MICROSCOPIC EXAMINATION

OF

SAMPLES

OF

COMMERCIAL ARSENIC,

AND THE

Practical Results to which it Leads.

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INTRODUCTORY NOTE.

The question as to the possibility of distinguishing, by means of the microscope, between samples of arsenic from different sources was first raised, so far as my knowledge extends, in connection with a recent criminal trial in Connecticut.† The suggestion, that such a result was probable, was made by Dr. M. C. White, of New Haven, and in a preliminary examination he satisfied himself that the two samples of arsenic placed in his hands did differ in one or more important respects. At this point I was called upon to carry forward the investigation, and, in this paper, I shall endeavor to state the results reached. I shall have reference to the question in its general bearing rather than to the special application which was, for the time, of immediate interest. For the assistance, however, of those who may have followed the testimony in the case, and have become in this way familiar with the names there employed for the kinds of arsenic under examination, I shall refer occasionally to these same samples, calling them *A*, *B*, *C* and *D*, respectively. They were known as the

Barn Arsenic, ... *A*.
Colgrove Arsenic, ... *B*.
McKee Arsenic, ... *C*.
Stomach Arsenic, ... *D*.

The quesions put to me were: 1. Could the Barn and Colgrove (and McKee) samples have come from the same source? 2. Could

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† State *vs.* Hayden.

this have been true of the Colgrove (and McKee) and the Stomach arsenic? The answers given to these questions will be inferred from the statements in the following pages.

THE TWO KINDS OF WHITE ARSENIC.

For the benefit of the non-professional reader, it should be clearly stated at the outset that there are two distinct kinds of white arsenic, or arsenious oxide, well recognized in chemistry. One of these is a white, transparent, *crystalline* solid, occurring in crystals which belong to the isometric or regular system, the commonest form being the octahedron. This variety has a specific gravity of 3.69.

The second kind of white arsenic is an *amorphous* substance, transparent and glass-like when freshly made, but changing gradually, on exposure, to a white mass looking like porcelain. This change begins at the surface and extends gradually to the interior; it is believed to be the result of a molecular alteration from the amorphous to the crystalline condition. The specific gravity of this second variety is 3.74, or, in other words, it is slightly heavier than the first; it is also a little more soluble in water.

Whenever white arsenic, of either kind, is volatilized by heat, or when a substance containing metallic arsenic is heated in contact with the air, so that the vapor of white arsenic is produced, this vapor will, on cooling, condense to the solid form and usually to the crystalline variety, yielding in most cases brilliant and perfect octahedral crystals. If, however, the temperature of the surface on which the condensation takes place is above a certain point, or if the condensation goes on under pressure, then the amorphous or glass arsenic is produced.

METHOD OF MANUFACTURE.

If any one of the ordinary works of reference were to be consulted for information as to the method of manufacturing commercial arsenic, with a view to discovering the probability of there being an easily recognizable distinction between samples made at different times or at

different places, the knowledge thus obtained would lead to a conclusion in the negative. The process described at length in *Watt's Dictionary of Chemistry*, or in *Ure's Dictionary of the Arts*, for example, is one which would seem to require a uniform final product. This process, in a word, consists in the resublimation of the previously sublimed and purified arsenious oxide, under such conditions as to lead to the formation of the amorphous or glass variety. This material, as it comes from the furnace, forms a layer, an inch or so in thickness, on the interior surface of the conical iron vessel in which the vapors were condensed. It is broken from the iron with chisels, and in this lump condition is, in part, sent to the mill to be ground, and a part is also put in the market as "lump-arsenic." If, now, all the pulverized white arsenic of commerce were—as the books named imply—obtained from the grinding of the amorphous or glass-arsenic, it must consist—as seen under the microscope—of minute formless grains; if pure, there could hardly be any distinction between different samples, except, perhaps, those produced by slight variations in the action of the mills, and the detection of these would be very improbable.

The first preliminary examination with the microscope of samples of ordinary white arsenic, from various drug-stores, showed me that the material did not correspond to what my previous knowledge had led me to expect. On the contrary, the arsenic consisted, in almost every case, not of minute irregular fragments exclusively, but rather of perfect octahedral crystals, often as a very large proportion of the whole. This observation made it at once evident that an additional explanation, beyond that which could be derived from the books, was needed for a full understanding of the subject. Several attempts were made to gain information from the localities in Germany and England where arsenic is manufactured. From the former, I learned simply that the lumps of the glass-arsenic, before grinding, often contained minute crystals in the cracks, which were probably formed during the latter part of the process of condensation. It was suggested that in this way the presence of the crystals in the ground product might be explained; and, on this supposition, the irregular lumps would have

to be taken as fragments of the glass-arsenic. There are certain samples of commercial arsenic (in Group VI., beyond,) for which this explanation would answer very well; it is, however, obviously inadequate to account for those which consist almost entirely of perfect crystals.

From England, through the kindness of Dr. C. LeNeve Foster, of Truro, Cornwall, I obtained several samples of the completed product from two prominent arsenic works, and also one of unground arsenic as ready for the mill. This last I found to be entirely *crystalline*, the crystals varying somewhat in size, and being more or less perfect in their development. This fact gave the explanation that was needed, for it became evident at once that the process of manufacture must be quite a different one from that above mentioned as being given in the books of reference. This is true for the arsenic as made in England, from which source most of that imported into America is said to come. It should be added that the description of processes given in *Watt's Dictionary of Chemistry*, for example, is expressly stated to be that employed at Reichenstein, Silesia, and the fact that arsenic is manufactured in large quantities in England is mentioned briefly, without further remark.

It will be evident from what has been said, that, in order to explain the differences between samples of arsenic revealed by the microscope, it was very important, at any rate from a scientific point of view, that the conditions of manufacture should be known as fully as possible. With this object in view, I visited, during the past summer, the prominent arsenic manufactories in England. One of these was at the Devon Great Consols mine, near Tavistock, Devonshire; and the other, known as the "Garland Works," was at Bissoe, near Truro, Cornwall. These were taken as representative establishments, and moreover, because, of two test-samples involved in my examination, one ("Colgrove Arsenic," or *B*,) was stated by the importer to be the "Garland" brand; and the other ("Barn Arsenic," or *A*,) was similar to samples sent to me from Tavistock by Dr. Foster. Through his kindness, and that of the gentlemen connected with these two places, I

was enabled to inspect, as thoroughly as circumstances permitted, the successive steps in the process of manufacture.

I will state here the results of my observations, so far as they are needed for the complete understanding of the points raised beyond:

The white arsenic manufactured in England is obtained mostly from the mineral arsenopyrite, also called mispickel, or arsenical iron, which is associated with the ores of tin and copper. One of the essential steps in the treatment of these ores, from which the useful metals are to be obtained, is the process of roasting. This consists, as is well understood, in the subjection of the pulverized ore, freed from gangue by washing, to a high temperature, commonly in a reverberatory furnace. By this means, the arsenic and sulphur, in combination with the metals, go off in vapor, as arsenious and sulphurous oxides, and the arsenious oxide is condensed in a series of chambers or flues. Thus each mine, where the ores are roasted, has its arsenic flues in which the white arsenic is obtained in greater or less quantities, and in varying grades of impurity, according to the character of the ore. The condensed product, taken at intervals from the chambers, is the *crude arsenic*, also called arsenic flour, or arsenical soot ("Giftmehl" of the Germans.) It varies in color from light gray to black, according to the amount of impurity present, and, in all cases, must be refined before it is fit for the market. This is sometimes done at the same works, as at Tavistock, but, more generally, it is sold to the refiner, who thus obtains his crude arsenic by purchase merely. It should also be added that, in the former case, ores, which are of value only for the arsenic they contain, are roasted for this.

The crude arsenic is refined by introducing it into another furnace, or series of furnaces, where it is again volatilized by the heat. When it condenses in the long series of chambers through which the vapors are carried, it is, if the process is fully successful, in the form of a perfectly white crystalline solid, which needs only to be ground and packed in kegs, to be made ready for the market.

The unground arsenic is, as stated, all in the *crystalline* condition, the temperature of the chambers being too low to allow of the forma-

tion of the glass variety. I should add, however, that at some localities, at the Garland works, for example, the glass-arsenic is also made as a special product, in the manner alluded to on an earlier page. This glass-arsenic is put on the market in the lump form, where it commands a higher price than the common kind. It is in demand for various purposes in the arts, and, as remarked later, is subsequently ground and sold to druggists, in cases where an article of known purity is required.

At each of the two works mentioned, I was able to examine the piles of arsenic ready for grinding, in the mill-room, and also to take from the closed chambers, then in operation, a small quantity of the material which had just condensed. Further than this, at Tavistock, I examined, with some care, a series of open chambers, from which the condensed arsenic had been in part removed. The accumulated heaps of unground arsenic consisted largely of a very fine flour-like powder, made up, as afterwards proved by microscopic examination, of extremely minute, perfect octahedral crystals; in the case of one sample taken from a closed chamber, these were uniformly from $^1/_{1000}$ to $^1/_{2500}$ of an inch in diameter. In addition to the powder, there were also masses of considerable size, in part coarsely, and in part finely crystalline. These were more or less coherent, having some little firmness, and yet soon falling to powder when handled. In them, the crystals were only in part perfect in form; more generally, they had grown on to each other, so that they presented a broken appearance when examined in the powder, under the microscope. In addition to these, there were also, in many of the chambers, festoons of crystals, or groups of crystals, sometimes of several inches in length, and hanging to the roofs or walls, and presenting, when untouched, a very beautiful appearance.

It would be a question of great interest, at least scientifically, as to the distribution of this crystalline product through the series of chambers. The conditions which determine the size of the crystals—whether they form, as a large part do, the perfect isolated ones, in the open space of the chamber, falling snow-like to the ground, or whether

they grow gradually together from the sides and roof—must be varied and intricate. Prominent among them are certainly the following: The temperature of the arsenical vapors, and the rapidity with which they lose their heat, which must vary somewhat with the heat of the furnace, and possibly when, as at Tavistock, the line of chambers are quite exposed, with the temperature of the surrounding air; also, the density of the vapor, which must diminish as more and more of the arsenic is deposited; and also the presence of various amounts of impurities, as, for example, sulphurous fumes. If a series of careful observations should be made, when the chambers are opened each time, through a number of months, some valuable data could certainly be obtained. But, in the absence of definite facts of this kind, it would be idle to attempt to speculate.

If, now, attention be turned to the process of grinding the arsenic, the bearing and importance of the facts stated in regard to the size of the crystals and crystalline masses in the unground material will be at once obvious. The stones employed in the mill are rather coarse and not set very near to one another. The consequence of this is, that they do not reduce the crystals, large or small, perfect or imperfect, to a uniform, impalpable white powder, as could be readily done in an agate mortar for example. On the contrary, the small crystals go through the mill untouched, losing nothing of their brilliancy of lustre or perfection of form, while the large crystals, whether originally perfect or not, are crushed to fragments, which, in general, show little or no trace of their original crystalline form. The conclusion to which we come may be stated thus:

If the unground arsenic, like that described as a flour-like powder, were entirely made up of minute independent crystals, it would go through the mill without essential change—such a sample of commercial arsenic when viewed with the microscope would be sure to still consist for the most part of small perfect crystals.

If, on the other hand, the unground material were all of it coarsely crystalline, this would be crushed by the stones, and the completed product, examined as before, would be found to consist of irregular

broken fragments with also the much finer dust of attrition; there would be no perfect crystals.

These are the two extremes. In practice it is obvious that both fine and coarse matter must exist in the unground arsenic, and hence the ground article must contain both complete crystals and broken fragments, or lumps. The importance, then, of a series of observations of the kind mentioned and extending over a considerable length of time, is this, that it would make it possible to predict with confidence the final result in every case. It cannot be questioned that the contents of the separate chambers must vary more or less from one another, and again, that those of the same chamber, at a given distance from the furnace, cannot be entirely constant, and these differences must appear in the ground product. Moreover, those experienced in milling tell us that many variations are to be expected from irregularities in the way in which the mill works at different times. We conclude, then, that readily recognizable differences are to be expected in the arsenic from the same works at different times, and perhaps, still more, in that from different works. I shall return to this subject again after stating the results of the microscopic examination of the samples arsenic.

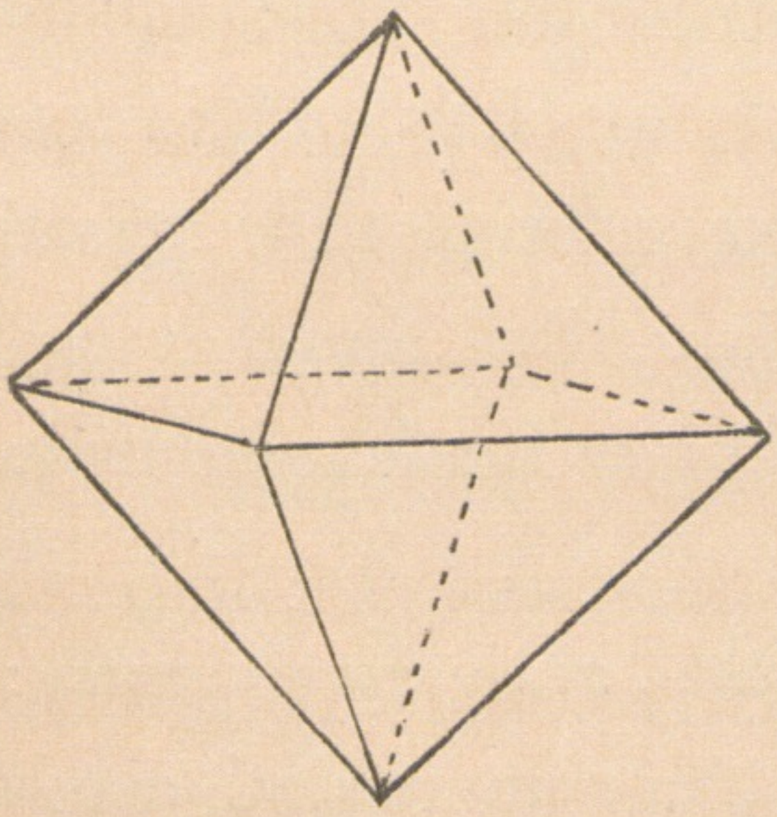
GENERAL FEATURES OF ARSENIC MICROSCOPICALLY EXAMINED.

If a series of samples of the ordinary arsenic taken from a number of drug-stores at random be subjected to microscopic study, they will be found to contain the various features which the description of the process of manufacture has led us to expect, that is:—1, the perfect crystals; 2, the irregular lumps; 3, the fine dust-like fragments. Moreover, these samples will be found to differ among themselves in the proportion of the crystals to lumps, in the size of each, in the shape of the crystals, and in the character of their surfaces. I will mention these points in somewhat greater detail.

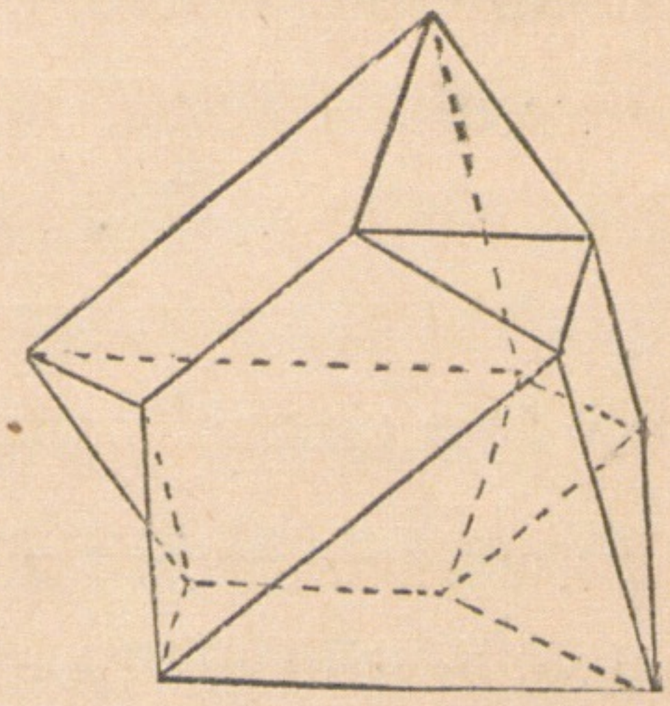
Crystals.—It has already been remarked that white arsenic crystallizes in the isometric system, and that the crystals are generally octahedrons. An inexperienced observer might, however, be occasionally

puzzled by the variety of forms presented in a single microscopic field, and it is not always easy to reconcile all of them with the simple octahedral crystal. (Fig. 1.) As the crystals are suspended in the Canada balsam, or other menstruum employed, they lie in all possible positions, and as the manner in which the shadows are cast varies with each, and is different, too, for transmitted and reflected light, it is easy to understand why the effects are so varied. This subject was discussed some years since by Mr. W. A. Guy, in the *Quarterly Microscopical Journal*, for 1862,* and with a considerable degree of thoroughness. It may, however, be useful for me to mention here the most common aspects of the octahedral crystals, more especially in transmitted light. I should also add that if a glass model of such a crystal, say an inch or two in length, be held in the hand so that the light goes directly through it, and then be turned in various positions, and the effects of the shadows cast noted, the subject will become at once intelligible even to one having no practical acquaintance with crystals.

1.



2.



If the crystals lie in the menstruum so that one opposite pair of edges is parallel to the glass slide and the thin cover respectively, only a narrow band in the middle will allow the light to pass directly through, and from the remainder the light will be reflected back, so that the triangular faces uppermost appear dark. Again, if two opposite triangular faces are parallel to the slide and cover respec-

*See, also, *Principles of Forensic Medicine*, by W. A. Guy and David Ferrier, Fourth Edition, 1875, p. 409.

tively, then the light will pass through these, except as cut off by the shadows cast by the six other faces. The appearance of the crystal is then hexagonal in outline, and as the focus is altered the shading is changed, so that the crystal seems to be rounded at the vertices.

Then, again, if the crystal lies with one apex down, and, consequently, presenting the other and the corresponding four planes above, it appears as a dark four-sided pyramid, all the faces being shaded.

These are the commonest forms observed in transmitted light, but they may be varied indefinitely, as the position of the crystal is changed slightly, though there is obviously a tendency, as the slide is prepared and pressure is exerted on the cover, for the crystals to take one or the other of these positions. In reflected light the effects, as to light and shade, are more or less exactly reversed. In addition, however, it must be added that distorted crystals are always common; that is, crystals in which some of the planes are extended beyond the point required by the perfect symmetry. Thus, one pair of opposite planes may be larger, so that instead of having a sharp angle, there is a long edge, and the planes correspondingly are quadrilateral, instead of triangular, in shape. This may be carried so far that the crystal is only a thin plate, hexagonal or triangular in outline, and having little resemblance to a normal octahedron. But any further discussion of the subject would be out of place here.

Still, again, compound, or twin crystals, are very common; that is, crystals whose form may be imitated if a symmetrical octahedron is cut through the middle, and one-half revolved half way round, or 180°, with reference to the other half. The resulting form is seen in Figure 2. This twin crystal, lying, as it does, in a variety of positions, presents various aspects under the microscope, but it is usually recognizable by the re-entrant angle.

From a scientific point of view, the variety of independent forms, and combinations of forms, which arsenic, as a substance crystallizing in the isometric system, might assume, is almost indefinite; thus, the cube, dodecahedron, trapezohedron, and so on, and their combinations,

may be suggested. In crystals of minerals found in nature, we often observe a greater or less variety of forms, and although but little is known of the laws which determine their occurrence, it is quite certain that there are definite conditions which decide this. Thus, we commonly observe that the crystals of a certain species—as, for instance, fluor spar—from a given locality, and with a given range of associated species, have a great similarity in form. This fact immediately suggests the possibility that the different forms, and their combinations, of crystals of arsenic may also be constant, under certain conditions; and hence, that these differences might be most important in deciding as to the source of two samples under comparison. Practically, however, I have thus far failed to establish this point, the fact being that, as in general with crystals produced, as we say, artificially, the crystalline forms are very simple, the octahedron and twin-octahedron being those which constantly recur.

We have, then, to conclude that the *form* of the crystal is not likely to be of much assistance in distinguishing different samples of arsenic. The *size* of the crystals is, on the other hand, a matter of the highest importance, and the one to which the attention should be carefully directed. In some samples the crystals are only $^1/_{4000}$ or $^1/_{5000}$ of an inch across; and in other cases, though still perfect in form, they may be $^1/_{300}$. The degree of constancy of size, in a given sample, is also an important point; in one case, the crystals being substantially all of a size; and in another, the variation being between wide limits. These subjects will be mentioned more in detail later.

One other point in regard to the crystals remains to be mentioned in this general summary of the points to be noted in a microscopic examination. It is the character of the surfaces. When a series of samples is examined uncovered, and by reflected light, a striking difference is usually observable between them. In some cases, the planes of the crystals are smooth and polished, reflecting the light with a great brilliancy. On the other hand, the surfaces of the crystal, in other cases, are dull and without lustre, they seeming to be slightly rough and uneven, sometimes as if pitted and again as if sprinkled

with powder. The explanation of the difference is an obvious one: it must depend on the grinding process. The brilliant crystals are found in those samples in which the amount of broken fragments is small, and hence in which but little crushing has been done; the dull crystals, on the contrary, are observed in those samples containing more or less of an excess of crushed fragments, and in which, consequently, the crystals have been subjected to a harsher process. There does not appear to be any reason for supposing that a change in the character of the faces of the arsenic crystals is likely to be brought about in any other way.

Lumps and Dust.—In regard to the irregular lumps—fragments of large or imperfect crystals, as they evidently are, in almost all cases—but little need be said just here. The size, whether uniform or not, large or small, is an important matter, and, still more so, the proportion of them in number to the crystals. The extremely minute fragment, or the *dust*, as I have called it, also has no character of its own. The amount of it, however, is an important point, and, as would be confidently expected, it is found to be nearly absent in the highly crystalline samples, and increases with the number of broken lumps—that is, as the evidence of grinding increases.

Impurities.—One other general point is to be mentioned, and one which might, in some cases, turn out to be of the greatest assistance in determining as to whether certain samples came from the same or different sources: this is the character and amount of impurities present. Commercial white arsenic has the reputation of being very generally adulterated. This impression prevails among the retail dealers, and such statements are found in the books, where glass, clay, and other substances, are mentioned as commonly used as impurities. There must be a foundation for a belief so generally held, so that, where circumstances allow, a search for impurities should be made. I am bound to state, however, that my examination has convinced me that arsenic is *not* very generally adulterated. Indeed, when we consider how small the cost of manufacturing arsenic is, and how cheap it is in the market—the wholesale dealer selling it at a few cents, only,

a pound—and, moreover, how readily a deception could be detected, the matter of adulteration seems very improbable. I have examined a few samples—say six or eight—by chemical means, for the presence of impurities, without finding any, and have held the question in mind during the microscopic examination of many more. In addition to other means, I have tested with polarized light, which would reveal the presence of almost all foreign substances (except glass), and with the same result. I think, consequently, that I am justified in saying that the adulteration is not practiced to the extent supposed.

GENERAL CONCLUSIONS BASED ON THE COMPARISON OF NINETY-TWO SAMPLES.

I am now ready to describe, in such detail as the case seems to demand, the special observations made on the samples of arsenic I have had under examination. The list includes only samples of commercial arsenic, and those which are believed not to have come from the same source, so far as the druggist's jar is concerned, although, in several cases, as will be explained, they may have been taken, originally, from the same keg. They are ninety-two in number, and were obtained mostly from druggists in New Haven, Hartford, Middletown, Meriden, Wallingford, Bridgeport, and also from the works in England.

These ninety-two different kinds received by no means, in each case, the same amount of examination. Four in the list, (*A*, *B*, *C*, *D*,) regarded as test samples, were studied with great minuteness; and of the others, sometimes one, sometimes three or four, or more, slides were mounted; there were, however, enough in every case to warrant such conclusions as are drawn from them. The investigation had a practical end in view—to answer certain questions as to the relations of the four test kinds; and the principal reason for extending the observations over so large a number of others was to make it possible to conclude through what range the variations extended, and how far a given sample was constant.

As a matter of convenience, as well as of practical and theoretical

interest, the 92 kinds of arsenic were separated into seven groups. The basis of classification was the relative proportion in number of crystals to lumps—this being the criterion most readily applied, although by no means the only one, nor indeed in many cases the most important. As types of the different groups there were taken, for five out of the seven, certain authentic samples received from Dr. E. R. Squibb, of Brooklyn. Four of these Dr. Squibb had had the kindness to obtain personally for me from the kegs in the hands of the importer, they representing as many brands known in the New York market; the remaining one (called "Squibb" below) was a sample of glass arsenic ground for medicinal use by him. The other two groups are represented by samples obtained at Tavistock. While the names of the different brands are given below in connection with each group, it should not be understood that any assumption is made as to the general character of any brand, if indeed that is constant at all. They appear as individual samples only, and not as representatives of the brand. The question, as to how far constancy of character is to be expected of arsenic from a given works, is discussed on a subsequent page.

The following is the list of the groups :

			Percentage of crystals.
Group	I.	"Welsh,"	95
"	II.	"Drayton,"	85–90
"	III.	Tavistock, A, ...	75–80
"	IV.	Tavistock, B, ...	50
"	V.	"Garland,"	30–40
"	VI.	"Dragon,"	10–20
"	VII.	"Squibb,"	0

Inasmuch as only one of the several possible points of difference is employed in this classification, and that one which evidently does not allow of being determined with exactness, the lines between the groups are by no means sharp ones. Farther than this, it is in many cases true that two samples included in the same group really differ more widely than two of different groups.

It will be understood from what has been said that the numbers given above are not intended to be *exact* percentages. The attempt was made in several of the more important cases to determine this ratio by actual count of the crystals and lumps, visible in successive microscopic fields for the same and different slides, but the difficulties were found to be great and the result was not very satisfactory. It seemed better, as anything approaching to absolute accuracy was neither possible nor indeed necessary, to make merely a mental estimate of the relatio as the slide passed gradually under the glass, the attention being especially directed to a definite part of the field as that covered by the micrometer grating.

I will now describe, in somewhat greater detail, the general characters of the samples falling under the above seven groups. This seems to be desirable, as, from the large number under examination and the widely-separated sources from which they came, it is fair to suppose that the different kinds of commercial arsenic were well represented.

Group I., represented by the sample "Welsh," received from Dr. Squibb, contains the kinds which are most highly crystalline. They can be compared only with the unground arsenic taken direct from the flues. The crystals are comparatively uniform in size, ranging about $^1/_{500}$ of an inch and smaller, and they are so perfect in form and lustre that it is difficult to believe that they can have been subjected to the grinding process. This is, however, only a surmise. Four of the ninety-two kinds in my hands fall into this class, and they were obtained from as many different towns. In each case, the true character was observed, independently of the microscope, when the packages were first opened, for the powder in the mass, owing to the brilliancy of the crystals, and, at the same time, their rather unusually large size, has a peculiarly glistening effect in a strong light.

Group II. has as its type the "Drayton" sample from Dr. Squibb. As the Tavistock arsenic is said to have been, for a number of years, put on the market by a Mr. Drayton, the contractor, it is not improbable that that may have been the source of this particular lot. The line between II. and III., and again that between III. and IV.,

are by no means sharp ones, although the extremes are wide apart, and can be instantly separated. The two latter groups, III. and IV., include most of the series of twelve Tavistock samples, and are hence so named.

Of the ninety-two samples, I have classed fifteen with II.; twenty-six with III., and fourteen with IV.; the division is not to be considered an exact one, although the result of extended examination.

These numbers given here, and in the same relation with other groups, are, in so far as this, of some little general interest, as they give a clue as to what kinds of arsenic are the more common, and—what is important—help to make it possible to form an estimate as to how far this method of distinguishing separate samples may be carried. Of these fifty-five samples, the majority could certainly be separated from one another with ease and confidence, and a different origin predicated of them; for not only is there this question of the ratio between the crystals and lumps to be considered, but, of even more importance than it, the uniformity, or want of it, in the whole material, as fine or coarse; then, again, the size of the crystals, and the question of their uniformity, and so on. These remarks of course apply also to the other groups.

The samples included in Group V., represented by the "Garland," from Dr. Squibb, are conspicuously different from those before considered, in their non-crystalline character. With the fourteen kinds falling here, the crystals make up always less than half, generally about one-third, of the whole. The number of lumps is consequently large, and with them comes also a large amount of dust. The crystals, too, show a greater or less want of brilliancy of lustre. Among some of these fourteen kinds, there is a wide difference in the other respects that have been named.

The Group VI., represented by the "Dragon" sample, is characterized by the very small number of crystals, and they bear on their surface the evidence of hard usage. In most of the sixteen kinds classed here, the lumps are large and the powder is coarse in appearance. This is not, however, universally true, for in a few of them the

reverse is the case, and the powder is fine, though in all cases, the crystals are only sparingly present.

Group VII. includes three kinds which show no crystals whatever. They consist of minute irregular grains, and are not to be distinguished from one another, except so far as this, that in one case the powder in the mass was of a decided yellowish tinge. The sample from Dr. Squibb was, as he informs me, ground by him, for medicinal purposes, from carefully-selected samples of lump or glass-arsenic. The microscopic character of the others corresponds to the same method.

SPECIAL COMPARISON OF SAMPLES A AND B.

The above statement is probably as minute as this discussion of the general problem will warrant, although it would, of course, be easy to multiply indefinitely the details about the different samples. It will, probably, be of interest to supplement this statement with a more careful description of two samples to which attention was particularly devoted. One of these, which I have called *A*, falls in Group III.; and the other, referred to as *B*, falls in Group V. The difference between the two, which forms the reason for thus separating them, as previously explained, is obvious to the most superficial examination. The first is largely crystalline; the second, just the reverse. But this difference was not the most fundamental one. This was rather to be found in the average size of the crystals in the two kinds. This may be briefly stated in this form: In *A*, the crystals were many and small; in *B*, they were few and large. This point is seen most distinctly when each crystal, as it passes under the eye, is compared with the micrometer grating; or, better, when the two kinds are independently drawn to the same scale, so as to magnify them equally. Figure 3, shows a portion, about one-third, of the circular field of *A*, as drawn by the writer, and Figure 4, of *B*, the magnifying power being, in each case, two hundred diameters. The original drawings were made with extreme care, to insure the exact re-production of every particle, in its proper size and relative position. These re-productions of them are accurate in this respect, though otherwise somewhat rough. The

original drawings were afterwards enlarged five times, so that diagrams of considerable size were obtained, the circles having a diameter of about forty inches, and every object being magnified one thousand times, linearly.

The inspection of these drawings shows, as is true of all the slides prepared, that the crystals in *A* seldom exceed $^1/_{1000}$ of an inch in diameter; more commonly, they are $^1/_{2000}$, and not infrequently they are as small as $^1/_{4000}$, being, as far as could be estimated, nearly equally distributed between these limits. There were also occasional crystals considerably larger—sometimes four or five, or so, in the field at once—which were in the neighborhood of $^1/_{500}$ of an inch. These are giants as compared with the much more numerous extremely minute ones, being eight times larger, linearly, or five hundred times in bulk.

In sample *B*, on the contrary, the crystals were seldom less than $^1/_{1000}$ of an inch; very rarely, one as small as $^1/_{2000}$ being found, and never any approaching $^1/_{4000}$. The ordinary size, and the crystals are, in general, comparatively uniform, was $^1/_{500}$ to $^1/_{700}$ of an inch, though occasionally still larger. As comparing the two, then, the crystals of the one are, for the majority, four or five times in diameter those of the other, or about one hundred times in bulk. It is the difference between sea-shore pebbles—say an inch or two in length—and cobble-stones. The crystals which made up the mass of the one were practically absent in the other.

Further than this, it was found, as has been intimated before, that in the highly-crystalline sample the crystals were brilliant and polished, while in the other they were dull and rough. Seen by a strong reflected light, this difference was most striking; the explanation has already been given.

Still, again, the lumps which made up perhaps one-fifth of sample *A*, were mostly small, but occasionally there appeared lumps of—comparatively speaking—enormous size. Some of these lumps had a length of $^1/_{100}$ of an inch, and even up to $^1/_{60}$. They were out of all proportion to the rest of the matter, being generally so large that a single one would have outweighed all the other objects visible under

the microscope, at the same time. There was virtually nothing that could be called dust. In sample *B*, on the other hand, lumps were not only numerous, but they were in general, pretty uniform in size, though there were occasional ones much larger, and comparable with those in the other.

The dust was present in large amount on every slide, though often unevenly distributed over it; in some fields it would be like a veil thrown over the whole, and in others it would be nearly absent; in the portion represented in the figure the amount is comparatively small.

The points of difference between these two kinds are then most striking. The relation can perhaps be made more clear by the following illustration (borrowed from another): Suppose that an ounce of each could be placed in two sieves with meshes $^1/_{1000}$ of an inch apart, and that it was possible to sift them thoroughly, and that then the part which went through and that which remained could be examined in each case. With the sample *A*, almost the whole would go through the sieve, and this would be found to be practically all minute crystals, while in the small amount which remained there would be an occasional large crystal, and a considerable number of lumps, some of them very large; the coarseness of the powder would be at once obvious to the unaided eye.

In the other case, the sifted powder, forming a small part of the whole, would be made up of dust-like fragments, like the samples of arsenic under group VII., also a few lumps and occasional crystals; that remaining would constitute the mass of the ounce and be made up of lumps and crystals, with the former much in excess.

The description of these two kinds of commercial arsenic has been introduced here in this detail, because, although no further interest attaches to them at the present time, it seemed likely to be of assistance to future workers to have given to them the exact grounds on which a different origin was with perfect confidence affirmed, this being the first time that this point had been raised.

It will be gathered from the general description of the ninety-two

samples examined, that so wide a difference as the above exists only between a small proportion even of those of which a difference of origin is, from the facts, known beyond all doubt. The question then naturally arises how great a difference must exist in order that a decision may be safely given.

AMOUNT REQUIRED FOR EXAMINATION TO ENSURE A SAFE CONCLUSION.

Before considering this, I will mention another point which has some importance: how large a portion must be placed under examination in order that the conclusion reached may be taken as representative of the whole. In regard to this, it is hardly necessary to say that it is thoroughly in accordance with the best scientific methods to base a conclusion on a part, even if very small, when there is reason to think that it fairly represents the whole. It would hardly be considered by the chemist as necessary to boil the whole ocean down in a cauldron to get the average composition of sea-water, nor—to use a homely but fair illustration—does the purchaser of a brand of flour hesitate to reject the lot when a trial has shown the portion taken to be bad. An average microscopic slide of arsenic is likely to have about $^1/_{20}$ to $^1/_{30}$ of a grain upon it, but though, to an ignorant jury, this may be made to seem an absurdly minute portion to base a decision upon, involving, as it well may, matters of great importance, the conclusion is, notwithstanding, perfectly legitimate. To be sure, one who is carrying forward such an investigation, would be certain to extend it over a number of slides, to remove any accidental variation which might be imagined to exist.

Of the samples especially involved in the writer's study, a large number of slides were made. Of sample *A*, for example, of the original quantity of which there was an ounce, I had three independent samples, and of them, twenty slides were mounted. But, while every field of a given slide differed, in some cases very widely, from every other, and while absolute identity could not have been affirmed between any two slides, the conclusions drawn from any one of the

slides would have been as truthful, as to the question under discussion, as that from the whole.

This remark may be extended quite as strongly to all the other cases. The only variation noticed at all—and it is interesting as showing the character of the variations possible—was in the case of the sample *A*. One portion of the powder—a few grains—was in a narrow glass tube, some inches in length. Several slides were mounted from it, by shaking the tube slightly and turning it gently from one side to the other, and so letting the powder run down slowly on to the glass. In the case of these slides, there was found to be a slightly larger proportion than in others, of the very large masses which have been described as greater in bulk, by one thousand times, than the average crystals or lumps. In other words, a partial sorting process had gone on, and it will be seen that the conditions were the most favorable possible for this, in consequence of the enormous disproportion in size of the particles, and the method of mounting employed. In all other cases, the arsenic was taken up from the whole lot on the point of a clean knife-blade, so as to avoid the possibility of such a difference. As has been stated, however, the slight increase in number of the big lumps, in these exceptional slides, would not have altered, in any respect, the conclusions reached, if it had been drawn from them alone, for they were too few, at most, to alter the general ratio given for the crystals to the lumps. In no other case was there any such difference discovered between one slide and another.

NATURE OF THE CONCLUSIONS WHICH MAY BE REACHED IN ANY CASE.

If, now, we return to the broader and more important question, as to the degree of difference upon which a conclusion may be based, it is evident that the conditions vary according as to whether it is a question of possible similarity of origin, or the reverse. In the first case, the most definite conclusion the miscroscope could give, would be this: that between the samples, *X* and *Y*, no difference could be discovered, and hence that they *might have come* from the same source;

it could be carried no further. This conclusion would be justified if, of a number of slides of *X*, and as many of *Y*, those of the one differed no more from those of the other than the slides of either differed among themselves. The most reliable method of testing this will be given below.

In the other case, no absolute answer can be given; but it will be seen that the difference need not be nearly so great as that between the samples *A* and *B*, already described. For example, of two samples examined by the writer with especial care, both fell in the same group, (III.,) but the difference was most clear, for the crystals in the one, though present in about the same proportion as in the other, were several times larger.

In examining test samples, with a view to deciding either of the questions asked, the best method is one which will eliminate all subjective bias as to the result.

METHOD OF EXAMINATION.

The method employed by Professor Brewer, in examining certain samples of arsenic in connection with the same criminal case, is one hardly to be improved upon. It is substantially as follows: Suppose the examiner to be tolerably familiar with the different forms which commercial arsenic takes, as seen in the microscope, and also familiar, in general, with the special samples under examination. Now, when a number of slides have been mounted of each of two kinds to be compared, each set should be marked so that it can be subsequently identified, but not so that the difference is visible as the slides are handled. Then, if quite familiar with the appearance of each kind, supposing them different, let him go through and attempt to pick out all the slides of the one from those of the other. Or, if not so familiar, or, if there are not such distinct differences, a known slide of each may be taken, and then by successive comparison with them the attempt may be made to separate the remaining slides as before. It is obvious that in this manner, all prejudice is eliminated, and the eye is free to act uninfluenced. If, now, all the slides of

sample *M* are separated in every case from those of *N*, the question as to a possible identity of origin is answered in the negative, and if they cannot be separated, it may be decided in the affirmative.

The observations of Professor Brewer show the working of this method so well as to be worth mentioning here, so far as they illustrate the point in hand. I placed in his hands, among others, small quantities of the following samples, which he was led to suppose were quite independent of each other:

A, *B*, *C*, *F*, *G*, *H*, *a*, *b*.

Of these, *a* and *b* were duplicates of *A* and *B*, respectively; *G*, ("Garland") I had found to be very similar to *B*, and *H* to *A*; *F* was the "Drayton" sample. Moreover, *B* and *C* had been, in fact, proved to have come from the same package, and my examination had failed to detect any difference between them. As the result of his examination, on a lrage number of slides, he reported that he could not separate—

(1.) *A*, *a*, and *H*; as also,
(2.) *B*, *C*, *b*, and *G*.

Furthermore, he had found *F* to be somewhat similar to the first group, so that in a single trial he could not separate all the slides from the others, but by repeated trials he had succeeded in doing this. The two groups (1) and (2) he found very different, and between them he had, in many trials, never made a mistake. When, however, the attempt was made to separate all the slides of *B* from those of *C*, assuming them to be different, so that such a separation would be possible, he had failed; each time the result was something like this—

B, *B*, *C*, *B*, *C*, *C*.
C, *C*, *B*, *C*, *B*, *B*, etc.

In other words, the differences between *B* and *C* were no greater than between separate slides of either one.

CONSTANCY IN MICROSCOPIC CHARACTERS OF A GIVEN LOT OF ARSENIC.

It has been assumed in what has preceded, that a given lot of arsenic

is constant in character; in other words, that this is true of the package which the druggist purchases from the wholesale dealer and places in his jar. This most important question may be considered first, by *à priori* reasoning, and then by the light thrown upon it by the facts observed.

The process of manufacture, which has been described, proves, in fact, that a given lot of arsenic must, in all ordinary cases, be essentially constant in microscopic characters. It may be assumed, for the sake of the argument, that the unground arsenic in the various chambers varies widely in degree of coarseness, so that these lots ground separately would yield different products. We may assume, consequently, that the pile in the mill-room, from which the operator shovels the material into the hopper, varies from time to time, and even that at a given time it is different in different parts; for example: if a new load from the chambers has been thrown down on what was still remaining. We may accept, too, the experience of millers as to all possible variations caused by irregularities in the running of the mill. But that the ground product, which runs off from the stones at one time—that is, while one keg or several kegs are being filled—that this should vary decidedly, is inconceivable.

It is not necessary to appeal to the fact that the miller is instructed to avoid accumulating the coarse material, for, in the long run, it is possible that he would consult his own convenience and do as it was easiest for him, without regard to orders.

In the first place, it is to be noticed that we have to do with a continuous process carried on month after month, and on a very large scale—for example, at Tavistock, two hundred tons, and at Bissoe, about fifty are made monthly. Accidental variations, then, may be left out of account, though, as we shall see, they would not be likely to affect the final result.

It will be easily understood that every step in the process is one tending to obliterate original differences. Not to go farther back, as one shovelful after another is fed into the hopper, and as they gradually run through, the material cannot fail to become very thoroughly

mingled. The action of the hopper is well illustrated by the passage of sand through a funnel. If some white sand be placed in first, and then some black sand on top, and the flow allowed to go on undisturbed, it will be found that a little of the white sand passes through first, then the two become gradually more and more intermingled as the flow continues, until, finally, the last of the black sand passes *before* the last of the white.* This mixing process must go on continually in the case of the hopper of an arsenic mill, and in much the same way, even making all allowance for the irregularity in shape, and the uneven, lumpy character of the unground material. The same mixing process, too, is continued all the time as the material passes between the stones and out of the shoot into the keg. The conclusion to which a consideration of the method leads us is this: that any sudden change of character is impossible; and, that there is every reason to expect close uniformity in the products of a certain time.

Farther than this, the whole tendency in the subsequent history of a lot of arsenic is to obliterate any difference which might by accident occur. Suppose, for example, that a keg half filled at one time, is filled completely at a subsequent date, and suppose farther, that the two lots are widely different. Then consider what takes place after this keg comes into the hands of the wholesale dealer. As he empties it in the course of his trade, he comes, in time, to a place where his scoop takes up a part of the two kinds in adjoining layers; this is weighed out into two, or five, or ten-pound packages, it may be, and passes on into the hands of the retail druggist, who pours it into his bottle. Then, he in turn, from time to time sells off an ounce, and then another, and so on. Any one who will take a bottle of a similar powder and pour off now a small portion, then place it erect, again invert it and pour off a second, and so on for several times, and carefully observe what takes place, will appreciate what a thorough

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* An experienced grain-weigher in Chicago had the kindness to suggest this illustration to me.

mixing process goes on with each motion, and how little chance there is that two different ounces from the same bottle should differ in any degree comparable with the two original layers supposed in the keg. But the only supposition on which the case rests may for practical purposes be said to be an impossible one.

Still another case remains to be considered: Suppose that the druggist's jar is, say, one-third full of one kind of arsenic when he fills it up with another quite different sort. In this case, it is conceivable that an ounce from the top and a second from near the bottom should vary widely, although what goes on in the jar, as described above, tends also to obliterate these differences. It is at least clear that the latter few ounces will contain a greater or less admixture from the top, while the top ounces may be quite pure. Farther, in many cases when the two kinds of arsenic differ as do *A* and *B*, the presence of an admixture of one in the other could certainly be detected by a careful examination.

The above is all *à priori* reasoning in regard to the question under discussion. The observed facts are numerous and strong enough to justify a similar conclusion. I will mention them briefly, only adding that they could be readily increased indefinitely, were not the conclusions too well established to require it.

These facts are as follows:

(1.) The samples *B* and *C* were found by the writer, very early in his investigation, to be closely similar; they were known to have come from two druggists in the same town. The fact, revealed by the microscope being considered, by those interested, to be of some importance, led to an investigation of the facts in regard to their origin. It was proved that *B* and *C* were part of an original two-pound package bought by one druggist from a certain wholesale dealer. Of this package, half a pound was sold to the second druggist, from which lot the sample *B* came, while *C* came from the remainder, in the hands of the first.

(2.) On October 10th, 1878, an ounce of arsenic was bought from a certain druggist, out of a ten-pound package, and the next

day, from the same lot, three additional ounces were purchased, each being placed in a separate paper. The four ounces from the same package were found to be in every respect similar.

(3.) An ounce from the keg of a wholesale dealer, and separate ounces from several retail druggists, who had obtained their supply from him, and from the same keg. All of these were similar.

(4.) Samples from the top and bottom of a bottle of arsenic bought by me in New Haven, could not be distinguished.

(5.) Five samples were taken by Prof. Brewer, from different parts of a keg containing three hundred pounds, at a wholesale druggist's; he could find no difference between them.

(6.) Samples taken by Prof. Brewer, as in (4), from top and bottom of a druggist's jar, were identical.

(7.) An ounce bought June 12th, and a second, October 27th, from the same bottle—the lot having been on hand for a year, or longer—were found by Prof. Brewer to be identical.

(8.) Samples taken by Prof. T. G. Wormsley from the middle, and each end of a keg in Philadelphia, in October, 1879, were identicat.

HAS THE ARSENIC OF A GIVEN MANUFACTORY A DISTINCTIVE CHARACTER?

Another question, of perhaps more scientific than practical interest, is this: whether the product from a given arsenic manufactory is, to any extent, constant in character. It has been stated on page 16, that this is quite doubtful, and that the names attached to the groups there have probably no special significance. Enough has been said to show, clearly, that both because of the variation in the unground material, and because of irregularities in the milling process, the ground product from the same mill must vary, and that between somewhat wide limits. The question proposed amounts to this: whether—leaving out of account occasional exceptional variations—there is still a tendency to constancy on the part of the arsenic; whether, that is, out of samples from a thousand kegs, the same characteristics would be found in a very large part of them. *À priori* reasoning, in the absence of

a large series of facts gathered from different works, is evidently of little value. Furthermore, it must be added that the examination of samples, bearing the names of their brands in the market, could not lead to any very sure conclusion. In at least one prominent case, the writer happens to know that the name of the brand would *not* be a sure proof of the works from which the arsenic really came.

Of the facts at the writer's disposal, the following are the most reliable: Twelve authentic samples from Tavistock have been the objects of careful examination. Two of these were taken from the mill at different times, in the spring of 1879, and the other ten were from small lots kept in the office, and which I was enabled to get through the kindness of Mr. Green, the superintendent. These samples bore dates ranging from 1870 to 1879. They are divided as follows, between the Groups II., III., IV., viz.: 3, Group II.; 3, Group III.; 6, Group IV. In other words, they are all rather highly crystalline than otherwise, though ranging from fifty per cent. of perfect crystals up to about ninety per cent.; the crystals, too, are pretty uniformly small, and the product appears quite uniformly ground. The number of samples is too few to warrant a general conclusion; but the fact that they are all crystalline, and that no one falls into Groups V. or VI., is certainly striking.

From the Garland works, I obtained four samples only. One taken by me from the mill in operation, and another from a barrel adjoining, made a few weeks earlier, could not be distinguished. This is a fact that bears upon the question previously discussed. They both fall in Group IV., or that having about one-half crystals, together with a third sample, made in April, 1879; a fourth, several years old, falls in Group V., or the "Garland" group.

Still, again, the "Garland" sample, from Dr. Squibb, and also sample *B*, reported by the importer to be "Garland," are, as already stated, not to be distinguished from one another. They are both very similar to the fourth sample of the "Garland" make, mentioned above, and still, again, to four other separate samples, obtained from as

many different kegs, imported at the same time, and each branded "Garland."

Of the samples, then, that I have examined, four of them, certainly "Garland," and six others reputed to be, three belong in Group IV. and seven in Group V.; furthermore, the latter not only fall in the same group, but are, in addition, very closely similar. All of the samples, then, agree in this, that they are not highly crystalline, the crystals never being in excess of the lumps; of the Tavistock samples, half are largely crystalline, and the others occupy a middle ground. Of all the other samples, the brands were known only in the case of the "Drayton," "Dragon," and "Welsh," so that no remarks can be made about them. There is an obvious difficulty about obtaining the facts as to the source of the material in the druggist's jar, and an uncertainty about them when obtained. For a variety of reasons, not the least of which is that already intimated, that the name branded on the keg cannot always be relied upon. It should be added that the keg from which Professor Brewer obtained the series of samples mentioned on page 29, was marked "Garland." The arsenic was found to be highly crystalline, falling in Group I. or II., so that it conflicts with the facts stated above.

The conclusion can hardly be given more strongly than this: that it may possibly be true that the arsenic of a given works is approximately constant in character, hence giving rise to a more or less constant difference between the product from two manufactories, as between the product at Tavistock and Bissoe (Garland.)

On the contrary, it is not impossible that the apparent agreement in the samples from the two sources named, so far as it goes, is *accidental* only, and that, consequently, the arsenic of a given works may vary between as wide limits as those of Group II. and V., or even I. and VI. This does not, however, militate, in the slightest degree, with the more important conclusion reached before—that the outcome of a given time is sensibly constant, and hence that, in many cases, the microscope is a sure method of deciding the question as to the difference of source for two test samples.

EXAMINATION OF ARSENIC OBTAINED FROM A STOMACH AFTER DEATH.

A final question still remains to be considered: whether any conclusions can be drawn from a microscopic examination of arsenic which has been taken into a stomach, and afterwards been obtained from it. It is quite safe to give a negative answer for all the ordinary cases. As is well known, a dose of two or three grains is sufficient to produce death; furthermore, although we cannot tell accurately to what extent arsenic is soluble in the juices of the stomach, we do know, from the rapidity of its action, that it is very speedily taken into the system. So small a dose as that supposed, then, would doubtless disappear, being completely absorbed in a very short time. This fact does not at all interfere with the success of the chemist in detecting the presence of the poison, for a change in chemical characters does not seriously complicate his processes. But it is obviously fatal to any microscopic examination.

Where, on the contrary, the amount of arsenic taken into the stomach is very large, a portion of it is likely to remain a considerable time unabsorbed, and if some of this can be obtained, it is easy to make an examination and decide as to the original character of the substance. In the case in connection with which the examinations were made, on which this paper is based, the amount of arsenic obtained from the body of the murdered girl was nearly ninety grains. It should be added, also, that a week after the homicide the body was disinterred, and, besides other things, the stomach placed in a jar containing alcohol. About six weeks after the arsenic was supposed to have been introduced, the stomach was opened by Professor Johnson and some sixty grains of unabsorbed white arsenic taken from it. In addition, thirty grains were subsequently separated from the vital organs and other parts of the body.

The fact that so large a part was substantially untouched by the fluids was to have been expected, since, after the parts of the body and the liquids immediately around the mass were saturated, the process of solution could go on only very slowly as aided by diffusion.

A small portion of the unabsorbed arsenic came into my hands for examination. This material was slightly brownish in color, and, though in very small quantity, had a disagreeable odor. When mounted in Canada balsam, it was found, rather contrary to expectation, to be in a condition perfectly suitable for study. A careful examination showed that it differed from samples of commercial arsenic fresh from the shops, in several particulars. They are, in order of importance:

(1.) There was a slight tinge of color over the crystals observable even under the microscope.

(2.) There were present occasional opaque grains having a bright canary-yellow color, which were almost unquestionably arsenious sulphide.

(3.) There was a greater absence of dust than in any fresh samples having a similar amount of broken lumps.

(4.) The surfaces of the crystals and also those of the lumps were covered with a series of regular markings or etchings. These are shown in Figure 6. The triangular points crowded together, and the inverted triangular depressions are to be noted.

All these peculiarities of this stomach arsenic or sample *D*, are to be explained by the peculiar conditions to which it had been subjected. The presence of the yellow arsenious sulphide was noticed by Professor Johnson when the stomach was first opened. It is explained by the action of the hydrogen sulphide produced in the process of animal decomposition upon the absorbed arsenious oxide. Moreover the occurrence of the same sulphide has been described in many similar cases.

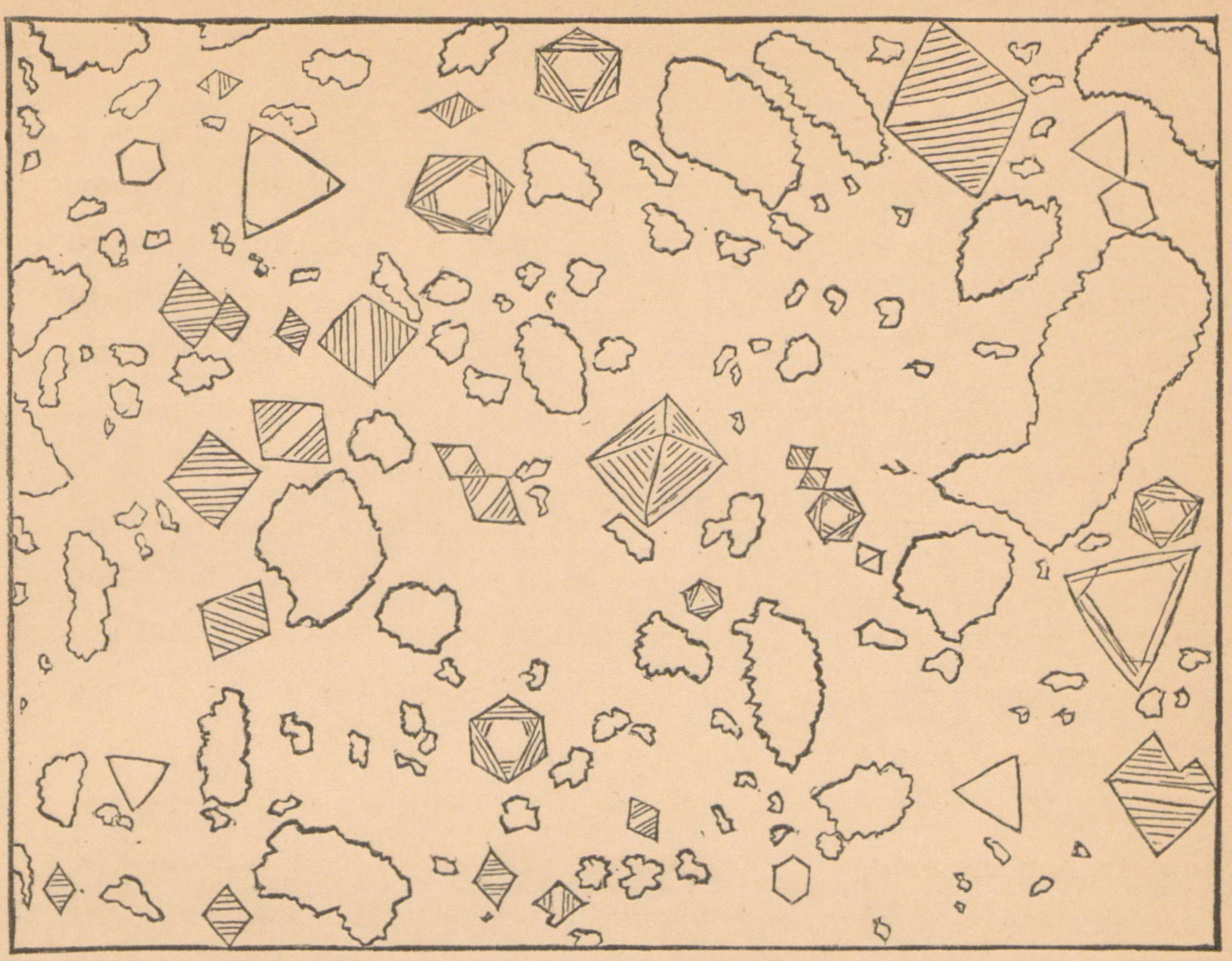
The absence of dust was to have been expected, for the minute fragments would necessarily be the first to discolve; and, moreover, the arsenic taken from the stomach was carefully washed to free it from impurities admixed, and this would have tended to carry off the dust.

Finally, the etchings cannot be otherwise than due to the slow solvent action of the liquid which surrounded the arsenic. This subject of etching-figures, produced artificially on the faces of crystals, is one of very high scientific interest, it being, as it were, a process of dissec-

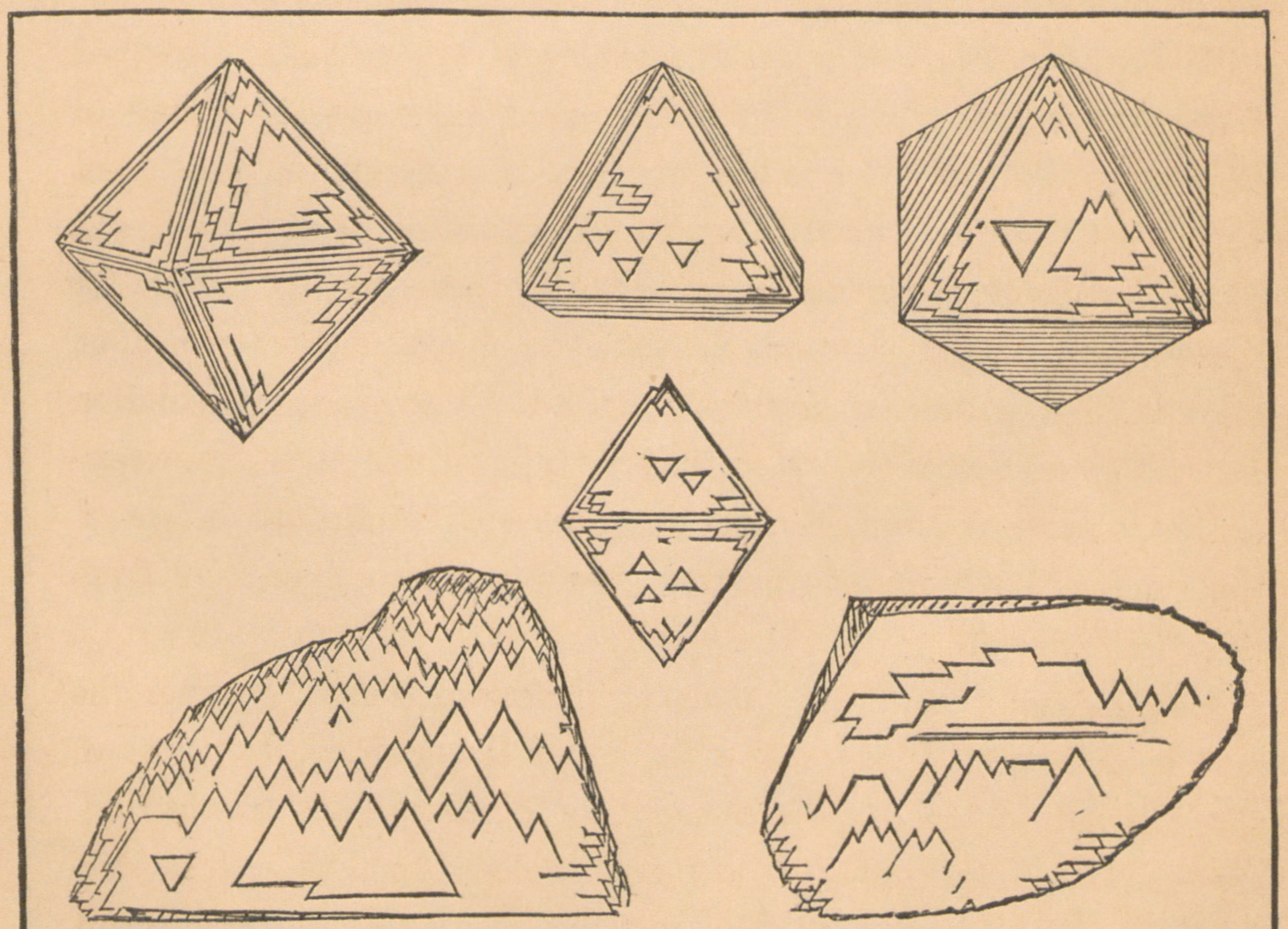
tion, and helping to give a clue to their molecular structure. It is a method of examination which has been extensively applied for many years in mineralogy and chemistry. The first investigation was made by Daniell, in 1816, and his results are contained in the *Quarterly Journal of Science.* Among other things, he experimented on alum, which crystallizes commonly in the same form as the white arsenic. His drawings of the figures produced by him in alum could pass for a fragment of an arsenic octahedron, from the sample here described. In later years, Baumhauer, Exner and others, have carried the same subject much further. The former, for example, has shown that triangular depressions, in the same inverted position seen in the figures, can be produced on octahedral crystals of fluor spar by the action of a solvent. Moreover, Rose has shown that these same triangles are produced on the surfaces of octahedrons of diamonds by a process of slow combustion. Figures of a more or less complex character may be produced on the faces of all crystals, when properly subjected to the action of corroding agents.

There is, therefore, abundant reason from other similar observed facts, for ascribing the peculiar workings of these arsenic crystals to slow solvent action. In order, however, to demonstrate the subject beyond all question, a small amount of fresh arsenic of sample *C,* was placed in a series of test tubes and subjected to the action of water for three weeks. In all of them the particles of arsenic were etched, or marked in the same way as those described. The process of solution had not gone so far as in the stomach sample, but the result was essentially the same. Drawings made from selected crystals and lumps of the sample *C,* so digested in water, could not have been told from those in Figure 6.

Eliminating, then, these points of difference which separate the sample *D* from all others, it is evident that the essential characters of the original material are not seriously impaired—the number of crystals and lumps and their size can be determined as well as in a fresh sample. Figure 5 shows a portion of a microscopic field of this sample, magnified two hundred diameters. It is accurate, except that



5.—Sample D, magnified 200 diameters.



6.—Sample D, magnified 320 diameters.

no attempt is made to re-produce the intricate lines of the etchings. It is evident that it could be fairly compared with any other sample. In the course of my examination, I had reason to compare it with the others of the ninety-two. It falls into Group V., beyond all question, in all essential characters, is not to be distinguished from several others of the group. I was led to compare it especially with samples *B* and *C*, and the result may be inferred from an inspection of Figure 4, and Figure 5. The absence of the etchings makes Figure 5 appear more close to Figure 4 than would the corresponding lots, under the microscope; but aside from this, and the greater absence of dust in *D*, the two large drawings could not be distinguished apart. In the ratio of crystals to lumps, and in the general size of each, as observed in all the slides, no difference could be detected between them. When the conditions, then, are favorable as in the case described, it is possible to extend this method of examination even to arsenic taken from a dead body.

CONCLUSION.

The general results of this examination may be summed up as follows: The study of a large number of independent samples of commercial white arsenic confirms the conclusions based upon the observations as to the method of manufacture, and shows that wide variations in character often exist. These differences, when they occur, are readily distinguishable by the microscope, and, in almost every case, it is, by this means, possible to conclude, of two test samples, whether they *could* or *could not* have come from the same source; and this is true, under favorable conditions, even if one of the samples has been subjected, for some time, to the action of the stomach.

SUPPLEMENTARY NOTE.

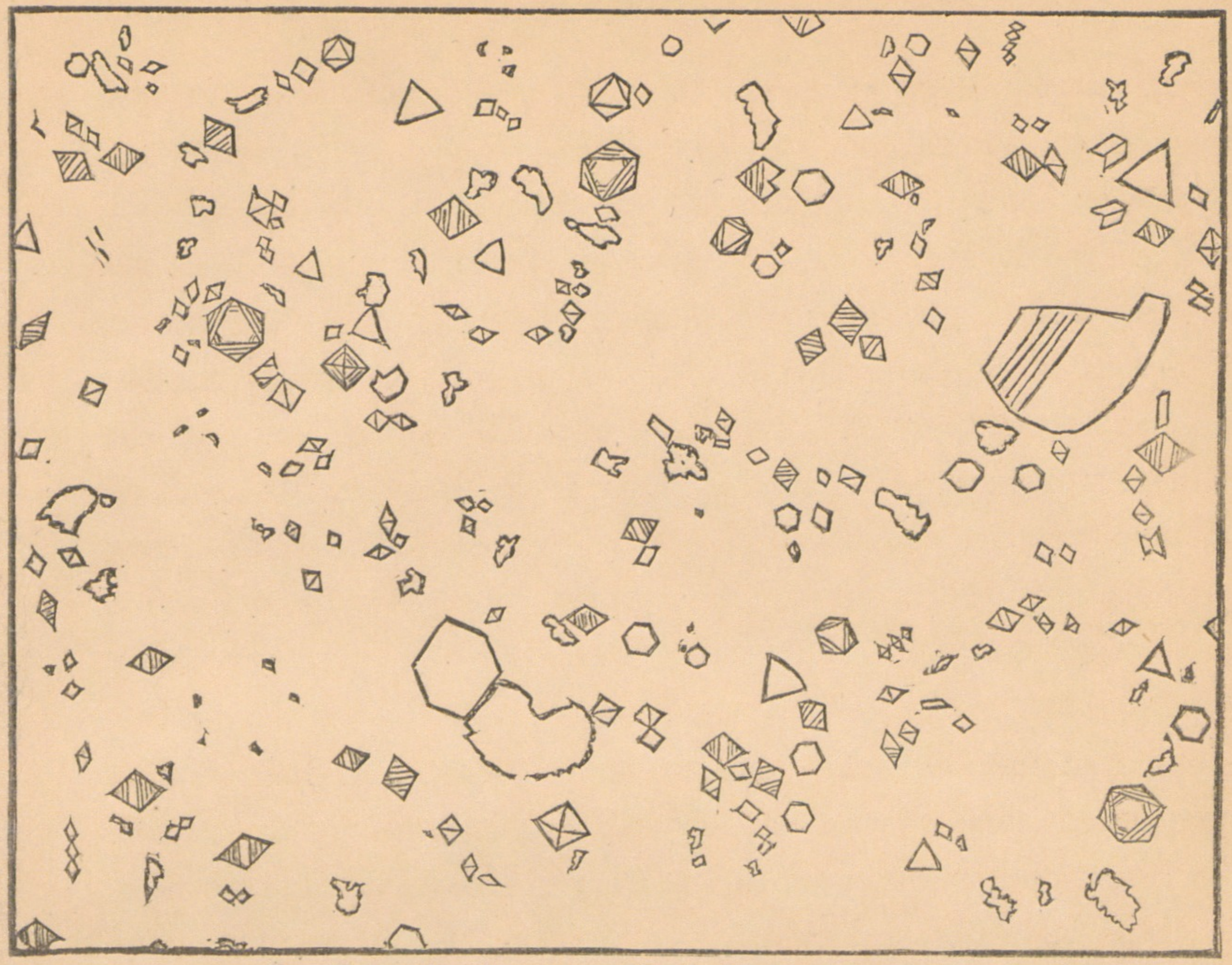
Since the preceding article was put in type, it has been suggested to the writer that for a proper understanding and appreciation of the object aimed at and the results attained in these investigations, the relations of the samples *A*, *B*, *C*, *D*, (p. 3,) should be explained. The facts as testified to during the trial are as follows:

A. An ounce of arsenic was purchased by the person accused on the day of the murder (September 3d, 1878,) from a druggist named Tyler, in Middletown, Conn. Three weeks later (September 24th, 1878,) in a preliminary trial, the accused testified himself to this fact, and also that this same ounce was then intact in a tin box secreted in his barn. A box, corresponding to the description, was found in the place named, and came into the hands of the state. This was the *Barn Arsenic*, or sample *A*. The state claimed that this arsenic was purchased and placed in the barn subsequent to the arrest, and hence had nothing to do with that bought in Middletown, September 3d.

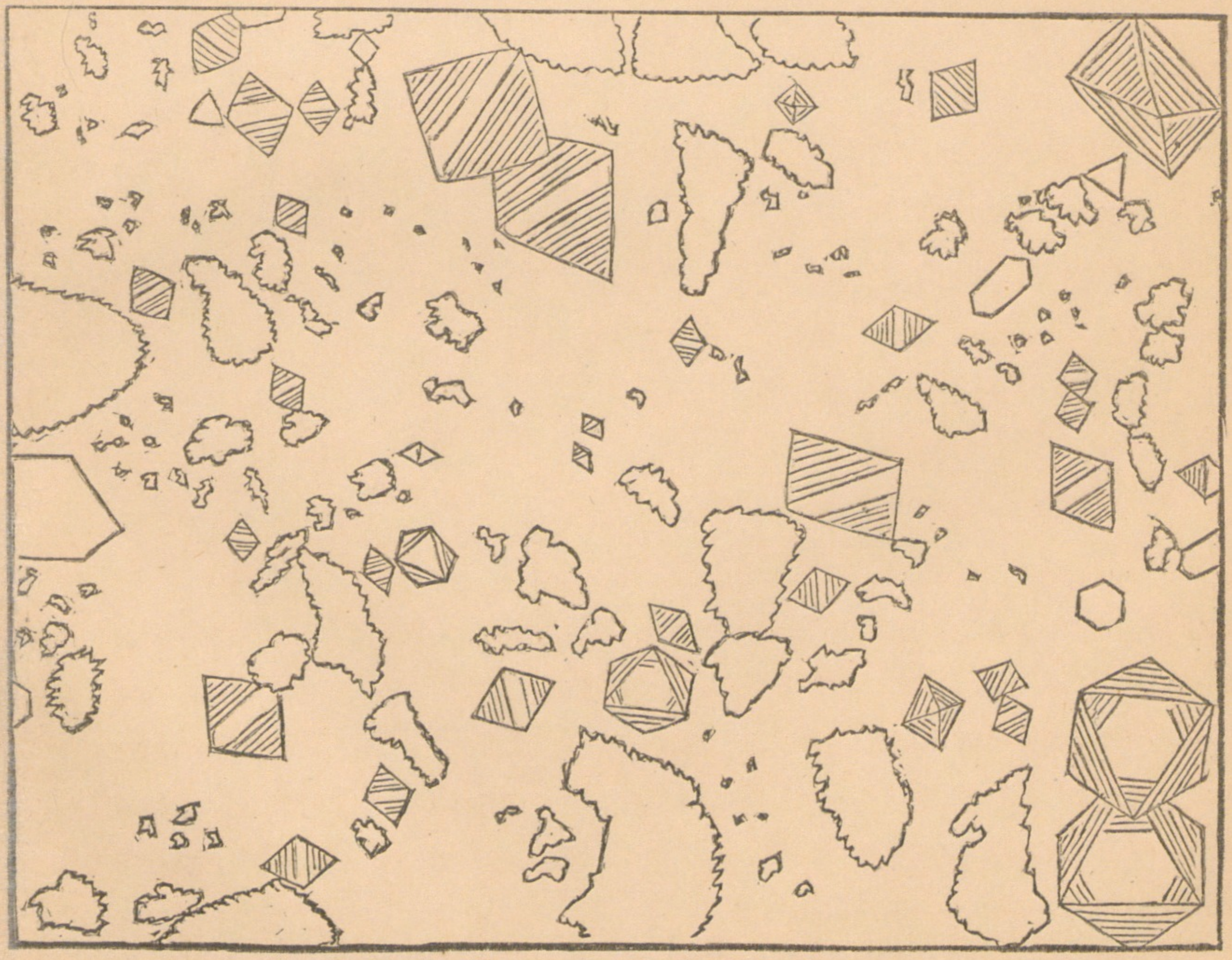
B. A second lot of arsenic (half an ounce) was obtained by the state from one Colgrove, of Middletown. This, according to his statement, was bought from the druggist Tyler, and, as the latter testified, was the last in the same jar from which the ounce spoken of above had been sold on September 3d. This was the *Colgrove Arsenic*, or sample *B*.

C. The druggist Tyler also testified that the arsenic in his jar, from which the portions obtained by the accused and three weeks later by Colgrove had been taken, was a half pound purchased by him in the preceding summer from another retail druggist, McKee, in Middletown. According to McKee this was part of a two-pound package of "Garland" arsenic, bought by him in May, 1878, in New York. An ounce, purporting to be from this same two-pound lot, was obtained by a person representing the state. This was the *McKee Arsenic*, or sample *C*.

D. The *Stomach Arsenic*, or sample *D*, as stated on p. 32, was part of sixty grains of unabsorbed arsenic taken from the stomach of the murdered girl.



3.—Sample A, magnified 200 diameters.



4.—Sample B, magnified 200 diameters.