SOME GEOLOGICAL APPLICATIONS OF THE ELECTRON MICROSCOPE

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INTRODUCTION

As early as 1935, Prof. E. F. Burton, University of Toronto, built an experimental type of electron microscope, and most of the pioneer work on the microscope was done on this particular model at Toronto. The compound magnetic electron microscope, type EMB, was developed in the RCA Laboratories, Camden, N. J., about 1940. To Dr. James Hillier, young physicist and pupil of Prof. Burton, goes most of the credit for putting the microscope in its present form. The latest model has the control board on a slant in front of the microscope which makes for ease of operation. A console model is also available.

Table I shows comparisons of dimensions of some minute objects.

Fig. 1 is a simplified drawing of the RCA compound magnetic electron microscope showing the various parts. Focusing is accomplished by varying the lens power. The specimen mount is the movable stage. Being inside the vacuum portion of the microscope, it is moved by means of fine screws and a flexible metal bellows.

The electron beam is concentrated on the specimen by the magnetic field produced in the condenser-lens coil. After passing through the specimen, the electrons are focused by the objective-lens coil into an intermediate image, and the projection-lens coil produces a further magnified image on the fluorescent screen in the final viewing chamber.

To facilitate the initial adjustment of the specimen, a port is provided for viewing the intermediate image on a fluorescent screen close to the plane of the projection-lens coil. The relatively low magnification of this image makes it easy to select the most interesting part of the specimen and to move it into position to be magnified further by the projection-lens coil.

Six observation windows enable a number of spectators to view the image simultaneously. The selected field of view is chosen, magnification adjusted to the desired value, and a photographic record may be made by raising the fluorescent screen and allowing the electrons to strike a photographic plate below the screen, the plate being carried in a holder in the vacuum system of the microscope.

Magnifications of 1000 to 20,000 are thus obtainable, and the definition in the photographs is sufficiently clear to allow further optical enlargement to obtain full useful magnification.

SPECIMEN-MOUNTING TECHNIQUE

Under the electron microscope an area approximately 0.01-mm square, is enlarged to the desired magnification. Thus, to photograph an area 1-mm square would require 10,000 exposures. To scan this area, however, takes only a few moments because of the maneuverability of the instrument.

For working with such small areas a special specimen-mounting technique had to be devised. The RCA people in Camden, N. J., mount specimens on a 400-mesh screen. The screen is dipped into a solution of collodion which dries quickly leaving a strong film, approximately 1 micron thick, between the individual wires.

The material for study may be placed on the collodion film in one of several ways—1) manually, under high-power binoculars; 2) precipated from solution onto the screen; 3) by passing the screen coated with collodion through a culture or preparation of the material; 4) by placing a drop of material suspended in a liquid onto the screen.

No wet or living tissue can stand the high vacuum of 10^{-4} to 10^{-6} mm of mercury in the electron microscope. However, this microscope is being used extensively in biological studies on materials ranging in size from organs of animals and insects downward through the bacteria and to the viruses, and even to large molecules. The material in turn, must be thin enough to allow the passage of electrons through it. Some material deteriorates when subjected to the intense electron bombardment, and some materials may heat up during the bombardment. Owing to the high vacuum this heat can not be transmitted away from the subject.

POSSIBLE GEOLOGICAL USES OF ELECTRON MICROSCOPE

A. *Identification and correlation of clays*

Quoting Hillier: " . . . particles of various types of clay have probably been subjected to more examination by means of electron microscope than any other type of material." Some clays are composed of grains of the order of some 50 angstroms thick, and a few angstroms wide. Studies in the nature and correlation of such minute particles in the electron microscope is dependent upon characteristic shapes and not on chemical combinations.

In Decatur County, Georgia, there is a clay that is used extensively in laboratories and refineries for filtering purposes. This is called *Attapulgus Clay,* so named for a nearby town. Chemical analyses of this clay show it to be chiefly montmorillonite, but the individual microcrystalline masses can not be identified or separated under the best light microscope. An electron-microscope picture (X40,000) of a sample of this clay, showed an abundance of bundles and masses of minute fibers. These fibers are the so-called microcrystalline masses that can not be identified under the polarizing microscope.

Infusorial Earth, sold by the Central Scientific Company, is described as a "siliceous earth made up largely of siliceous fragments of *Infusoria*, used as fulling material and as a filtering and absorbing agent." An electron-microscope picture (X40,000) of this material showed fibers very similar to the Attapulgus clay. The similar shapes of constituent parts of these two materials attest to their similar physical properties.

Clays might lend themselves to study and identification in the electron microscope along the following lines:

1) Minute crystals of rutile have been identified in titanium-rich clays. These crystals are too small to be identified under a light microscope. This would lead to a study of the submicroscopic mineralogy and crystallography of clays.

2) The nature and occurrence of the clay material in oil-producing sands is a study in itself. Recently, a micaceous flake about 1 micron in length, was obtained from an oil sand and photographed in the electron microscope (Bates, Gruver, and Yuster 1946). The nature and abundance of such clay materials might be a valuable aid in the detailed correlation of oil sands, in the study of reservoir behavior, and in setting up water-flooding projects in essentially depleted oil fields.

3) Structural details of clays, pertaining to possible physical and physio-chemical properties of the clays.

4) Presence of submicroscopic organic forms too small to be identified, or even noted, under a light microscope.

5) Studies of the response of clays to the high vacuum of the electron microscope, and changes due to electron bombardment.

B. Studies of Crude Oil

It will be necessary to develop a technique for studying crude oils in the electron microscope. A specimen of crude oil was mounted in the usual manner on collodion film and a monotonous gray field was seen except for one object, or group of objects. This was composed of a number of oval bodies; some of these were solid, while others appeared to be breaking up. It is possible that this object was not able to withstand the high vacuum and the electron bombardment in the electron microscope, and the photograph caught the material in the process of breaking up.

A possible approach to the study of crude oils in the electron microscope may be outlined as follows:

1) Study all foreign substances in the oil and in the extracts.

2) Note and identify bacteria in the oils.

3) Study the behavior of the oil during preparation, and reaction to the high vacuum and electron bombardment.

4) Study the nature of coloring material in asphalts.

5) RCA engineers have photographed what they believe to be giant molecules in the electron microscope. Perhaps actual molecular differences may be found and be used for correlation.

C. *Paleontological Studies*

The electron microscope should be valuable in studying details of fossils too small for study under a light microscope. Examples are: Diatoms, spores, algae, and some protozoans. Electron-microscope pictures of diatom shells indicate the detail and arrangement of holes or perforations too minute to be seen with the light microscope.

TABLE I

Comparison of the dimensions of some minute objects and some units of measure

	Centimeter	Millimeter
Atom's nucleus	$\frac{1}{1,000,000,000,000}$	10^{-11} (0.00000000001)
Atom's outside diameter	$\frac{1}{100,000,000}$	10^{-7} (0.0000001)
One angstrom unit (A°)	$\frac{1}{100,000,000}$	10^{-7} (0.0000001)
One millimicron ($\mu\mu$)	$\frac{1}{10,000,000}$	10^{-6} (0.000001)
Electron-microscope's limit of vision	$\frac{1}{1,000,000}$	10^{-5} (0.00001)
Influenza virus	$\frac{12}{1,000,000}$	12×10^{-6} (0.00012)
Tobacco mosaic virus	$\frac{28}{1,000,000}$	28×10^{-5} (0.00028)
Light-microscope's practical limit of vision	$\frac{1}{10,000}$	10^{-3} (0.001)
One micron	$\frac{1}{10,000}$	10^{-3} (0.001)
Red blood corpuscle	$\frac{4}{1,000}$	4×10^{-2} (0.04)
Head of a pin	$\frac{1}{10}$	1.0
Centimeter	1.0	10.0
Inch	2.54	25.4

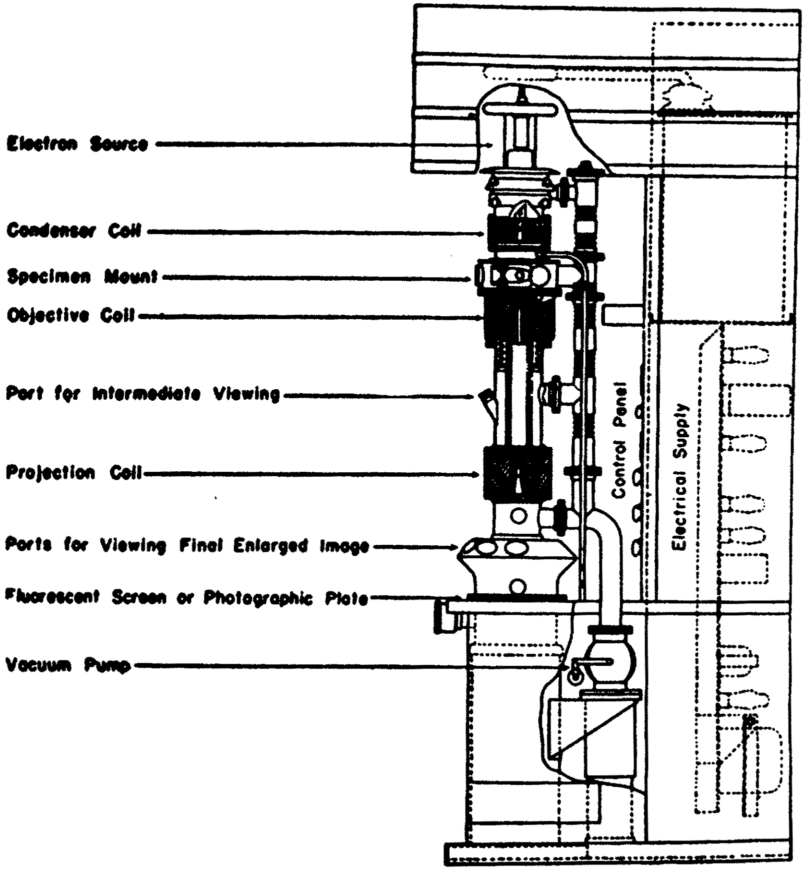

Fig. 1. A simplified drawing of the electron microscope taken from the pamphlet, *Electron Microscope*, prepared by the R. C. A. Manufacturing Company, Camden, N. J.

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