THE PHYSICAL CHARACTERISTICS OF THE ELEMENTARY GRAINS OF A PHOTOGRAPHIC PLATE.*

BY

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WHEN we speak of " grain " in a photographic plate, we generally use the term in a rather loose sense. We employ it to denote, in a general way, both the characteristics of the individual granular deposits of silver and the arrangement or agglomeration of these constituent particles, as an entirety, with sometimes emphasis on one phase of the subject and sometimes on another.

It is the purpose of the present paper to sharply differentiate between these two phases by outlining a few fundamental conceptions of plate grain; also to present some of the more interesting data obtained in the study of the elementary particles of a silver halide emulsion.

There are present, in nearly all developed and dried photographic plates, deposits of silver of varying size and shape. On close examination it is found that these deposits are made up of small elementary units, which in a high-speed plate negative vary in size, from the ultra-microscopic to five or six microns in greatest dimension, the average variation being from 0.2 μ to 4 or 5 μ, and the mean size about 2.5 μ.

Fig. 1 shows a photomicrograph of a section of a high-speed photographic negative, illustrating these elementary units. These elements are grains in the strict sense of the term, for, as will be shown later, they are inherently conditioned in position and size by the position and size of the original silver halide grains. That is, they are to a certain extent isolated from each other by intervening walls of gelatine.

In viewing a dried down negative, however, by transmitted light, under moderate magnification, or none at all, we see not these isolated grains, but, in effect, agglomerations of grains by the projection of light through interstices between many grains in numerous " grain planes " throughout the emulsion layer. Therefore since the average layer is about six grains deep, and

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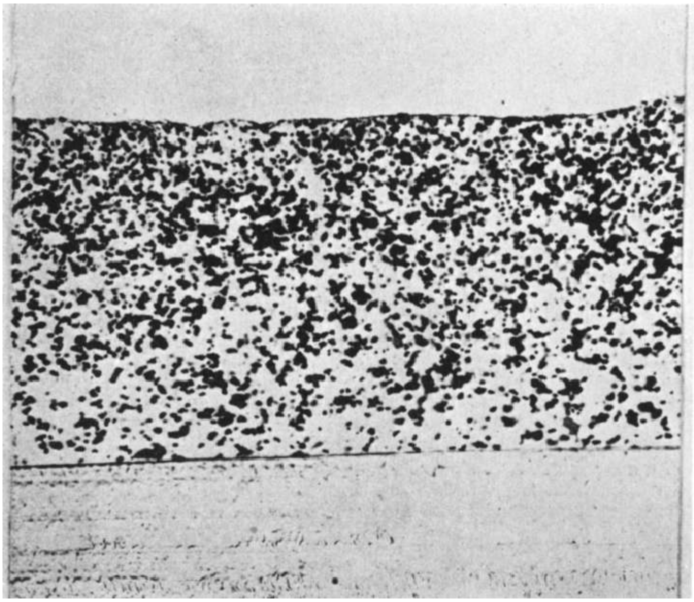
since the grains themselves are distributed on a probability basis in each layer, we obtain more or less regular large patches and chains of grains as a result, the pattern and regularity depending on the particular type of emulsion used.

It is this granularity which makes up what is commonly meant in speaking of grain. It is the grain met with in projection work, in enlarging and in portraiture.

FIG. 1.



Section showing individual silver grains. Magnification, 350 diameters.

This overlapping and agglomerating of grains can be seen nicely by observing a horizontal plane view of a photographic film through the entire emulsion, in comparison with a thin vertical section through the same film (Fig. 2).

It is not the purpose of this paper to discuss the matter of plate granularity, meaning agglomeration of individual grains, which phase of the subject is now the subject of investigation in this laboratory.

As has been stated, the physical characteristics of the developed elemental grains depend largely upon the characteristics of the elemental silver halide grains.

Silver bromide occurs, in the average emulsion, in the form of more or less regular semi-transparent crystals belonging to the isometric system, the most regularly recurring figure being the tetrahedron. The larger grains are evidently builds or aggregates of hemihedral tetrahedra or other imperfectly developed forms. In addition there are present numerous fragmentary and truncated particles.

The physical characteristics of these grains seem to be controlled by the method by which the silver bromide is precipitated, on the temperature of precipitation, amount of gelatine present, concentration and presence of additional salts.

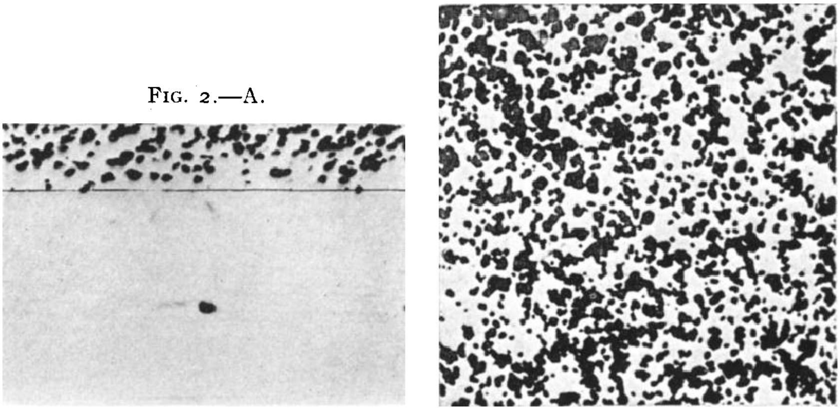


FIG. 2.—A.

FIG. 2.—B.

"A," vertical section, showing grain-deposit. "B," horizontal plan of grain deposit. Magnification, 375 diameters.

A fairly accurate idea of the size, etc., of these crystals will be gained from the values given in Table I, which gives the physical characteristics of four typical emulsions.

TABLE I.

Plate	Average grain size*	Range in grain size†	Shapes
Cine Positive Film	1.0μ	0.2 – 2.0μ	Regular, uniform
Seed 23 Plate	2.0μ	.2 – 3.5	Regular, uniform
Seed Graflex Plate	3.2μ	.2 – 6.0	Irregular, wide variety
Special Experimental Emulsion	4.0μ	.2 – 8.5	Very regular, variety

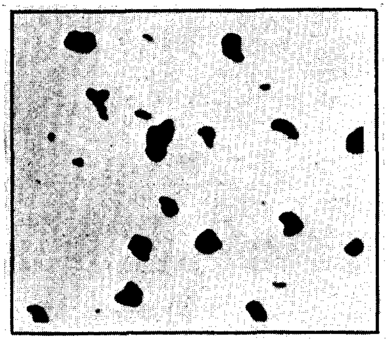
* Greatest dimension.

† Resolved.

The fragmentary grains are very numerous in nearly all emulsions. The special experimental emulsion referred to in the above table proved to be very adaptable for the study of individual grain characteristics, its great regularity in shape and freedom from fragments reducing confusion in microscopic examination to a minimum. However, it does not differ greatly, except in this matter of regularity, from the performance of other emulsions, hence the author feels justified in basing certain conclusions on the performance of this emulsion.

The question has often arisen: Are these unexposed grains crystals of pure silver or are they composed of a gelatino-silver complex? From the results of this investigation it seems logical to assume that the inner mass of the grain is pure silver salt, for when water strikes the unexposed crystals no swelling is at all observable, even under the highest power magnification. However, in the majority of cases, when development is complete, the silver deposit is vastly different in form from that of the parent crystal. During development the growing silver mass becomes twisted and distorted. This suggests strong external forces at work, probably due either to an adsorbed layer of gelatine or to almost perfect adhesion to the surrounding gelatine. In the silver bromide crystal, even when water is present in the system, this strain is insufficient to break down the cohesion of the particles of the crystal and distort it, but when the spongy deposit of silver begins

FIG. 3.

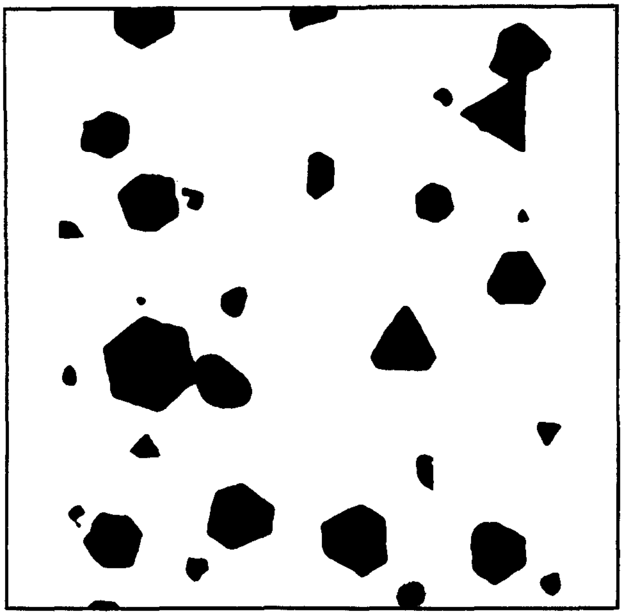


Developed grains. Seed graflex. Magnification, 1350 diameters.

to form, in soot-like particles, the enveloping " bag " of gelatine more or less distorts it.

In the average high-speed plate this distortion is great, causing the developed grains to resemble black popcorn or irregular chunks of coal. In the plate " Special No. 1 " this distortion is at a minimum, the developed deposits being almost entirely within the confines of the original crystal. Figs. 3 and 4 illustrate these typical extreme cases. From Fig. 4 we can also gain information as to the geometrical form of the parent crystals.

FIG. 4.



Developed grains. "Spec. No. 1." Magnification, 1350 diameters.

As has been previously stated, these developed grains are masses of fine, sooty black silver, held together by the surrounding gelatine. They may be separated by swelling the gelatine or by applying other mechanical force.

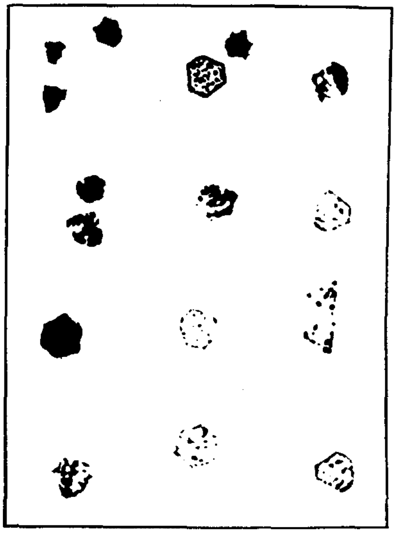
The progress of the development of individual grains has been studied in detail by the following method:

Regularly coated plates were flashed to light, developed slightly, and washed thoroughly to arrest and remove developer.

Some of the emulsion was then removed and examined under high-power magnification. Fig. 5 shows a number of such grains at various stages of development. In most cases development starts at considerably more than one particular point, even in the case of small fragments, and continues (providing time is allowed) until the entire crystal is reduced.

In no case of normal procedure has a curious phenomenon described by Scheffer[1] been observed. Scheffer described and illustrated the development of silver bromide grains under high-power magnification. He showed that in his specimens the grains shot out, or grew, feelers or tentacles during development. These tentacles were subsequently capable of affecting other silver bromide grains, inasmuch as contact seemed to cause developability.

FIG. 5.



Silver bromide grains in various stages of development. Magnification, 1350 diameters.

In only one particular series of enormous overexposures, developed under the arc illumination of the microscope, have any such phenomena been observed by the author. The emulsion in the case in question was coated in a very thin film on the micro-

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[1] W. Scheffer, "Microscopical Study of Silver Grains," *British Journal of Photography,* 1907, No. 2441, vol. 54.

slide. The primary cause of the shooting out of feelers was here considered to be due to channels or fissures opening up in the gelatine when the developer struck it. In the case of normal thickness of coating (10 to 30 microns) the elastic action is gradual enough in the case of drying after coating and in subsequent swellings to allow time to adjust internal strain. In the case of extremely thin coatings, drying, after the original coating, is far too rapid to permit of equalizing of strain. Such strain regions, in all probability, being greatest in the neighborhood of such " foreign " particles as silver bromide grains, subsequent sudden swelling results in a cleavage at these points. At least the case was special and decidedly abnormal in conditions of

FIG. 6.

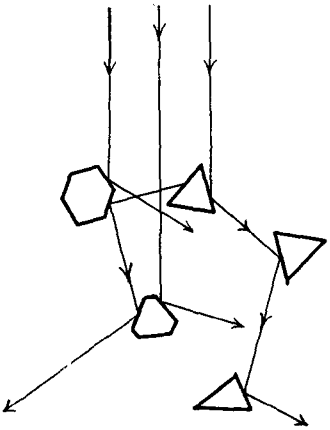
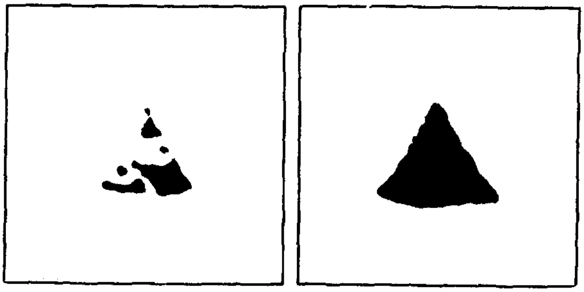


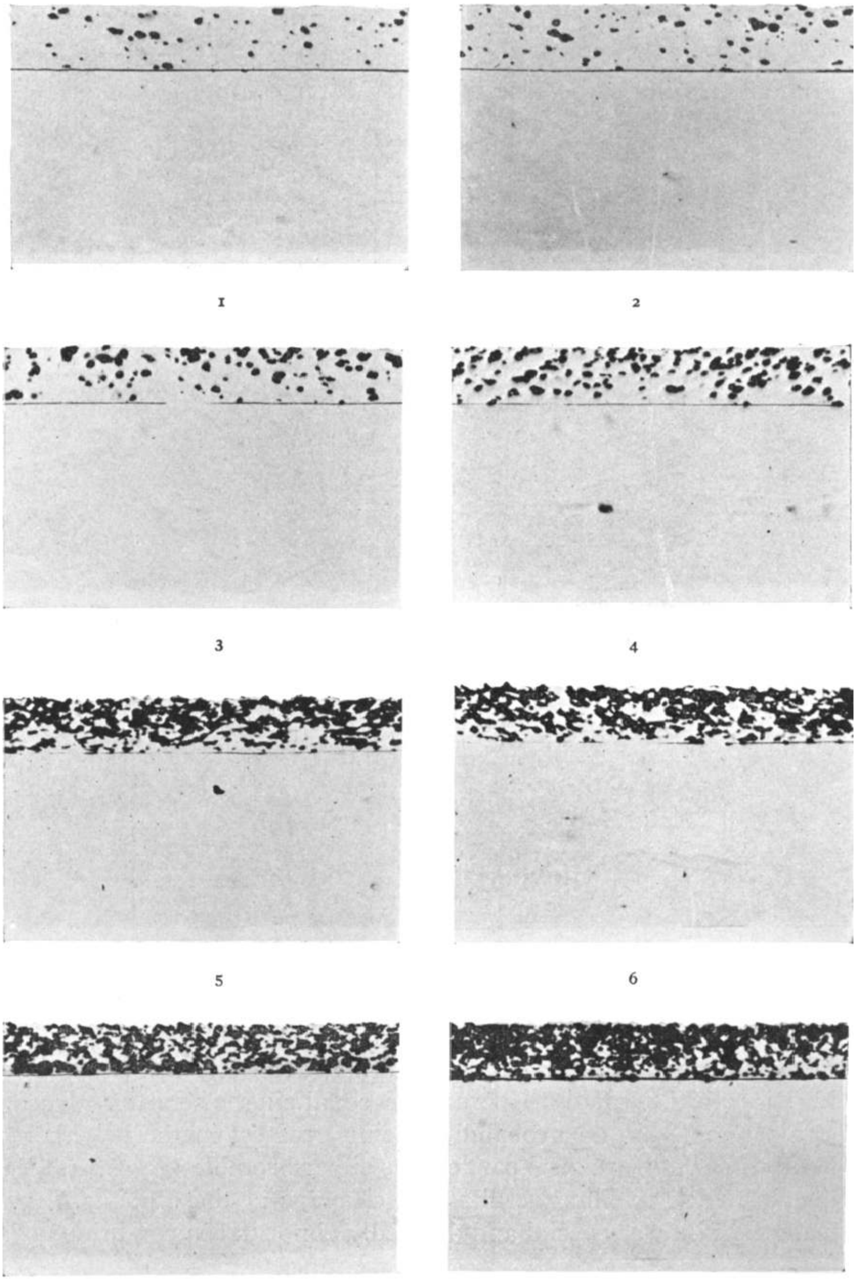
Diagram representing scatter of incident light by silver bromide crystals.

FIG. 7.



Stages of development of single grain. Magnification, 5000 diameters.

FIG. 8.



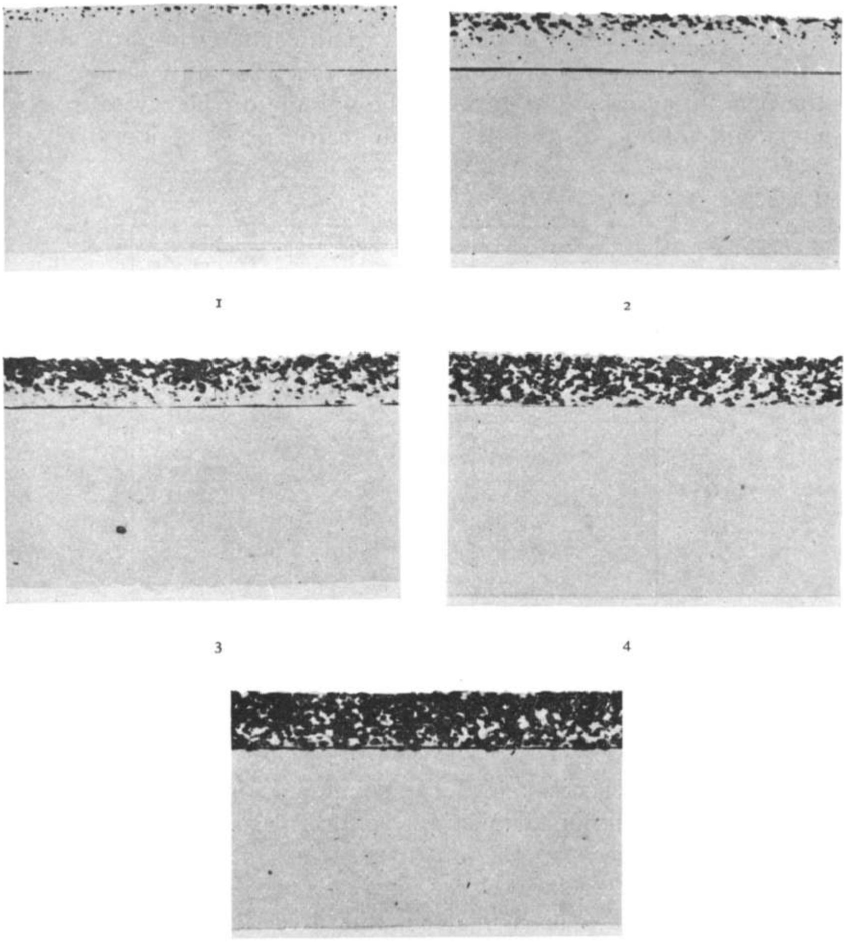
1 2 3 4 5 6 7 8

Series of vertical sections (dry), showing growth of image with exposure. Magnification, 375 diameters.

exposure, physical characteristics of the emulsion layer, and development.

In all cases of normal conditions development seems to be a more or less steady transition from silver salt to reduced silver, with the gelatine functioning to cause some distortion of the shape of the individual deposits.

FIG. 9.

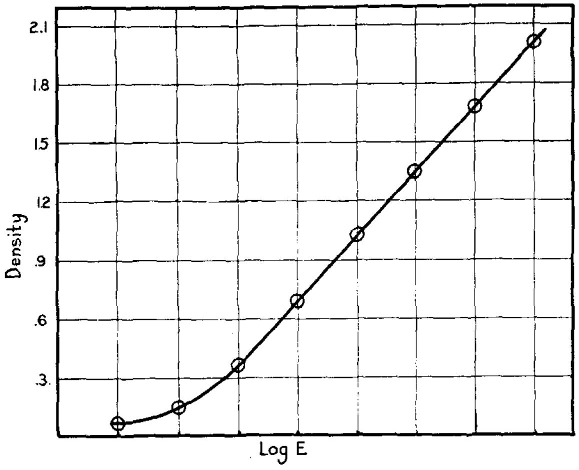

1 2 3 4 5

Series showing growth of image with development. Magnification, 375 diameters.

Since the development of a grain starts at a number of points at once, it follows that there must be formed, even in a short exposure, numerous nuclei. This is not to be wondered at when we consider the scatter of light by the emulsion layer (Fig. 6). Probably thousands of molecules or crystal units of each grain are affected by such a seemingly simple exposure.

Two stages of the development of the same grain are shown in Fig. 7. The developed grain in this case is slightly larger than the parent crystal. The ratio of the volume of the crystal to the apparent volume of the developed grain is a function of both inherent characteristics and development. In nearly all cases the developed grain occupied apparently more space than the crystal—"apparently," because the inner mass of the developed grain probably contains gelatine.

FIG. 10.



Hurter and Driffield curve of strip of which sections are shown in Fig. 8. Circles indicate densities of sectioned parts.

No attempt has been made in this investigation to correlate the performance of individual grains with the behavior of the sensitive film as a whole.

The effects of exposure and development and developer on the entire mass, and a study of the resulting "graininess," has not been touched on. However, in the sectioning of dry film to study grain size some interesting photomicrographs were obtained which are shown in Figs. 8 and 9. Fig. 8 shows a section of each step of a Hurter and Driffield test strip whose *D*-log *E* curve is given in Fig. 10. The developer in this case was pyro-soda. The density gradient in each case is somewhat surprisingly shallow.

Fig. 9 shows the developing stages of equal exposures after varying times of development. Many of the fine grains at the lower edge of the image are no doubt parts of large crystals whose development was arrested.

In conclusion I wish to express my indebtedness to Mr. L. A. Jones and Dr. S. E. Sheppard for numerous helpful suggestions given during the course of this investigation.

ROCHESTER, N. Y., September, 1917.

The Elimination of Grade Crossings in Cities. S. T. WAGNER. (*Transactions of the Wagner Free Institute of Science of Philadelphia,* vol. viii, July, 1917.)—A grade crossing is generally understood to mean the crossing of a railroad by a highway when both are at the same level. The same term is applied to the crossing of one railroad by another at the same level. The existence of grade crossings is a necessary evil. When railroads were first constructed in places where the grade crossing is now in existence, there was no other way in which many of these could have been built. At the time the railroads were built, neither the railroads nor the communities which have grown into towns and finally into cities would have been able to bear the expense of construction which would have avoided the crossings at grade, and their existence was therefore an economic necessity.

The history of the work of systematic elimination of grade crossings possibly extends back to about the year 1880, although it did not begin to be considered an important subject until within the past twenty years. During the past fifteen years progress has been steady, and the movement toward the elimination of the most dangerous ones has been rapid on the part of the cities and the railroads. Probably the most extensive work of that kind has been done in the city of Chicago, where, on account of the level character of the ground and the large number of railroads, the conditions are worse than in almost any of the large cities of the United States. It is stated that the elimination of 780 grade crossings had been arranged for in Chicago up to 1911. Philadelphia is credited with the next largest number, namely, 120, and Buffalo third, with 94 to its credit.

In general there are six methods by which a grade crossing can be abolished: (1) Raising the street over the railroad; (2) lowering the street under the railroad; (3) lowering the street and raising the railroad; (4) raising the street and lowering the railroad; (5) rais-