Chapter 12

Map Reproduction

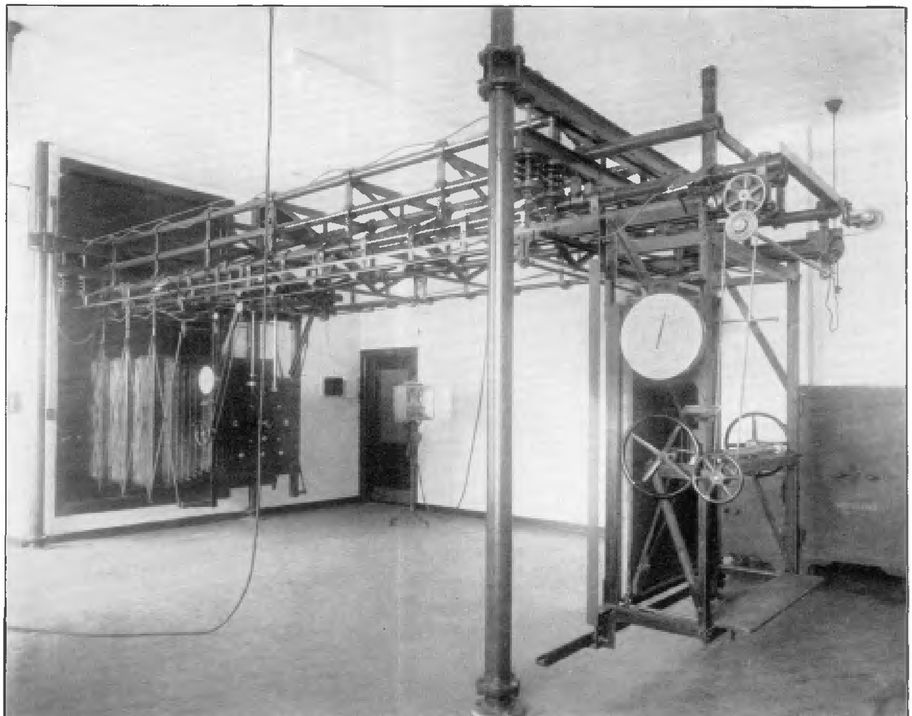
68. Map Reproduction. Few if any textbooks give a description of the processes used in map reproduction. It is the purpose of this chapter to give the engineer a brief outline of the processes used to show what happens to his map after completion.

Through the courtesy of Colonel C. H. Birdseye, the author had the opportunity of making a complete inspection of this work, and acknowledgment is here made of the time and material given by Colonel Birdseye.

69. Photolithography. Reproduction by photolithography is the method employed most widely for reproduction of maps drawn on drawing paper or for maps drawn on tracing linen for reproduction to a different scale. The process involves photographing the drawing to the proper scale; preparing the negatives by painting out, retouching, or hand engraving; processing the negatives direct to printing plates; and printing the maps in a power press. These operations all tie together, and each step may be performed in at least two ways. It is important to realize that each operation reverses the material and that they all depend on how the map is to be printed, that is, on an old-style reciprocating flat bed press or on a modern offset press.

70. Copying Camera. The first step is of course to photograph the drawing. The Geological Survey has a battery of five large precision map copying cameras specially designed by the Survey, as follows: (*a*) A 50 × 50 inch straight copying camera, with a 7 × 8 foot copy board. Glass plates sensi tized at the time of use, film, or paper negatives can be used in this camera, but the Survey generally uses plates or film not larger than 30 × 40 inches (see Fig. 96). (*b*) A 32 × 32 inch straight copying camera, employing wet plates, dry plates, film negatives, or paper negatives and so equipped that the copy holder can be tipped down in a horizontal position and different sections of the map can be placed conveniently in proper position. The size of negatives generally used are 24 × 30 inch or smaller. (*c*) A 36 × 36 inch prism camera, the sensitized plate being at right angles to the copy board and the images on the emulsion side of the plate reading right. Negative 30 × 36 inches are generally used in this camera. (*d*) A 24 × 24 inch prism camera used largely in connection with copper plate engraving of standard atlas sheets. (*e*) A 24 × 24 inch straight copying camera of fixed focus used entirely for one to one ratio of small maps, such as land plats, which are reproduced to the same scale. Plates 20 × 24 inches in size are generally used in this camera.

71. Wet Plates. All the precision map reproduction work of the Geological Survey, as well as of all the other Federal map reproduction agencies, involves the use of wet plates. They are made by using selected plate glass of thickness varying with the size of the plate. The first operation is to flow evenly over the plate a solution of albumen used to hold the other solutions on the plate. When dried, the plate is coated with collodion, an organic



Courtesy Geological Survey.

FIG. 96. Precision Map Copying Camera.

base composed of ether, alcohol, gun-cotton, and iodide. The plate is then lowered on a rack into a stone or enamel bath containing a silver solution. The plate is fully sensitized after it has remained in the silver bath about 5 minutes, and it is placed in the negative holder of the camera which, on all except the small prism camera, extends into its darkroom.

The drawing is placed on the copy board under plate glass and the photographer focuses the camera for sharp definition at the proper scale, testing the scale by means of measurements on the ground-glass focusing plate or a ground-glass template, in the focal plane of the camera. All of the three larger cameras are operated either from the darkroom or from the outer laboratory.

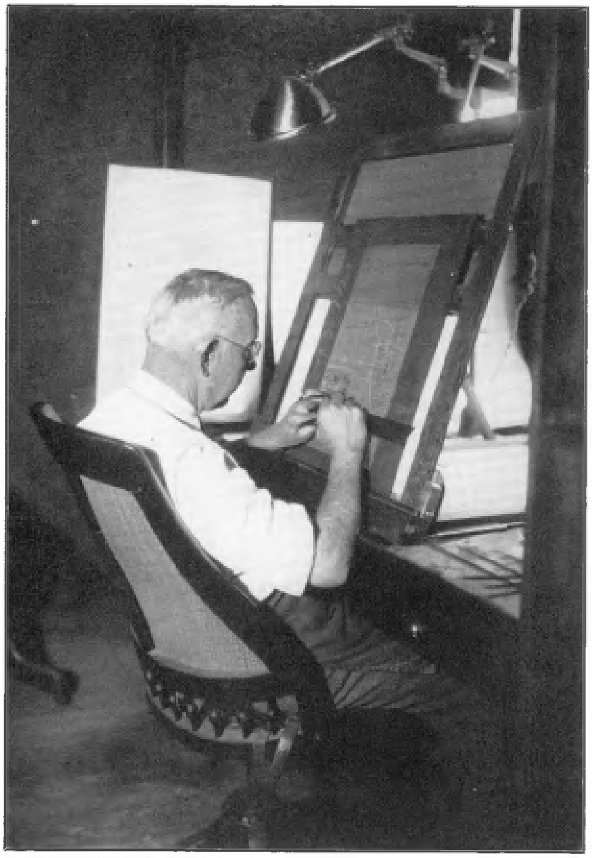
The copy is illuminated by two arc lights placed in front, but slightly to each side, of the copy board. The proper exposure is timed accurately, usually from 2 to 4 minutes. Then the photographer, still working under a safe light in the darkroom, develops the plate, using a solution made up of sulphate of iron and acetic acid, and washes it with clear water.

During this development the images on the negative appear, and when it is finished the plate is taken into the outer laboratory and subjected to several operations. It is first cleared up by an application of cyanide of potassium flowed over the plate, which removes all silver not affected by light. The plate is washed thoroughly and placed in a rocker bath containing a copper sulphate solution. After being washed again, the plate is placed in another rocker bath containing a nitrate of silver solution, which tends to bring out the desired black and white background. These two rocker bath operations are usually repeated with thorough washing of the plate between each operation so as to give the proper density to the plate.

All the above operations after the plate is brought from the darkroom result in a properly fixed and intensified negative. If a stained plate is desired, on which every line appears but none will print but must be cut by hand on the negative, none of the three previously mentioned operations outside of the darkroom is performed, but the plate is again washed thoroughly (but is not cleared up with cyanide or placed in either rocker bath) and is flowed with a dye solution, which stains the plate so that it is opaque so far as light is concerned.

After all these operations, either on an intensified or a stained negative, the plate is coated with a gum-arabic solution to protect the surface.

72. Negative Cutting or Glass Engraving. If the drawing contains several colors, such as black,



Courtesy Geological Survey.

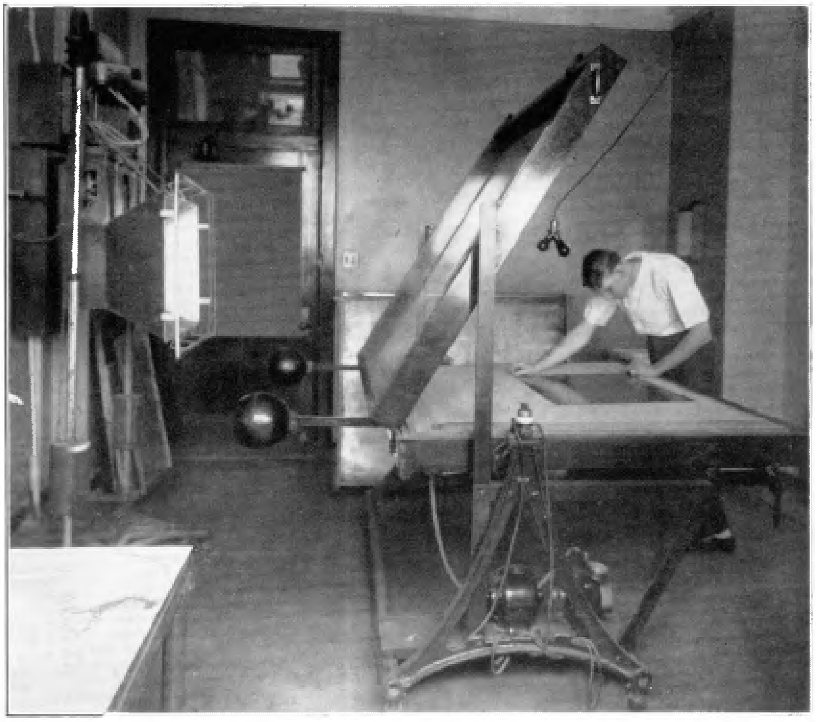
FIG. 97. Glass Engraving.

blue, and brown, and is to be reproduced in these colors, three or more negatives are made at the same setting of the camera and copy board. The negatives are then sent to the negative cutting section, the plates are retouched to remove any spots, etc., and, for example, in multicolor work, the negative cutter paints out by means of a brush and asphaltum on one plate everything except the black, on another everything except the blue, and on the third everything except the brown, restoring with a fine engraving tool any line that has been removed but should be retained. If the drawing is poor, the photographer makes a stained negative, no line on which will print, and the glass engraver will then cut by hand each line on its proper plate, cutting through the film but not into the glass (see Fig. 97). This operation has been called glass engraving, and an exceedingly expert negative cutter can prepare a negative which will print the different map features, including lettering, nearly as fine as a map engraved on copper plates.

73. Photoprocessing. The plate is then sent to the photoprocess section, where a metal printing plate is made. If the negative fully covers the map or if several negatives can be joined perfectly on the final printing plate, it is processed direct to a sensitized aluminum plate by placing it over the sensitized metal plate in a vacuum printing frame and exposing it to light from one or more strong arc lights. If the negatives are slightly distorted in scale, if they cover irregularly shaped parts of the final map, or if the map is to be printed from lithographic stone, the process man makes a zinc plate and sends it to the transfer section, where the final printing plate or stone is made, as is explained later.

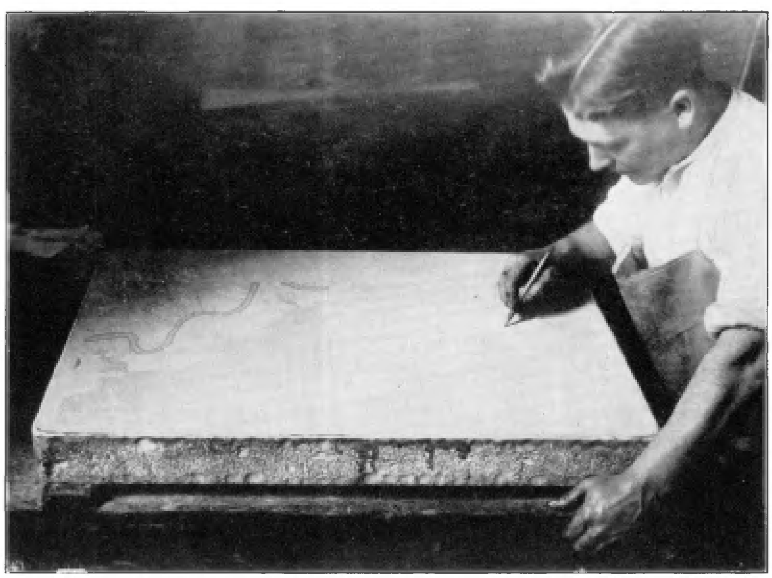
The metal plate, either aluminum or zinc, is sensitized in somewhat the same way as the photographer used with the glass plate, but by different operations and by the use of different chemicals. A freshly grained plate is cleaned by using a solution of hydrofluoric, nitric, and acetic acids, after which it is washed and chemically treated with a solution of phosphoric acid and gum. The plate is then rinsed and while wet is placed in a whirler and flowed with a sensitive solution composed of albumen and dicromate of ammonia. The whirling motion distributes the solution evenly and the electric heater inside the whirler dries the plate.

After the plate is evenly sensitized and dried, it is placed face up in a vacuum printing frame, the negative is placed on the plate in its proper position with the film side down with such parts as are not to be exposed covered with black opaque paper, and the air is exhausted so that the negative and plate are brought into close contact. The assembly is illuminated by strong arc lights, the proper time of exposure being recorded by an alarm clock set to conform to the strength of the lighting and the clearness of the negative (see Fig. 98).



Courtesy Geological Survey.

FIG. 98. Photoprocessing Glass Negative to Printing Plate.



Courtesy Geological Survey.

FIG. 99. Lithographic Artist Drawing on Stone.

The first negative is then removed from the frame, and any other negative that is required to complete the map is inserted in its proper place with the exposed part of the plate and the undesired parts of the negative covered by black paper. The exposures are repeated until the subject is fully covered.

The process man develops and washes the plate in much the same way as the glass plate was developed and washed except that he first coats the plate with a solution of asphaltum, or ink developer, washes the plate thoroughly, and, if the ink has a tendency to stick, he flows the plate with a solution of bicarbonate of soda and washes it again with clear water. The plate is then rolled up with greasy lithographic ink, powdered with "dragon's blood," etched with phosphoric gum, and washed again thoroughly. The plate is now ready to print unless the lithographic artist has to make corrections or additions or to repair minor defects.

74. Lithographic Drafting. The lithographic artist can draw or letter on a metal plate or lithographic stone, by means of a fine brush or pen, just as well as a draftsman can draw on paper or an engraver can cut in copper or on glass (see Fig. 99). When certain features are to be shown in tints or patterns, the transferrer prepares an impression from the base plate, dusts it with chalk, and the chalk impression is "offset" to another plate which enables the lithographic artist to "gum out" the areas not to be covered by tint or pattern and to draw the tints and lines by fine brush or pen. The plate is then returned to the transferrer who adds the proper patterns printed on transfer paper, and cleans and "rolls up" the plate with lithographic ink ready for printing.

Courtesy Geological Survey.

FIG. 100. Transferring Map Data from Zinc to Stone.

Transferring. The transferrer follows a process similar to what is known as the decalcomania process. In other words, he coats a sheet of soft fiber paper with a sticky starch and glycerin solution, rubs up the zinc plate with lithographic transfer ink, places the transfer paper with sticky side down on the zinc plate, and runs the combination through a transfer press operated under pressure by hand or electric power. The transfer paper then is pulled from the zinc plate carrying with it all the lines inked on the plate. If no adjustment to a "stick-up projection" is required, the transfer paper is placed face down on a metal printing plate or lithographic stone (see Fig. 100), run through the transfer press again, and all the inked lines are transferred just as one used to transfer pictures from paper to hand in the old decalcomania process. The plate or stone is then rolled up with lithographic ink and is ready for printing unless the lithographic artist has some additions to make.

If the zinc plates are somewhat distorted in scale or cover irregular portions of the map, a draftsman draws what is called a stick-up projection on a metal mounted plate. The transferrer then cuts up the transfer papers and fits them in proper places on the projection, tapping the paper with a sharp-pointed stylus so that it will remain in proper position. He can shrink or stretch the transfer paper by heating it in an oven or moistening it with a sponge. The stick-up transfer plate is then placed in contact with the printing plate or stone and run through the transfer press so as to transfer all the lines to the final printing medium.

75. Typesetting. For printing names, titles, and scales, the Geological Survey has a well-equipped type compository—setting type by hand and not by linotype machines. In most cases all type matter is printed with printer's ink on opaque white paper, but sometimes on transparent tissue paper, and is pasted on the drawing before the drawing is photographed. The type matter can be, and often is, printed on transfer paper with lithographic ink and transferred in place on the final printing plate. The only exceptions to the use of printed matter are when a fine draftsman has lettered all the drawing by hand, or, when the map is to be engraved on copper plates, the copper plate engraver needs only rough copy. The only real advantage in having the lettering engraved by hand is to have it all complete on the proper copper plate, thus avoiding making one or more extra printing plates.

76. Copper-Plate Engraving. This is the method used by the Geological Survey in final publication of most of its standard topographic atlas sheets and geologic maps and folios. It is probably, for the first edition, the most expensive of all the map-publication methods, but it gives the best results and has several advantages over other methods in cases where frequent reprint editions with extensive additions or corrections are required. Copper is the easiest of all the metals to engrave because of its relative softness, and for the same reason it is the easiest metal on which to make corrections. Corrections are made by scraping out the line or lines to be replaced, turning the plate upside down, and punching the copper up from the bottom by means of a punching machine, so that a smooth and even surface is restored. This surface is then burnished and re-engraved. One of the principal advantages of this method is that clear copy only is required so that much of the expense of fine drafting and lettering of the original drawing is eliminated. The principal disadvantage is due to the extreme artistic skill required and the accompanying long period required to train an expert copper-plate engraver. The Survey has a large staff of such experts, some of them being specialists on contours, some on culture, some on lettering, and some on water lining. Of course a few are expert in all these lines, but it has been the accepted practice to have each phase of the engraving done by experts in that phase.

Copper is fairly light and cheap and does not corrode as much as zinc or aluminum. Steel is too hard to cut, almost impossible to correct, and would be likely to suffer from rust. The Survey does not print direct from the copper, but transfers the data from the copper plates to aluminum or zinc printing plates or to stone, so that after the plate is cut the only wear and tear on it is in pulling transfers under pressure and in making corrections. Therefore, a properly engraved plate should last a lifetime.

It is true that maps without contours and simple contour maps can be engraved on glass a little more quickly and nearly as well as on copper. However, closely spaced contours, for example 5 to $\frac{1}{16}$ of an inch, cannot be cut on glass nearly as well as on copper. The Geological Survey is using glass engraving on all its planimetric maps and on most of its simple contour maps. Whenever possible it photographs a pencil drawing on which all the lettering has been printed in type and pasted on the map. This procedure, however, delays the issue of advance sheets until the lines can be cut on glass, because the pencil lines will not print clear enough unless drawn in very uniform black pencil lines. It takes an expert draftsman about as much time to repencil a sheet as it does to ink it.

Careful records have been kept of comparative costs of similar sheets engraved by both methods, which show that difficult contour maps can be engraved better, more quickly, and more cheaply on copper than on glass. However, the Geological Survey is now cutting all maps on glass that indicate a saving in time and money.

The procedure in copper-plate engraving is as follows: The copy is usually on drawing paper, with the culture features inked in black, the water features in blue, and the contours in brown. The lettering and wooded areas are usually on two separate sheets of tracing cloth or celluloid. The scale of the copy is usually larger than the publication scale. The copy is photographed by the prism camera in the same way as described for photolithography, by making one wet plate to publication scale. A reversed zinc plate is then made by the process described above except this is done without any retouching of the negative. If the map is to be printed in four colors—black, blue, brown, and green—the engraver constructs one projection for the black plate by using projection tables, scale, and beam compass just as a draftsman would do, except that he cuts the meridians and parallels on copper rather than drawing them on paper. He then copies the intersections of the projection lines on two other copper plates but does not draw them solid. No copper plate is made for the woodland which is printed in green and is prepared by photolithography. The engraver rubs the zinc plate with wax, places a thin piece of celluloid over the zinc, and burnishes the celluloid so that it retains in wax on the bottom of the celluloid all the lines on the zinc plate. He then lays the negative impression face down on the three copper plates, fitting the registration marks to the engraved projection and burnishing it on the copper in the correct position. The plates are then subjected to acid fumes which stain the lines on the plate. In the meantime the editor has checked carefully each detail of the map, working on a photographic copy of the field sheet. On this he has placed the lettering in acceptable positions and given all instructions for the engraving.

The engravers then take the copper plates and cut them in reversed form by hand, each line in its proper position (see Fig. 101). Several different kinds of tools are used but only a few mechanical devices can replace actual handwork. As soon as a plate is finished, a proof is pulled by rolling the plate with ink, cleaning off the surface so that the ink remains only in the cut lines, placing a sheet of dampened paper over the plate, and running it through a transfer press. The plate proof sheets are then sent to the editor who examines every line and letter.

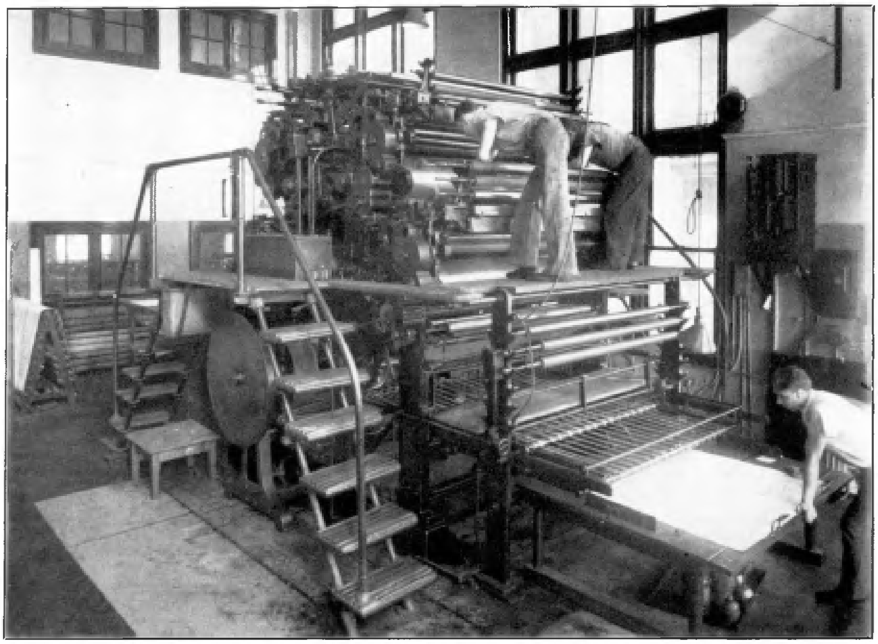
The transfer section then prepares the printing plates by pulling transfers direct from copper, and transferring the impressions direct to aluminum or stone, as the case may be, just as was described for color photolithography. The procedure, of course,

Courtesy Geological Survey.

Fig. 101. Copper Plate Engraver.

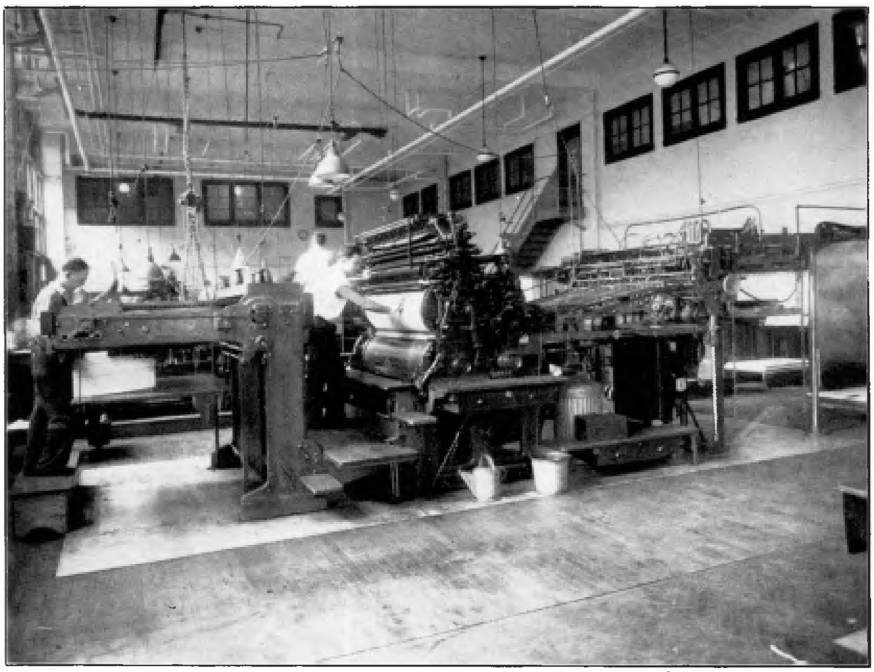
differs in preparing plates for direct printing on a contact press or for printing on an offset press. For the former a reversed printing plate is required, which is made by pulling an impression direct from the copper and laying it down on a grained printing plate or printing stone. For the latter a direct printing plate is required. The Survey used to have to print velox paper prints direct from the copper, photograph these in reversed form, and lay them down in direct form on the printing medium, but it now uses a special transfer rubber blanket and transfers the data from the copper to the blanket and then to the printing plate in direct form.

One of the photographers of the Survey has recently perfected a process of photographing the actual copper plate without coating the plate with



Courtesy Geological Survey.

FIG. 102. Multicolor Press, Semiautomatic Feed. Prints Maps in Four Colors. 42 × 64 in.



Courtesy Geological Survey.

FIG. 103. Offset Press, Automatic Feed. Prints Maps 41 × 54 in.

anything to fill the engraved lines. He uses a special emulsion and developer on the wet plate which can be photoprocessed direct to printing metal, with sharper and clearer lines than can be secured by the transfer process. In this operation he can reduce or enlarge the scale and make direct or reversed negatives.

The printing plates then go to the printing section and a combined proof is printed with all the color plates in proper register. The combined proof is sent to the editor for final examination and, on approval, an edition of three to ten thousand copies is printed.

77. Lithographic Printing. The Geological Survey uses different types of lithographic printing presses. It has one large multicolor rotary press taking printing plates 44 × 64 inches and printing four plates in four colors at the same time. This press is semiautomatic feed and is the largest map printing press in Washington (see Fig. 102).

The Survey has one offset rotary press taking printing plates 41 × 54 inches (see Fig. 103) and one taking printing plates 28 × 34 inches. Both of these are automatic feed.

The Survey has two Hoe flatbed presses taking metal plates or stones 36 × 52 inches. One of these is automatic feed and the other is hand feed. The Survey also has three Hoe flatbed presses, two of which are converted by the Hall attachment into offset presses so as to print either direct or offset from flat surfaces. The plate size of one is 30 × 42 inches and of the other two is 26 × 36 inches. All print from either stone or metal and are hand feed. The capacity of all the presses moving at full speed is 12,000 impressions per hour. During the fiscal year of 1935 the Survey printed about 4,600,000 copies of 3000 different maps and diagrams.

The basic principle of lithographic printing is the use of lithographic stone or metal plates so prepared that the lines on the plates to be reproduced attract ink and repel water, and the rest of the surface on the plates attracts water and repels ink, these two substances being non-affinitive. Therefore, in any lithographic printing press, the plate first passes under a water roller, then under ink rollers coated with the proper color of ink, and then under the mop paper. Except in an offset press a rubber blanket fastened to a cylinder takes the impressions from the plate and transfers them to the paper.

Lithographic stone is a special limestone with a very fine-grained surface which holds ink or water according to the principle cited above. Old stones are regrained by running them through a plainer and shaving off the top surface. Most lithographic stone comes from quarries in Bavaria, and repeated efforts have failed to find suitable stone in America. The Survey has purchased no new lithographic stone in several years and is rapidly changing to plates because of much less weight and bulk and because they can be used in cylindrical high-speed presses.

Lithographic plates are usually aluminum or zinc sheets and can be used in either flatbed or rotary presses. New sheets are smooth and shiny and would not hold ink. New as well as old plates are grained so as to give them a frosted surface, something like frosted glass, by placing them in a graining machine comprised of a large tray in which the plate is placed face up covered with water, quartz sand, and marbles made of wood, marble, or steel, depending on the texture of grain desired. An electric motor vibrates this tray in a rotary fashion and the sand acts as an abrasive and gives the plate a "sanded" surface. The only function of the marbles is to keep the abrasive moving uniformly over the plate.

The greatest difficulty in printing that the Survey used to have is in the matter of paper. The maps are of course printed on sheets and not on paper from rolls and much trouble used to be encountered in the changing size of paper due to different conditions of humidity and temperature, so that frequently during hot, humid summer months the Survey could not print large multicolor maps in perfect register.

In 1934, through an allotment from the Public Works Administration, the Survey installed a modern air-conditioning system in the stock and press rooms, with automatic control of temperature and humidity. This new system enables it to print at any time large maps in perfect register. This air-conditioning system is quite different from the comfort air-conditioning system installed at a later date throughout the rest of the Interior Department Building.