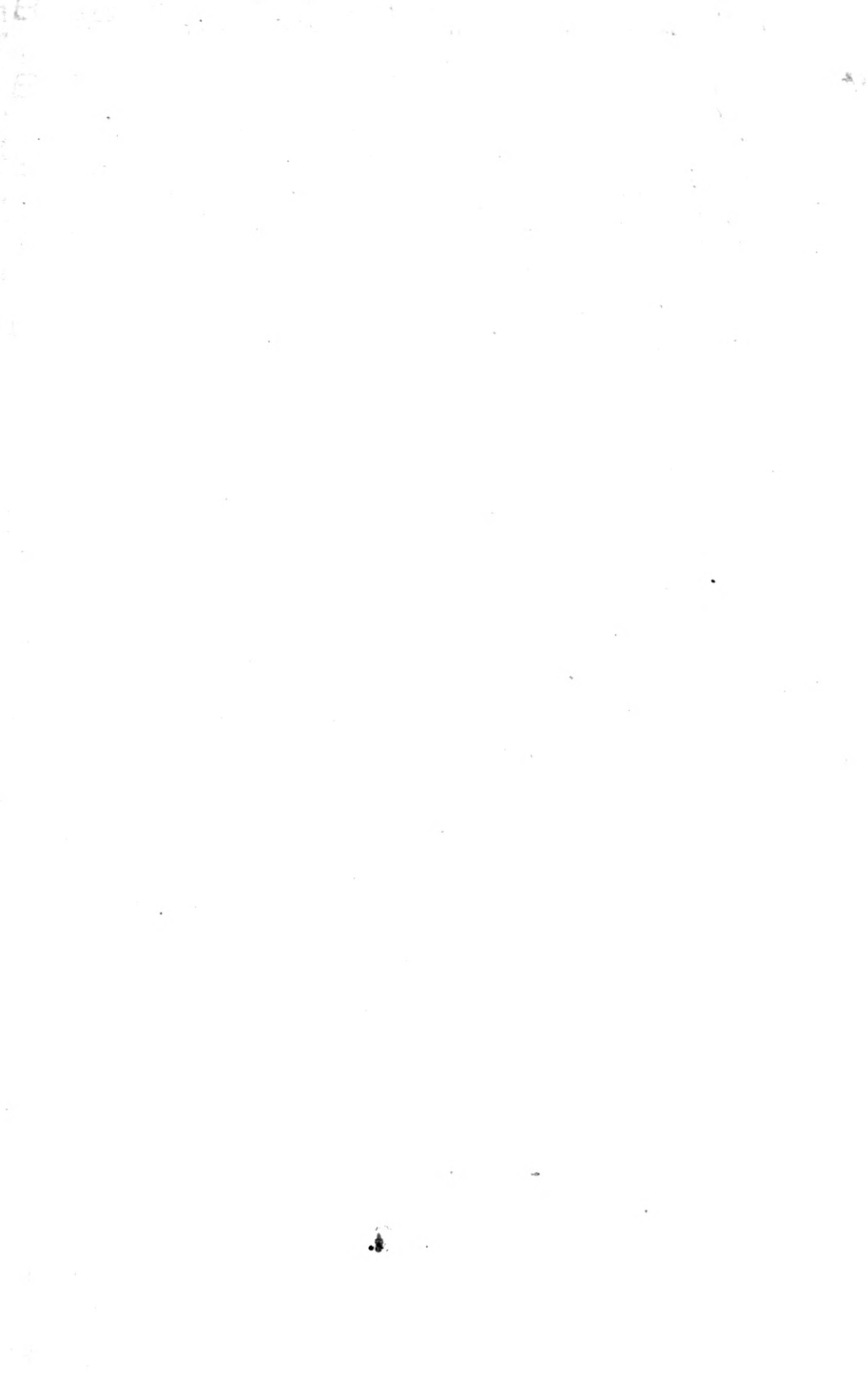
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PUBLICATION 101.

GEOLOGICAL SERIES.

VOL. III, No. 1.

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# THE RODEO METEORITE

BY

OLIVER CUMMINGS FARRINGTON, PH. D.

Curator, Department of Geology.

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CHICAGO, U. S. A.

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# THE RODEO METEORITE.

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This meteorite is an iron mass found about 1852 by a goat-herder in an arroya north of the Nazas River, 12 kilometers northwest of the hamlet of Rodeo, State of Durango, Mexico. The location is approximately  $25^{\circ} 20'$  N. lat. and  $104^{\circ} 40'$  W. long. Upon discovery of the iron it was made to do duty as an anvil at a forge for many years. As received at the Museum, evidence of its industrial use was to be seen in its having been beaten flat and smooth on one side. The surface so treated is apparent in Plate II., by its smoothness and turned-over edges. The meteorite as a whole is irregular in form and without marked orientation. Its extreme dimensions are 12 x 9 x 8 inches (30 x 23 x 20 cm.). Its weight when received was 97 pounds (44.1 kgs.). An attempt had evidently been made at some time to cut off a portion of the mass with a cold-chisel, thus producing the incision shown in Plate I. Above this a small surface appears that was filed smooth for etching. In other respects the surface of the meteorite has the natural contours. The surface in general, though irregular, is everywhere rounded, showing no angular or sharp edges. There are many partially defined pittings of various depths and diameters, the largest of these having an elliptical outline and being 4 inches (10 cm.) in length, 3 inches (8 cm.) in width, and about  $1\frac{1}{2}$  inches (4 cm.) in depth. The position and character of this pit are shown in Plate I. In color the surface of the meteorite is darkened by exposure, but it has nowhere rusted deeply, and in several places the nickel-white color of the metal is visible. In such places Widmanstätten figures often can be seen also. On any polished surface of the meteorite, too, the figures appear nearly as plainly as after etching.

Several complete sections of the meteorite were made in order to determine its interior structure. All show on etching well-defined figures octahedral in character. A photograph of one of these etched sections is shown in Plate III. The bands (Balken) are more numerous than the meshes (Felder), yet the latter occupy a considerable amount of the total area. Through a belt about two inches (5 cm.) in width running across the middle of most of the sections a minutely dotted appearance is presented resembling that described by Brezina

as characterizing Charcas\* and referred by him tentatively to minute inclusions of troilite. An examination of the dots in Rodeo with the lens shows them to be minute, shallow, saucer-shaped pits. They are scattered irregularly along the bands of kamacite, and are to be seen in some of the swathing kamacite, but never in the plessite. The tendency of the iron to rust at these points is greater also than at others. They appear therefore, to mark the occurrence of some more soluble ingredient in the kamacite. This is probably not troilite, but may be an iron containing less nickel than the kamacite. The lamellæ of the meteorite may be grouped into two classes; one about 1 mm. in width, swollen, and with wavy outlines, and the other about half as wide, and with more nearly rectilinear outlines. As a rule, these two kinds of lamellæ have a different orientation as compared with each other. The kamacite is granular, much lighter in color than the plessite. A considerable quantity of swathing kamacite is present. While in general it follows the outline of the inclusions and forms a narrow border to them, at times its outer border is quite independent of the shape of the inclusions and it covers relatively broad areas. The tænite is well developed, silver-white in color, and displays the structure of a section brilliantly on holding one at an angle to the light. The plessite is not depressed by etching as is the kamacite. At times it occupies the meshes alone, while again the meshes may display elaborate combs resulting from skeleton growths of tænite. Scattered irregularly through the sections and forming an important feature in the structure of the meteorite, occur numerous inclusions of schreibersite. The form of these inclusions, especially those of large size, is in general elongated, and rectangular or spindle-shaped. Some of the smaller inclusions, however, are star-shaped, while others have no well-defined form. The largest inclusion noted (shown in the upper right-hand corner of Plate III.) has a length of one and a half inches (4 cm.) and a width of one-fourth of an inch (.5 cm.). The schreibersite is tin-white in color, brittle, and magnetic, and affords the usual blow-pipe and chemical tests for that mineral. The inclusions are always bordered by a band of swathing kamacite about 1.5 mm. in width. The inclusions, while having no apparent regularity of arrangement among themselves, are usually disposed, especially the elongated ones, parallel to the Widmanstätten figures, or in other words, the octahedral structure of the meteorite. This can well be discerned by a study of Plate III. Another inclusion of an interesting character found in one of the sections was a nodule about one centi-

\*Wiener Sammlung, 1895, p. 275.

meter in diameter, of a black, amorphous, friable substance resembling graphite. The form of the nodule in the direction of the section is nearly circular, but in the third dimension its extent is unknown, as it penetrates into the main body of the meteorite, which has not yet been cut. No band of swathing kamacite surrounds the nodule, it being set bodily into the mass of the iron. In appearance and physical properties the substance of the nodule resembles graphite fully, but it is magnetic and fuses in the reducing flame at about 4. Mixed with potassium nitrate it deflagrates readily, but throws out incandescent sparks in addition to the flaming usual to graphite. Potassium carbonate results from the reaction. Oxidation with sulphuric and chromic acids according to the French method\* affords an appreciable quantity of CO<sub>2</sub>. On heating in oxygen the substance glows and becomes of a red-brown color. It was found to be little, if any, attacked by the ordinary acids. After a long treatment with aqua regia, however, and addition of ammonia to the solution, a slight precipitate of iron hydroxide was obtained. When powdered and added to a copper sulphate solution, copper was reduced by the substance. Its specific gravity (obtained by Thoulet's solution) was 2.38. On account of the above properties it would appear that the substance is chiefly graphite, but contains in addition some form of iron, probably a carbide, intimately mixed with it. Such a mixture should exhibit the properties of magnetism, reduction of copper from copper sulphate and insolubility in acids, which are possessed by this substance. Such properties seem not to have been possessed by graphite which has been described from other meteorites. It is common for meteoric graphite to be accompanied by troilite, as has been noted by Smith† and other authors. The Rodeo graphite, however, seems to contain no troilite. A specimen labelled graphite in the Museum collection of what is probably a portion of a "salamander" from the Isabella Furnace, Etna, Pennsylvania, was found to exhibit properties much like those of the Rodeo graphite except that it is heavier, the specific gravity being 5.56, and the structure is foliated rather than compact. Since a "salamander" originates by the accumulation of graphite and graphitic substances in smelting operations, it seems reasonable to suppose that the Rodeo nodule is a similar segregation of graphite originally more or less disseminated in the iron.

An analysis of the meteorite was made by Mr. H. W. Nichols, of the Department of Geology of the Museum. Material for analysis was secured by drilling a half-inch hole to a depth of seven-eighths

\* Blair, *The Chemical Analysis of Iron*, third edition, p. 136.

† *Am. Jour. Sci.* 3, 2, p. 394, 433.

of an inch, and rejecting the drillings from the crust portion. For the determination of iron, nickel, and cobalt, a portion of 1.3733 grams was dissolved in strong hydrochloric acid. Solution took place rapidly and completely, only a few unweighable black flecks being left after oxidation with nitric acid, evaporation to dryness and addition of water. Iron was precipitated three times by treatment with ammonia and ammonium chloride as directed by Fresenius, except that a large excess of the reagents was used. After solution with sulphuric acid and reduction with hydrogen sulphide, the determination was made by the usual titration with potassium permanganate. Copper was precipitated by hydrogen sulphide from the filtrate from the iron precipitate and then determined electrolytically. Nickel and cobalt were separated in acetic acid solution as sulphides and separated by potassium nitrite. Nickel was then determined electrolytically, but cobalt as sulphate, the electrolytic determination of this element having proven at times unreliable. Manganese was tested for in a portion of 2.8248 grams dissolved in nitric acid and oxidized with potassium chlorate according to Ford's method. No precipitate was obtained. The treatment with nitric acid showed the meteorite to be passive until water was added. Sulphur and phosphorus were determined in a portion of 4.8321 grams dissolved in fuming nitric acid by the slow addition of hydrochloric acid. From this sulphur was precipitated as directed by Blair when iron is present, purified by fusion with sodium carbonate, and weighed as barium sulphate. Phosphorus was determined by the acetate method and weighed as magnesium pyrophosphate. Carbon was determined in a portion of 2.5678 grams by oxidation with chromic and sulphuric acids and weighed as carbon dioxide. During the treatment the odor of hydrocarbons was observed, similar to that obtained in the solution of pig iron. This indicated that some of the carbon was present in a combined form, while an insoluble residue showed that some existed as graphite. The analysis gave the following results:

|         |       |
|---------|-------|
| Fe..... | 89.84 |
| Ni..... | 8.79  |
| Co..... | 0.28  |
| Cu..... | 0.07  |
| P.....  | 0.80  |
| S.....  | 0.02  |
| C.....  | 0.09  |
|         | <hr/> |
|         | 99.89 |

The composition of the meteorite is thus seen to be that usual to medium octahedrites, with a high percentage of phosphorus. From

the large amount of schreibersite visible in the sections, such a content of phosphorus would be expected.

Including Rodeo, the meteorites now recognized from the State of Durango are, with dates of their fall or find, as follows:

|  |      |
|--|------|
| Avilez, Spherulitic chondrite, Ce .....                | 1856 |
| Bella Roca, Fine octahedrite, Of.....                  | 1888 |
| Cacaria, Hammond octahedrite, Oh.....                  | 1867 |
| Rodeo, Medium octahedrite, Om.....                     | 1852 |
| Rancho de la Pila, Medium octahedrite, Om.....         | 1804 |
| San Francisco del Mezquital, Siratik ataxite, Ds ..... | 1868 |

The localities of these have been determined as accurately as possible by the writer from various published accounts, and are represented as determined on the accompanying map (Plate IV.). Of these meteorites only one, Avilez, is a stone; the others are all irons. Of the irons, Cacaria and San Francisco del Mezquital are sufficiently distinguished by their structure, Cacaria being a Hammond octahedrite and San Francisco del Mezquital an ataxite. Rodeo and Rancho de la Pila are both medium octahedrites, but the localities from which they come are about seventy miles apart. Hence only Bella Roca needs to be compared with Rodeo in order to determine whether it belongs to the same fall. The localities of Rodeo and Santiago Papasquiario, near which Bella Roca is said to have been found, are in a direct line about forty miles apart. This is much farther than parts of a single meteor could have been naturally distributed according to our present knowledge. That they might have been separated by human agency is possible, but not probable, since the country between these localities is thinly settled and difficult to travel over. From the appearance of the surface of the Bella Roca meteorite Brezina concluded\* that it could have lain exposed but a little while. The Rodeo meteorite, however, is known as far back as 1852. Brezina also describes Bella Roca as a highly oriented individual showing an almost complete fusion crust. Neither of these observations would apply to the Rodeo iron. From the point of view of structure the two irons do not differ essentially. The appearance of the lamellæ is indeed quite similar, with the exception that Rodeo has a preponderance of the wider lamellæ, sufficient, in the author's opinion, to warrant classing it as a medium octahedrite. Bella Roca is classed as a fine octahedrite by Brezina. There is also a similarity between the two irons in the fact that the schreibersite inclusions follow the octahedral lamellæ, in their orientation. The schreibersite in Rodeo,

\* Wiener Sammlung, 1895, p. 271.

however, is considerably stouter in habit than that in Bella Roca. The chief point of difference between the two irons, however, and one which in the writer's view seems alone to warrant their separation, is that in Rodeo there is an entire lack of the inclusions of troilite which form so striking and important a feature of the composition of Bella Roca. Although eight full-sized sections have been made of Rodeo, no troilite has as yet been observed in it. In Bella Roca, however, as is well known, troilite is an abundant and characteristic constituent. The chemical analyses of the meteorites do not show important differences, but this would not be expected as between medium and fine octahedrites. Still the analyses show a relative absence of sulphur and hence of troilite, and abundance of phosphorus and hence of schreibersite in Rodeo, while the opposite condition holds in Bella Roca. The analyses compare as follows, that of Bella Roca being by Whitfield:\*

|                 | Fe    | Ni   | Co   | Cu   | P    | S    | C             |
|-----------------|-------|------|------|------|------|------|---------------|
| Bella Roca..    | 91.48 | 7.92 | 0.22 | —    | 0.21 | 0.21 | 0.06 = 100.10 |
| Rodeo . . . . . | 89.84 | 8.79 | 0.28 | 0.07 | 0.80 | 0.02 | 0.09 = 99.89  |

In view, therefore, of the distance between the localities and the difference in structure and composition, there seems to be sufficient reason for regarding Rodeo as a distinct fall.

\* Am. Jour. Sci. 3, 37, p. 439.



The Rodeo Meteorite.  $\times \frac{1}{2}$ . The incision and smoothed surface in the upper right-hand corner are of artificial origin. The remainder of the surface presents the natural appearance.

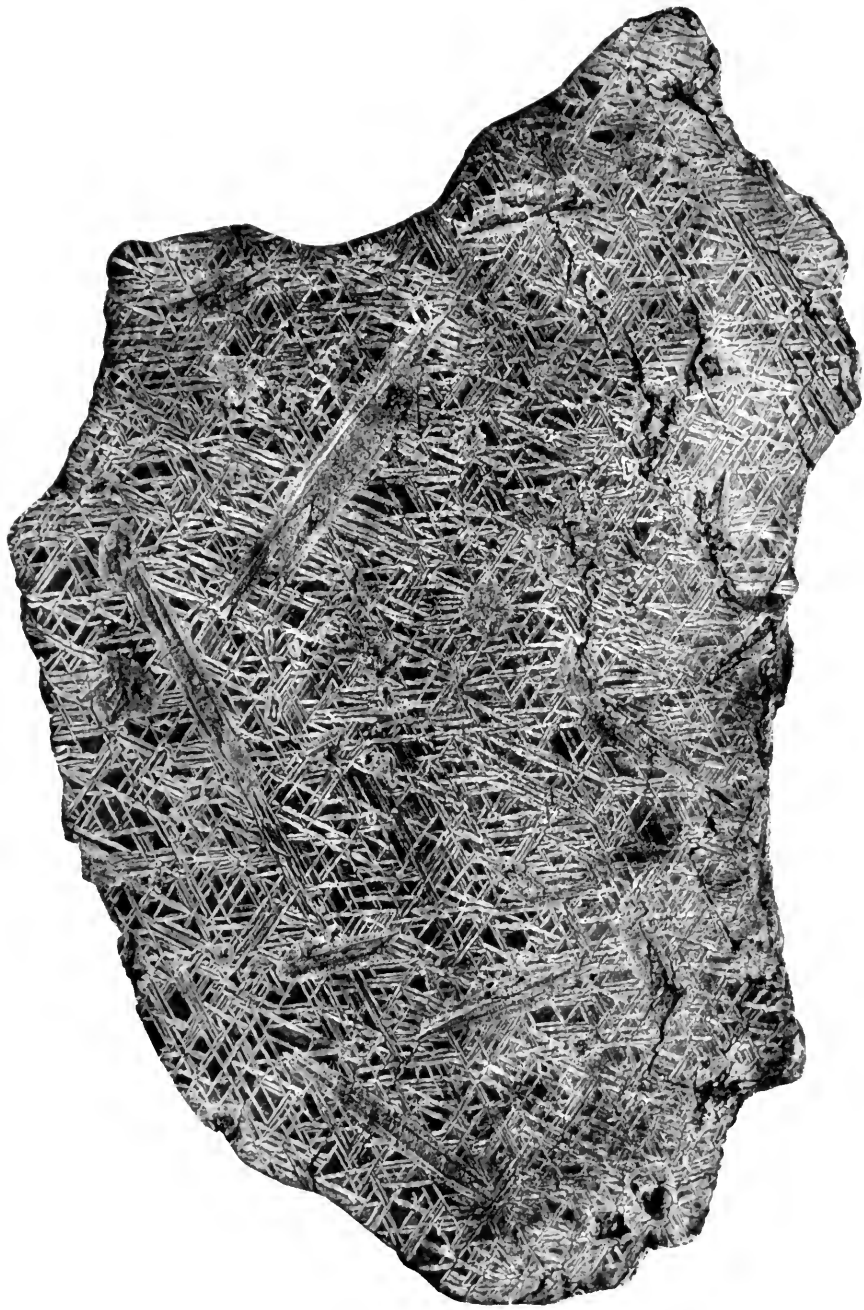
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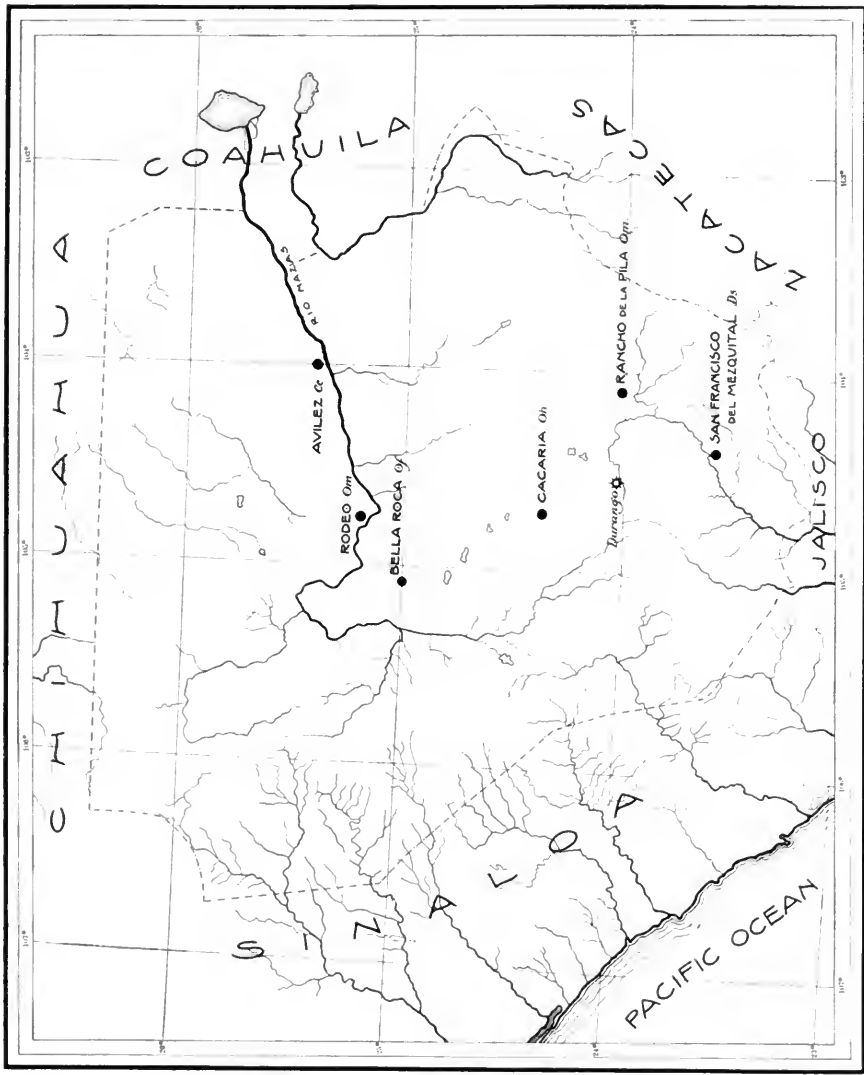
The Rodeo Meteorite.  $\times \frac{1}{2}$ . The smoothed surface at the left is due to the use of the meteorite as an anvil.

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Etched section of the Rodco Meteorite.  $\times \frac{5}{8}$ . The inclusions are schreibersite surrounded by swathing kamacite.

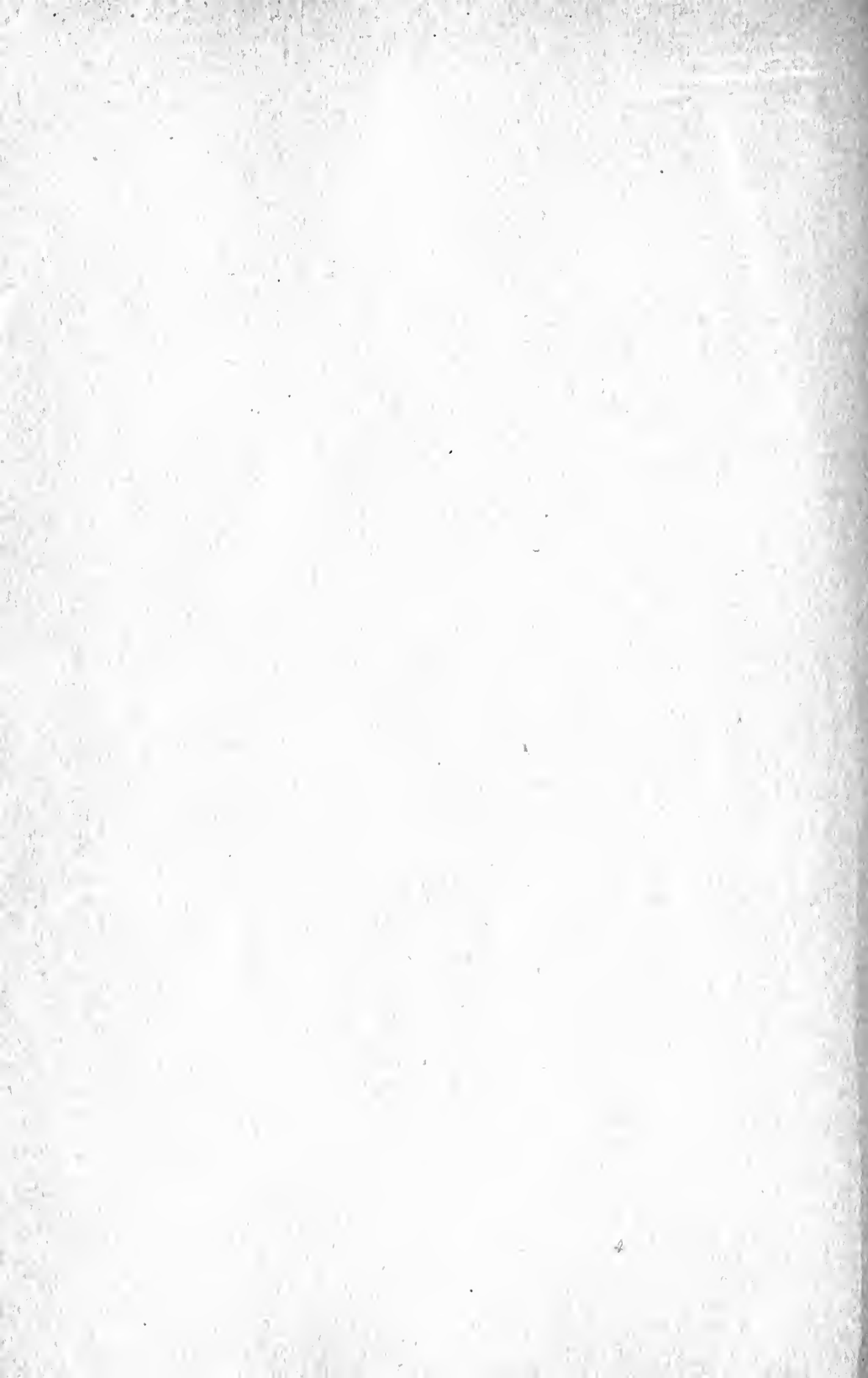
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Map of the State of Durango, Mexico, showing location and character of known meteorites.

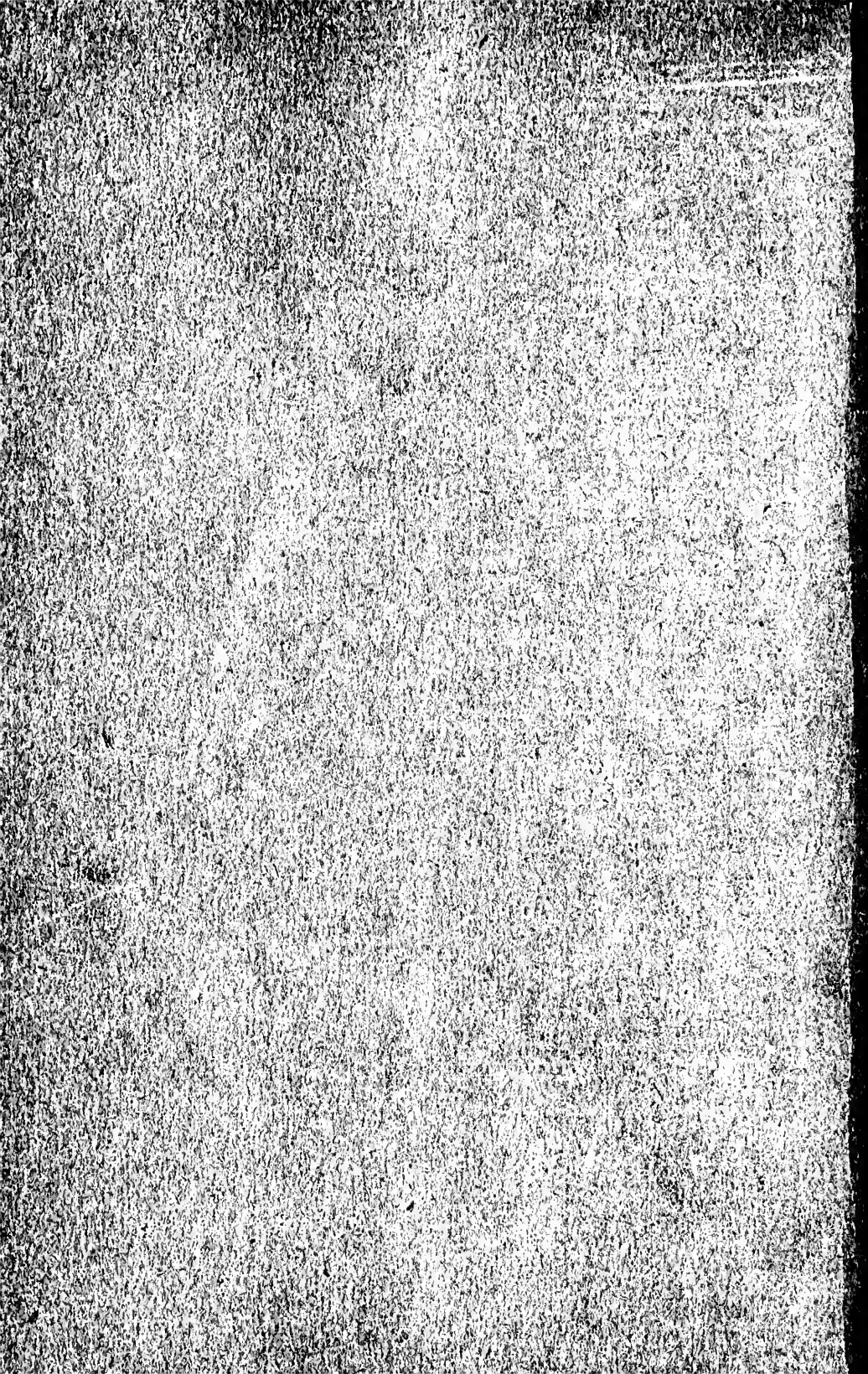
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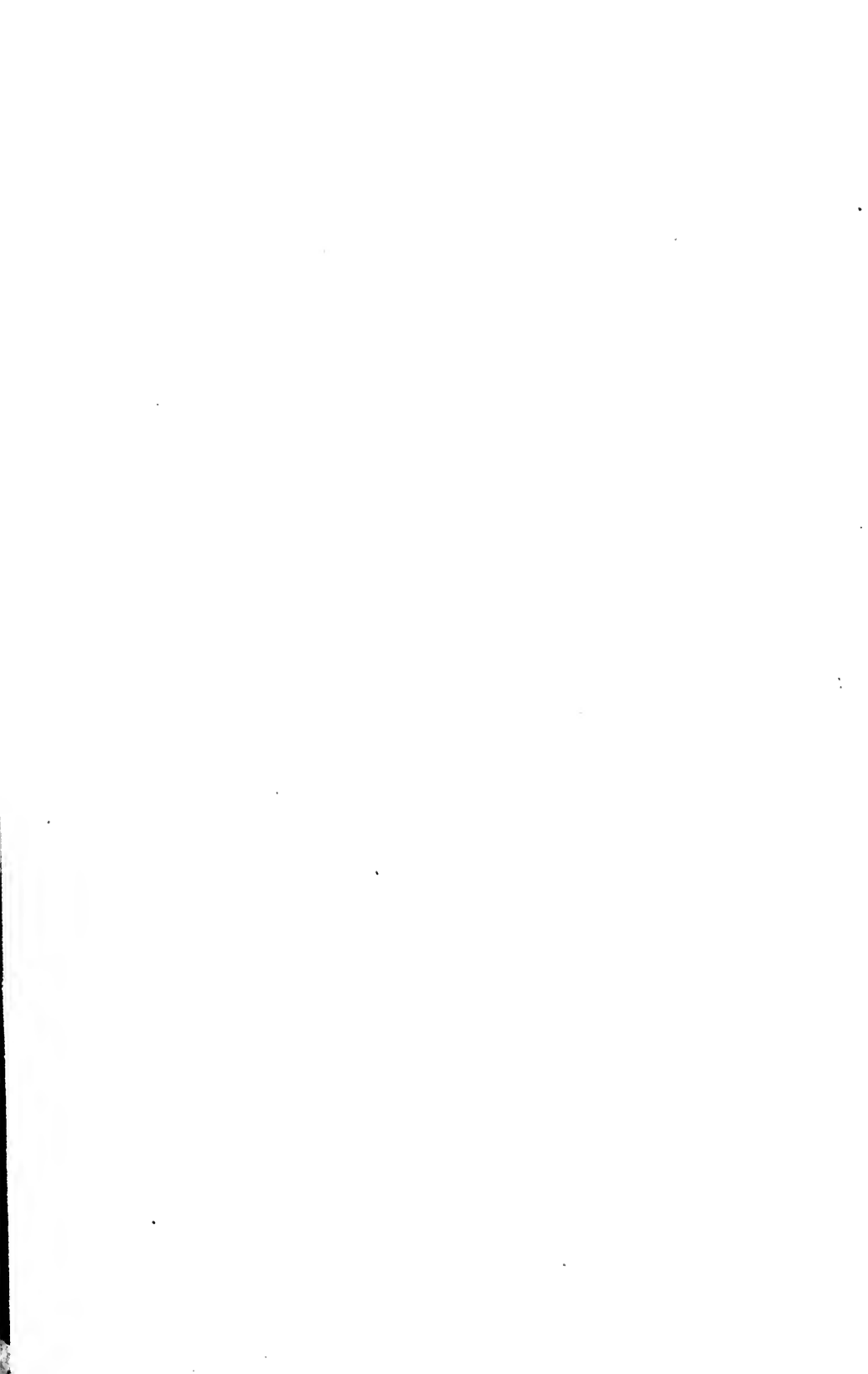




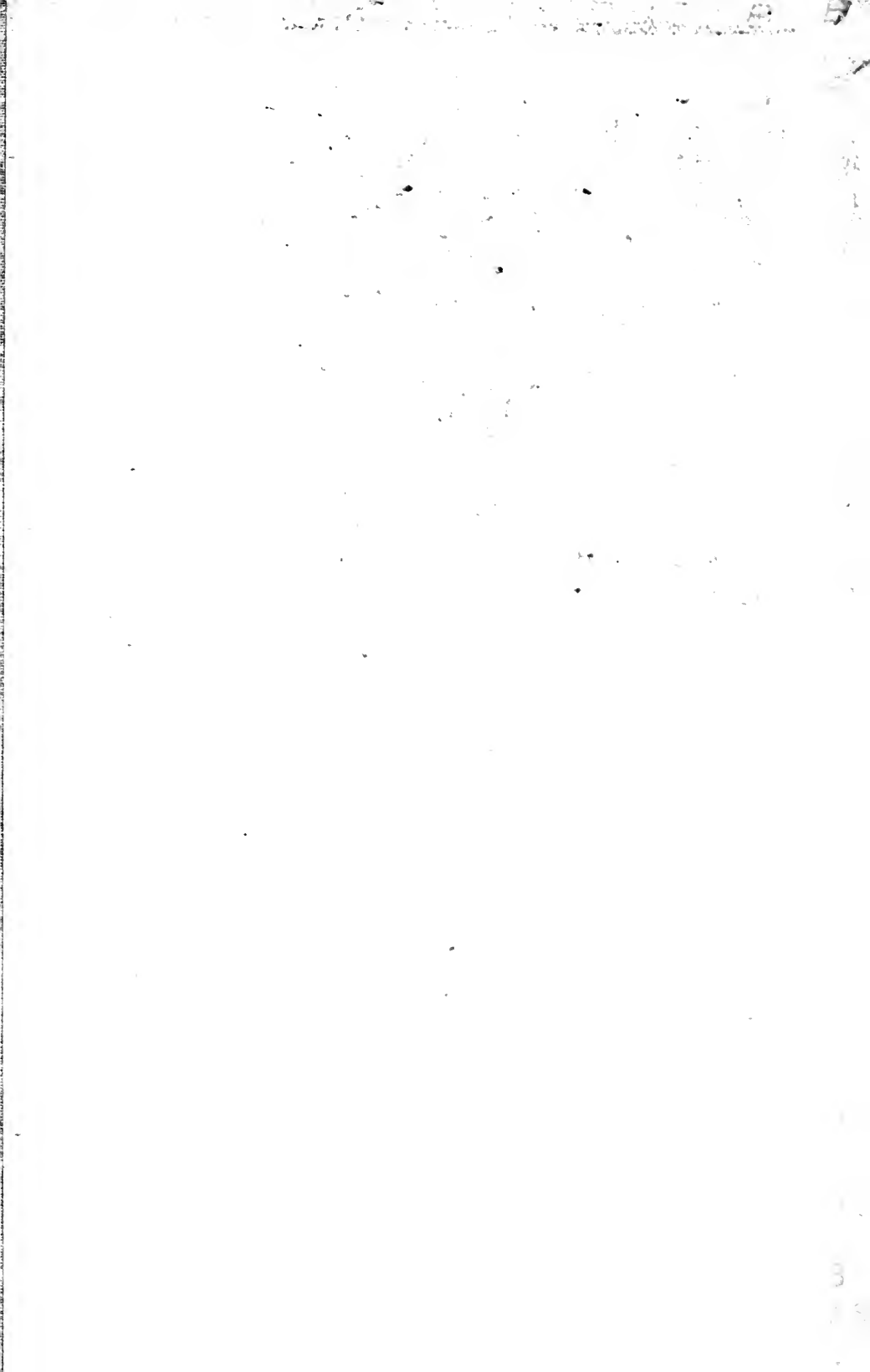












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