PHYSICS

Seeing the Invisible

A New Super-Microscope Achieves the "Impossible" And So Opens Vast New Fields to Eyes of Scientists

By RONALD L. IVES

THEY PROVED it couldn't be done —by mathematics of the most complicated sort—but Dr. L. C. Graton, Harvard's superskilled microscope expert, went ahead and did it anyhow. To a scientist of his attainments, the word "impossible" is a challenge, not a stop sign.

It all started a generation ago, when Dr. Ernst Abbé, Zeiss microscope expert, set 1500 diameters as the limit of magnification. Now, Dr. Graton, using equipment of his own design, claims magnifications of 6,000 diameters, and sees no theoretical limit to further magnification. When better lenses are ground, Dr. Graton believes, even greater magnifications will be possible.

Some idea of the old theoretical limit of magnification and the new working magnification can be gained by comparing it with photographic enlargement. Using a miniature camera negative, which is about 1 inch by 1½ inches, Abbé's law stated that magnifications equivalent to clear, sharp enlargements up to 125 by 187 feet were possible (we won't go into the problem of film grain here), while Dr. Graton actually gets magnifications equivalent to a print 500 by 750 feet! This is roughly equivalent to enlarging an air mail stamp to eight acres. By the old theory, it could only be enlarged to half an acre.

Sturdy

Dr. Graton's new wonder-microscope, designed in cooperation with Dr. E. B. Dane, Jr., also of Harvard, doesn't even resemble a standard laboratory instrument. With every minor vibration magnified 6,000 times, the slight and negligible play in the frame of a standard microscope would put the image completely out of sight, or bring in another, unwanted, image.

Built on a bed of steel rails, as strong as a screw-cutting lathe, and mounted on a concrete floor, the new instrument is just about vibration-proof. True, nearby blasting or an earthquake might jiggle it, but neither blasting nor earthquake is frequent in Cambridge.

Did you ever try to get a perfect focus with a microscope? Even with the fine adjustments supplied by the maker, focussing is a finger-straining, nerve-jangling job. Aware of this difficulty, from his long years of experience with microscopes, Dr. Graton designed a motor-driven adjuster so sensitive that it will, in a few seconds, shift the lenses into exact focus, without any wear and tear on the microscopist's fingers. The operator just presses a button to bring the lens nearer to or farther from the work.

By shifting gears, he can change the motion of the lens from fast to slow and back again. "Throw it into second compound and back off another millionth," may not be said in Dr. Graton's laboratory, but that's about how they adjust their instrument. So sensitive is this adjusting mechanism that it would take a fast man, turning the controls by hand, seven minutes to move the lens 1/100 of an inch. This is about the thickness of a sheet of paper.

Making Discoveries

Constructed with the ruggedness of a locomotive and the accuracy of a fine watch, the instrument is one of the finest pieces of machinery ever built. It has to be, with every error magnified 6,000 times.

Already, with the new magnifications, Dr. Graton and his colleagues are making discoveries which may push the horizon of the visible back still farther. So valuable was the new instrument in ore analyses that a duplicate, somewhat improved in design, was immediately ordered by the Canadian Department of Mines, and is now in use solving some of the puzzles of Canada's rich and complicated mineral deposits.

Special methods of polishing the fragments of rock for inspection under the new microscope had to be devised. Naturally, if the rock is badly scratched, the scratches will mess up the image seen or photographed through the microscope, just as cat-scratches on your face would make your portrait look pretty terrible.

Until recently, rock samples were polished on cloth, with jeweler's rouge (not the kind your wife buys, but a redder, harsher kind that doesn't cost so much). Now, sheets of soft lead are used in place of cloth, and flatter, scratchless surfaces can now be made.

From his experiments, Dr. Graton has decided that the limits of magnification are not in the lenses at all, but in the surface being photographed.

With most camera lenses, you can take a picture of a man from a distance of ten feet and have his ears and his nose in equally sharp focus. This is called "depth of focus." As the lenses become larger, letting in more light, this depth of focus becomes less, until with very fast lenses, the image of a man's nose will be sharp, while his ears will be so far out of focus as to look fuzzy.

Little Depth of Focus

Dr. Graton's microscope lenses, being as large as they can be made (even so, they are smaller than the average dental filling), and being used at distances smaller than the thickness of a sheet of paper, have very little depth of focus. If there is an almost infinitesimal difference in level between two parts of a rock specimen being examined, only one level will be sharp in the finished picture, unless a compromise is made, in which both levels appear a bit fuzzy.

There is a mathematical law, carefully worked out some years ago, saying that bumps and flaws smaller than one-fourth of the wavelength of the light passed through a lens do not matter. Now Dr. Graton finds that they do matter, and is able, with his one-ton instrument, to get focus accurate to within one-tenth of the wavelength of the light used. Naturally, with this accuracy, an error of about one-fourth the wavelength of the light used will put everything out of order.

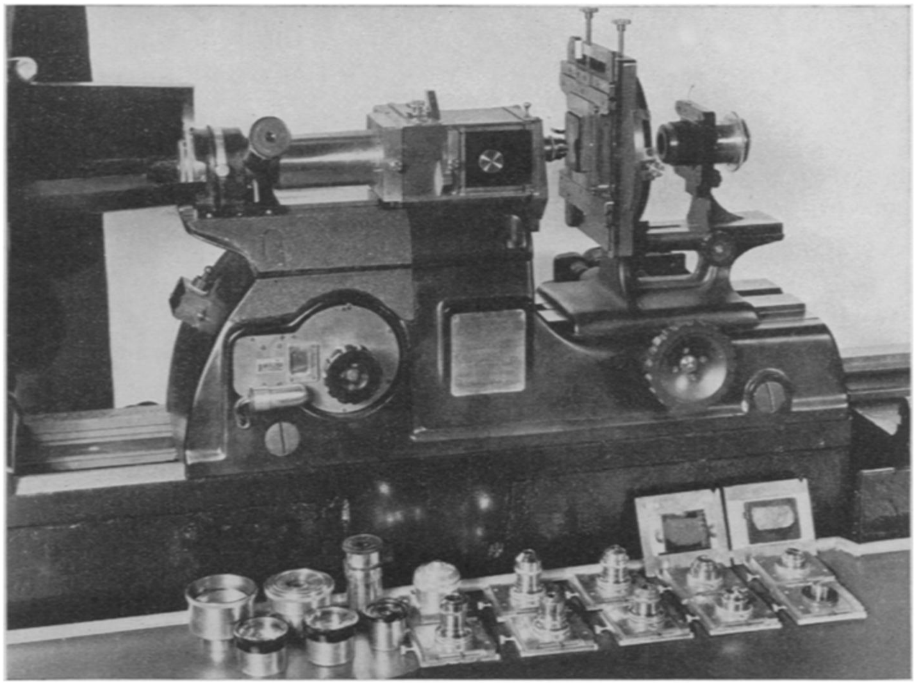
With the great accuracy possible in the new instrument, many of the supposedly impossible things in microscopy have already been done, and no new limits are in sight. Today, with the new instrument and the newly-developed grinding equipment, the nature and construction of many minerals are being worked out, not by theory and long formulas, but by looking at them and seeing. Gold particles so small that they couldn't be seen or photographed before are now inspected with ease, and their relation to the other minerals in the ore sample can be easily determined.

Once it is surely known where the particles are, methods can be devised for getting the gold out of the rock, perhaps profitably. Naturally, if the gold costs more to get out than it sells for, even Dr. Graton's microscope isn't going to help very much.

Instruments of this type will be useful in applied science just as they have already opened new fields in pure science. Mining geology is only one of a number of fields where better microscopes are useful. In the metal industry, where the crystalline structure of metals seems to bear a definite relation to their strength, more detailed studies can now be made. Perhaps the maddening problem of fatigue of metals can be solved by these studies.

We have all encountered this. Remember the "crystallized" rear axle on your car that broke 40 miles out of nowhere, in the rain? That was fatigue of the metal.

When a metal is strained a number of times, the structure changes, and with it the properties of the metal. When you went over too many bumps, the molecules in that rear axle rearranged themselves, and the axle became brittle, instead of resilient. Microscopic studies of axles that did and didn't break under road usage have already showed what happened. Will better microscopes show how non-fatigable metals may be made?



INVESTIGATE THE INFINITESIMAL

Part of the new Harvard super-microscope, with which magnifications of 6,000 diameters have already been secured. A few of the lenses used with it rest on the bench in the foreground.

May Find Virus

Medicine can benefit from the instruments and methods worked out by Dr. Graton and his colleagues. Things that now are indistinct under the best medical microscope can, perhaps, be magnified until the details are distinct. This may lead to finding of the elusive "filterable viruses," which are blamed for so many things that can't be otherwise explained. Are there filterable viruses, or is it merely a scapegoat word, used instead of 'I don't know'?

Although still too crude to see an individual atom, this microscope can probably shed new light on many chemical phenomena. With it, things only 100 times as large as an atom can be examined. In this classification are many crystals, and crystals are very important in modern chemistry. Sugar, salt, caustic soda, sulphur, and a host of other familiar chemicals are crystals. Today we separate many substances by "fractional crystallization," but we are none too sure just how crystals grow. Perhaps, by applying the Graton technique, we can learn more of the early stages of crystal growth, and with this understanding, attack the problem of making crystals grow as we want them. The dividing zone between the growing of mineral crystals in the earth and of sugar crystals in a vat is becoming narrower each year.

What will the use of greater magnifications mean to the paleontologist, who searches for the skeletons of extinct animals in rock laid down millions of years ago? From studies already made on micro-fossils, billions of barrels of oil have been located, other areas have been shown to be barren of oil, and the locations of the seas and continents of long ago have been mapped. Will this new microscope reveal a whole new series of ancient life forms, so small that present methods have missed them? The possibilities are interesting, although no real search has yet been made for the microbes that preyed on microbes of the past.

Can Study Bacteria

Bacterial classifications, now made on the basis of the shape only, may be simplified and made more accurate when the Graton microscope, and the methods of securing higher magnification learned from it, are applied to bacteriology. With such magnifications, the internal structure of bacteria can be studied, and the small living forms classified on the basis of finer details, instead of mere gross shape.

Dr. Graton's new microscope should not be regarded as a new discovery (although discoveries have already resulted from its use) but as a more exacting tool for science. It may be, as a result of the painstaking care put into its construction, the means of getting more accurate determinations of many things that are now uncertain. Already, it has pointed the way to a new era in microscopic work, where micrometer methods will replace the present rough yardstick-like, rule-of-thumb measurements. Getting things right, instead of getting something that might do, will be easier with it, and studies heretofore impossible can now be made with this and similar instruments.

"Try It"

Makers of microscope lenses, using formulas now proved to be wrong, made lenses that worked better than the formulas called for. With these lenses, Dr. Graton did things regarded as impossible. What will he be able to do with lenses designed according to new formulas, with no limit known to the magnification possible? Dr. Graton himself will not say, but recommends a "try it and see" policy, in which tests of actual lenses, under working conditions, are substituted for mathematical formulae.

Roughly, Dr. Graton believes in performance tests, instead of sales talk. No matter how good the formula, he states, the lenses and other equipment should be tested to see exactly what they will and will not do. A mining man would say that Dr. Graton placed more faith in assayer's report than in prospectus.

Not long ago, magnifications of more than 1500 diameters were regarded as impossible. Recently, Dr. Graton, with his new instrument, got useful magnifications of 6000 diameters—making images cover sixteen times as much area—and empty magnifications, making things bigger, but showing no additional detail, of as much as 50,000 diameters.

The microscopist today is in somewhat the same situation as the explorer just after America was discovered—he knows of new kingdoms of conquer, but hasn't mapped them yet.

What will he find?

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PHYSICS

Soap Bubbles Aid Explosion Studies

AT THE National Bureau of Standards in Washington Uncle Sam's scientists have been blowing soap bubbles in the laboratory and learning new secrets of how explosions occur in gases. Particularly they have been seeking to learn how fast a flame from an explosion will speed through space, a matter intimately tied up with explosive fires and indirectly with the efficiency of internal combustion engines.

Scientists Ernest F. Fiock and Carl H. Roeder, in a report prepared for the National Advisory Committee for Aeronautics, outline their methods of soap-bubble blowing and why it has value in combustion research.

The trick is to blow a soap bubble with an explosive gas, such as carbon monoxide, and make it form around a gap between two metal wires. Across this gap an electric spark can be made to jump, ignite the gas and create the explosion. Just as the explosion is to occur a high speed motion picture camera, taking over 1,600 frames a second, goes into operation and photographs the progress of the flame.

Key point of the soap bubble method is that it occurs essentially in free, or unconfined, space, because the soap film expands very easily to any pressure increase. As a matter of fact, the method is said to give results under constant pressure and at the same time enables the direct observation of the relative speeds of the flame and the expanding, but yet unburned, gases.

For explosions of carbon monoxide it was found that flame speeds reached values of 900 centimeters per second or about 20 miles an hour.

The soap bubble method has been a pioneering effort in the broad study of gaseous explosions. The general project is being continued, says Mr. Fiock, by additional methods which should have an even wider range of applications.

Science News Letter, October 1, 1938

ENGINEERING

Racing Sailboats Fitted With Streamlined Rod Rigging

Borrowed From Aviation Design, New Rigging Is Aiding Boats To Victory By Reducing Drag

THREE racing sailboats which have compiled impressive race records during the 1938 yachting season owe part of their success to the newest thing in sailboat equipment, streamlined rod rigging — borrowed directly from the streamlined struts of airplanes.

Using rigid streamlined rods that resemble the struts widely used on aircraft before the introduction of internal bracing, the Goose, Venture and Foo, three racing craft in the six-meter, eight-meter and Star classes respectively, have scored again and again on Long Island Sound and elsewhere this summer.

They gain reduced wind resistance from the novel type of rigging, used in place of the more conventional steel cable. More important, they gain rigidity of mast setting, an important fine point in racing design, where a minor improvement will mean the difference between a place and a victory.

Developed by E. Burke Wilford, a Philadelphia aeronautical designer, and the Pennsylvania Aircraft Syndicate, the streamlined rod rigging stems directly from the rigid round rods with which the yacht Ranger, successful defender of the America's Cup a year ago, was equipped by Mr. Wilford.

The novel type of rigging may add perhaps a tenth of a knot (a knot is a rate of one mile and a sixth per hour) to a boat's speed, but that adds up to a quarter to half a mile in a race lasting several hours, no mean addition to any racing vessel's performance.

Use of the rods instead of cables means less stretching of the rigging. This, Mr. Wilford told Science Service, spells a mast more rigidly centered. Improper positioning of the mast can seriously affect the boat's performance. When cable is used, constant "fussing" is required. On the other hand, a single adjustment of the rod rigging may do for a season.

Drag of the streamlined rod rigging ranges between one-eighth and one-third that of the cable, depending upon wind direction and the boat's particular sailing maneuver, according to Mr. Wilford. The rigging was wind-tunnel tested insofar as possible.

Another gain in reducing drag comes from the fact that less rigging is needed. Not all the rigging consists, however, of streamlined rods. In some places round rods are used for convenience; in the case of moving cables, cable must still be used. A flat tape is, however, being studied as possible replacement.

Although the rod rigging required by the Ranger was very expensive, cost of a set of rods and accessories for the smaller sized boats is said to be very little more than the conventional rigging.

Science News Letter, October 1, 1938

GEOLOGY

Valley of Dead Sea Was Pushed Down

THE DEAD SEA and the valley in which it lies, famous in Biblical history, did not merely drop to their present position far below sea level. They were actually pushed down, Dr. Bailey Willis of Stanford University has reported to the Geological Society of America.

The Dead Sea area started its downward movement early in the age of dinosaurs. It continued as a catch-basin for sediments until mammals began to dominate the earth. Then its borders rose into high hills, rimming the region with a mass of complexly folded rock.

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