the earth and moon depend on the identification of frictional processes, whether they lie within the solid earth or in the oceans (*4*).

A spectral line, $m_3 = M_3 \cos 2\pi f(T + \varphi)$, of amplitude M_3, frequency f, and phase φ has a mean-square value of $\frac{1}{2} M_3^2$, which is spread over a frequency interval T^{-1}; T is the length of record. The spectral density is then

$$S(f) = \tfrac{1}{2} M_3^2 T = 2.5 \times 10^{-16} \quad (2)$$

for $12^h.42$ lunar tide for frequency interval T^{-1} centered at f. A year's observation of the length of day with a radio interferometer gives a spectral density at the semidiurnal period of 10^{-8} second, a value comfortably above the noise level. Radio star determination of the length of day would thus permit a study of the yearly variations in the retardation of the earth's rotation period.

The amplitude of the tide depends on the Love number k. In Eq. 2, k has been assigned the conventional value of 0.29 (*1*). It provides a measure of the deformability of the planet Earth, which depends not only on the elasticity of the mantle but also on motions within the earth's fluid part. At present, k is determined from observations of the Chandler wobble, having a period of 14 months. A precision determination of the spectral lines in the fluctuation of the length of day permits an investigation of the dynamic response of the core to tidal excitations at a variety of frequencies. This is of great current interest because it is possible that the driving force for the earth's magnetic field is dynamical in origin (*5*).

The precision investigation of the spectral lines is likely to yield significant data regarding the earth's interior and possibly frictional processes within the oceans. Investigation for the continuum at higher frequencies than has been possible in the past will be of greatest importance to meteorology. The error spectrum in the radio interferometer for a fortnightly period is about 10^{-12} second. Atmospheric variations can give rise to fluctuations exceeding this by substantial margins. Thus, it will be possible to determine the variations of angular momentum of the atmosphere for periods longer than 1 to 2 weeks. This determination, coupled with satellite determinations of the heat balance within the atmosphere, will make possible detailed investigations of major weather anomalies, their thermal sources, and their influence on the large-scale dynamics of the atmosphere.

The only system so far proposed which would be competitive with Gold's suggestion for precise determination of variations of length of day is that of Alley and his associates (*6*). In their system, an optical corner reflector would be placed on the moon and illuminated by a ground-based laser; the varying range would then be obtained. This determination of the earth's rotation rate with respect to the moon yields an expected accuracy of about one part in 10^8 for a 1-day interval. In order to obtain the earth's rotation, the moon's motion must be very accurately separated from it. The combination of observations of the kind suggested by Gold and those of an optical reflector on the moon would improve our information about the earth's rotation and the moon's motion. The combined information would then strengthen the basic dynamical data of the solar system.

GORDON J. F. MACDONALD
Institute for Defense Analysis, Arlington, Virginia 22202

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12 June 1967

New Reflected-Light Microscope for Viewing Unstained Brain and Ganglion Cells

Abstract. *We have designed and constructed a new type of reflected-light microscope to form images including only light reflected near the plane of the object. This selectivity of image formation is based on a mechanical flying-spot technique. Objects difficult or impossible to see with earlier microscopes, such as unstained cells and cell processes in brains of living salamanders and in excised dorsal root ganglia of frogs, have been observed routinely with this microscope.*

A new type of light microscope makes possible observation of brain cells and brain-cell organelles in living vertebrates over extended periods. Conventional transmitted-light microscopy, including phase and interference microscopy, is unsuitable for such observation because of the thickness of the material to be examined. Because light reflected back into the microscope from many different layers of tissue degrades the quality of the image of the object, conventional reflected-light microscopy is usually unsatisfactory with low-contrast, translucent material such as unstained brain tissue.

The new microscope was designed to scan the optical field in order to eliminate much of the unwanted reflected light and to take advantage of the contrast-enhancing properties of an illuminated field of small diameter (*1*). A disc of copper foil, 20 μ thick and 85 mm in diameter, was perforated near its periphery with 26,400 electrolytically etched holes approximately 90 μ in diameter, with an average shortest distance between centers of 280 μ; the holes were arranged in Archimedean spirals. The disc was reinforced and placed between the light source and the objective (Fig. 1). The image of the light source was focused on one side of the disc; only light passing through the holes in the disc illuminated the object. An image of these holes was formed by the objective in the object plane. The pattern of holes in the disc was such that when the disc was rotated three times per second the entire optical field was scanned 120 times per second. Light reflected from the object also had to pass through holes in the disc to reach the eyepiece, but these were holes on the opposite side of the disc; the disc's two sides were made optically congruent by inverting prism systems.

Of the light reflected back into the microscope, only that reflected from the plane of the object formed an image in the plane of the rotating disc; only this portion of the reflected light could pass, without attenuation, through the holes in the disc and be seen through the $\times 15$ orthoscopic eyepiece focused on the disc. Light reflected from above or below the plane of the object was largely intercepted by the opaque portions of the disc; thus the reflected-light image could not be degraded by scattered light reflecting into the microscope.

Undesirable reflections from optical surfaces within the microscope itself were eliminated by use of crossed polarizing filters, with a quarter-wave

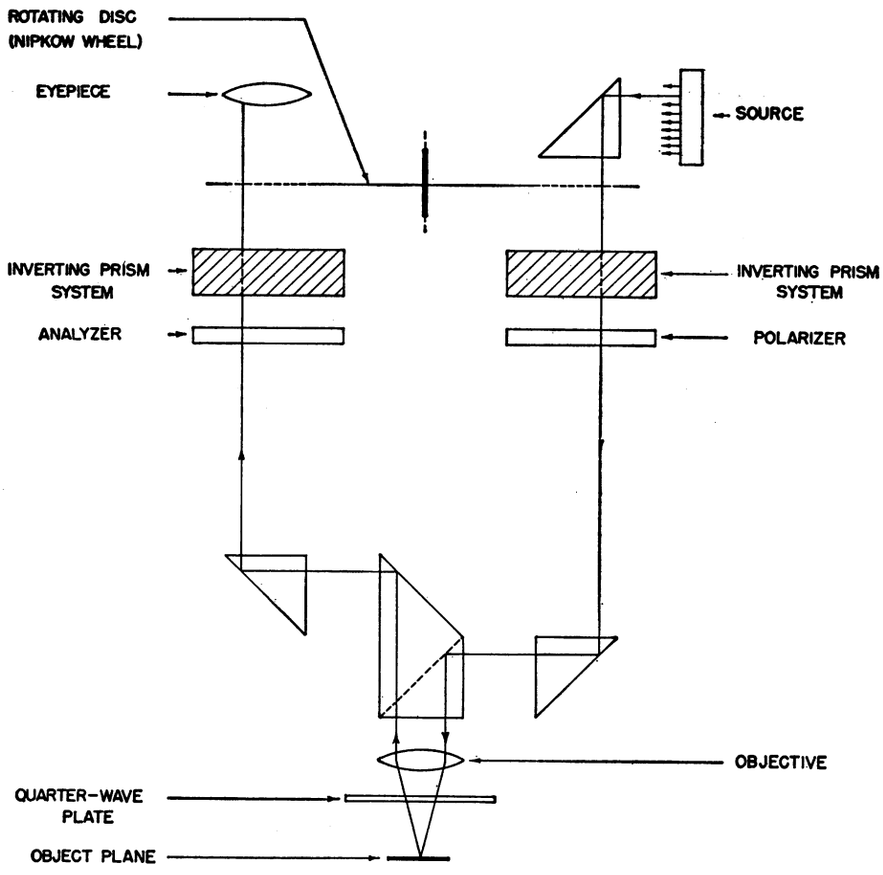

Fig. 1. Schematic diagram of microscope, tracing a single ray from light source to eyepiece and ignoring the effects of the inverting prism systems.

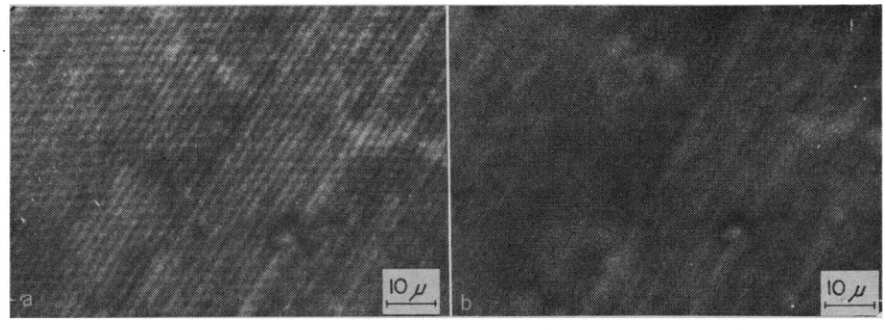

Fig. 2. Two photographs of the same portion of a reflecting replica grating (1.9 μ per line) covered by a sheet of transparent plastic and immersed in 0.65-percent saline: with the rotating disc in the microscope (a) and with the disc removed (b).

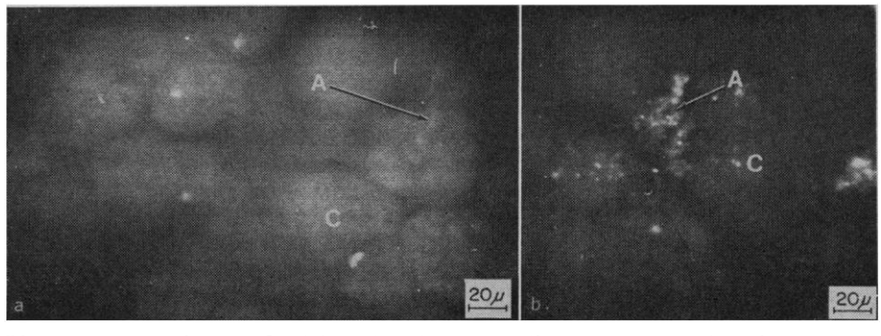

Fig. 3. Two unstained, unfixed frog dorsal root ganglia. With the rotating disc removed from the microscope, these cells could not be seen. *A*, axon; *C*, cell body.

plate beneath the objective—a feature of other reflected-light microscopes of advanced design (*2*).

For most observations, a ×22 Leitz Ultropak objective was used with its ring condenser removed; with this one could resolve easily lines of a replica grating spaced 1.9 μ apart (Fig. 2a). Even with long-working-distance objectives, however (the ×22 Ultropak objective has a free working distance of 2.2 mm), the depth beneath the surface at which the microscope could be focused was limited by the optical quality of the material observed. Although objects could be seen below the surface of translucent nervous tissue, the more transparent the material the deeper one could see into it.

Figure 2 shows an example of the image-enhancing performance of the new microscope; the two photographs are of the same object, a portion of a reflecting replica diffraction grating, taken with and without the rotating disc in the microscope. Without the disc, the new microscope is essentially a conventional reflected-light instrument. A sheet of transparent plastic was placed over the grating, and both grating and plastic sheet were immersed in 0.65 percent saline. A lamp with a tungsten-ribbon filament was the light source. In Fig. 2 the angled, near-vertical lines are the lines of the grating; the horizontal lines in Fig. 2a are scanning lines.

Excised dorsal root ganglia of frogs (*Rana pipiens*) were observed and photographed (Fig. 3); much more detail could be seen with the eye than could be photographed. No photographs of these cells were taken with the rotating disc removed from the microscope because without the disc no cells could be seen. With the disc in place, outlines of cell bodies could be traced from the surface of the ganglion to a depth of 50 to 100 μ. Cell bodies with axons emerging from them, and such cell organelles as nuclei and nucleoli, were observed. The observed morphology of ganglion cells corresponded well with that described in studies of fixed and stained material (*3*).

Figure 3b is one of a series of five photographs taken at focal planes 10 μ below one another. Outline drawings were made from these photographs, and a drawing was made on the basis of the photographs (Fig. 4). Some liberties were taken to illustrate histologic features seen many times but not all seen in a single view of one ganglion.

In addition to dorsal root ganglia of

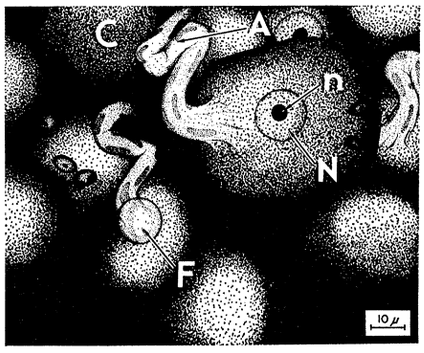

Fig. 4. Composite drawing based on many observations of unstained, unfixed frog dorsal root ganglion cells. *A*, axon; *C*, cell body; *F*, fat globule; *N*, nucleus; *n*, nucleolus.

frogs, the brains of anesthetized salamanders (*Triturus v. viridescens*) have been continuously observed for as long as 5 hours. Observations of the same salamander have been repeated after many days; nerve fibers in the optic tectum and cell bodies on the floor of the fourth ventricle were seen.

The loss of light within the current prototype of the new microscope was so great that, for observations of the living salamanders and of the freshly excised dorsal root ganglion cells, it was necessary to use the reflected image of the sun as the light source. The image formed at the eyepiece of the microscope generally included less than 0.001 percent of the light entering the microscope. When the sun was the light source, the amount of light that generally reached the cells was less than that of a conventional reflected-light microscope with a lamp having a tungsten-ribbon filament. This loss of light necessitated long exposures (1 to 4 seconds) for photography, so that the photographic image was degraded by vibrations in the microscope; current changes in design of the microscope should greatly reduce this loss.

With a new model of the microscope that is less wasteful of light, and with the objective fitted with a needle-like prism that can be inserted into nervous tissue (*4*), it may be possible to watch neurons during electrophysiologic experiments to see, for example, whether morphological changes accompany functional activity.

M. David Egger

Department of Anatomy,
Yale University School of Medicine,
New Haven, Connecticut 06510

Mojmír Petráň*

Institute of Biophysics,
Charles University School of Medicine,
Plzeň, Czechoslovakia

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* Research associate, Department of Psychology, Yale University, during part of the work.

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Zeolitization of Tuffaceous Rocks of the Green River Formation, Wyoming

Abstract. *The alkali-rich zeolites mordenite and clinoptilolite have been discovered in tuffaceous rocks of the Green River Formation, Wyoming. This occurrence strongly supports the alteration of glass to alkali-rich zeolite to analcime as the paragenetic sequence of alteration of tuffaceous rocks deposited in ancient Lake Gosiute.*

Mordenite and clinoptilolite occur in tuffaceous rocks of the Tipton shale member of the Green River Formation. The analcime-rich tuffs of the formation have been known since the work of Bradley (*1*), but this is the first recorded occurrence of mordenite or clinoptilolite in the Green River Formation. Moreover, this occurrence strongly supports the suggestion of Hay (*2*) that analcime in tuffs of the Green River Formation formed by alteration of an alkali-rich zeolite precursor. Analcimic tuffs elsewhere in the Bridger Basin occur at the same stratigraphic interval in the Tipton shale member as do the mordenite and clinoptilolite-mordenite tuffs described in this report (*3*). The clinoptilolite-mordenite and mordenite-rich tuffs are characterized by relict vitroclastic textures, whereas the analcimic tuffs generally lack vitroclastic textures.

Characteristic x-ray diffractograms for mordenite and a clinoptilolite-mordenite mixture (Fig. 1) were obtained from two separate tuffs, both 0.1 to 0.3 feet (0.0305 to 0.0915 m) thick, in U.S. Bureau of Mines drill core 1-3, located in section 15, T18N, R10W, Sweetwater County, Wyoming. The drill core is 217.4 feet long and penetrates the lower part of the Wilkins Peak member, all of the Tipton shale member, and the top of the Wasatch Formation. The tops of the clinoptilolite-mordenite and mordenite-rich tuffs are, respectively, 87.9 and 90.4 feet above the base of the Tipton shale member. As by Bradley (*4*), the base of a coquina bed containing abundant *Goniobasis* sp. was used to designate the base of the Tipton shale member of the Green River Formation.

All of nine tuffs above the clinoptilolite-mordenite and mordenite-rich tuffs proved to be analcimic; the one below, montmorillonite-rich. The oil shales above the mordenite-rich tuff are analcimic also. The lowest analcimic oil shale in the drill core is directly above the mordenite-rich tuff; thus the transition from analcime to mordenite is very sharp.

Previously analcimic tuffs in the Green River Formation have been cited as an example of the reaction of saline lake waters with silicic volcanic glass to form analcime (*1*). However, Hay recently suggested that analcime can form at low temperatures by reaction

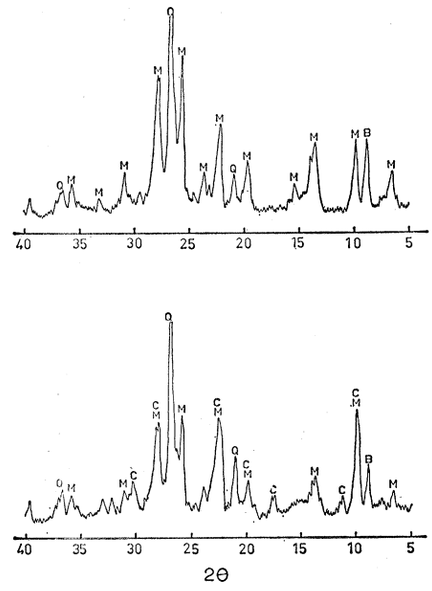

Fig. 1. Diffractometer patterns of mordenite-rich tuff (top) and clinoptilolite-mordenite tuff (bottom). Radiation is Cu$K\alpha$ (λ, 1.5418 Å). *M*, mordenite; *C*, clinoptilolite; *Q*, quartz; *B*, biotite.