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DEPARTMENT OF THE ARMY TECHNICAL MANUAL

TERRAIN MODELS AND RELIEF MAP MAKING

DEPARTMENT OF THE ARMY • APRIL 1956

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TERRAIN MODELS AND RELIEF MAP MAKING

PART ONE. INTRODUCTION

CHAPTER 1

GENERAL

1. Purpose

This manual provides sufficient information to enable personnel to construct terrain models and reproduce plastic relief maps and molded aerial photographs.

2. Scope

Part one of this manual is concerned with basic information that is essential to a general understanding of the types and uses of relief models. It also covers the methods and technique of preparation and construction that are common to all types of relief topography. Part two is concerned with the preparation of terrain models, including planning, materials used, and technique of construction. Part three describes methods of producing plastic relief maps and molded aerial photographs. Consideration has been given to the fact that some of the methods discussed in part three are of the ultimate goal, also that some of the equipment and supplies mentioned in the different methods are not always available to field troops. Appendix II is a discussion on the Graphically Simulated Relief Model, taken from Technical Report No. 67, prepared by Aeronautical Chart and Information Center in May 1955.[1]

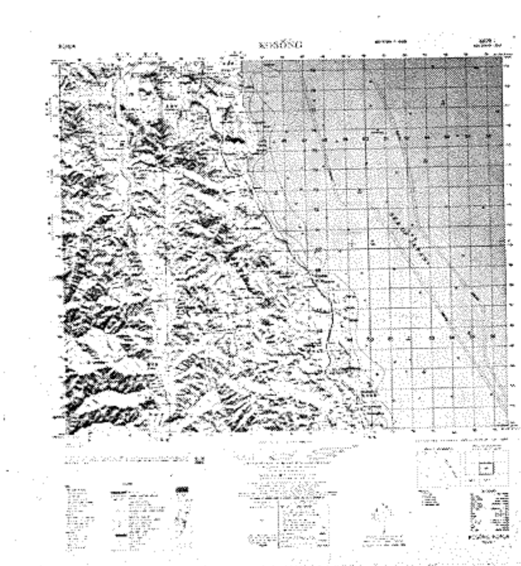
[1] Copies may be obtained from Commander, Aeronautical Chart and Information Center, Second and Arsenal Streets, St. Louis 18, Mo.

CHAPTER 2
BASIC CONSIDERATIONS

Section I. TYPES OF RELIEF MODELS

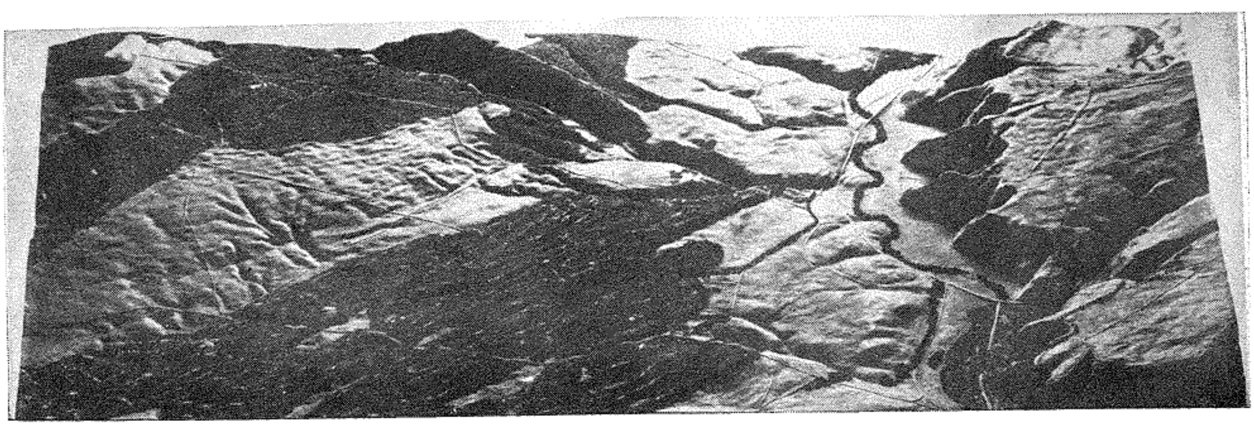
3. Definitions, General

There are three types of relief models of topography: terrain models, plastic relief maps, and molded aerial photographs (fig. 1).



A Plastic relief map

C Terrain model



B Molded aerial photograph

Figure 1. Types of models.

a. Terrain Model. A scale model of the terrain showing land-forms, and in large-scale models, industrial and cultural shapes. It is designed to provide a means for visualizing the terrain for planning or indoctrination purposes, and for briefing on assault landings.

b. Plastic Relief Map. A topographic map preprinted on plastic material and formed by heat and vacuum over a reproduction positive mold. These maps have many uses, among which are tactical and strategic planning of military operations, briefing and debriefing of troops, interrogation of POW's, and training missions.

c. Molded Aerial Photograph. A vertical aerial photograph usually annotated with military symbols which have been molded or formed to show terrain forms. These photos are generally used for planning tactical air missions, reconnaissance missions, and other missions where topographic maps are not readily available.

4. Classification of Terrain Models

Terrain models play a very important part in military operations. They were used extensively in World War II and during operations in Korea. Due to the natural representation of terrain, they are of great assistance in the planning of land, sea, and air attacks. For each operation, a model of specified size and scale can be developed according to the desired use, whether it is high-level strategic planning, small beachhead assault, or bombing missions. In general the scale is determined by the intended use of the model. Table I gives the scale and use of each type of model.

INTENDED USE	STRAGETIC PLANNING	TACTICAL PLANNING	ASSAULT LANDING	ASSAULT	AIR BORNE LANDING	AERIAL TARGET
HORIZONTAL SCALE	1:250,000 AND SMALLER	1:25,000 TO 1:250,000	1:5,000 TO 1:25,000	1:10,000 AND LARGER	1:500 TO 1:5,000	1:2,500 TO 1:5,000
VERTICAL EXAGERATION	3:1 TO 10:1	2:1 UP TO 4:1	1:1 TO 2:1	2:1 OR 1:1	1:1 OR 2:1	1:1 OR 2:1

Table I. Classification of Terrain Models

a. Classification According to Use.

(1) *Strategic-planning models.* These models embrace continents, countries, extensive land areas, or principal island masses, and are used in high-echelon planning. They are small-scale models showing only the general character of the terrain and features of considerable prominence, and are often prepared years in advance of operational needs.

(2) *Tactical-planning models.* These are medium- or large-scale models giving more detailed terrain information than the strategic-planning models. They are normally produced by the base plant and occasionally by model-making units located in the theater of

operations. They are used in corps and division headquarters in planning for operations of a tactical nature.

(3) *Assault-landing models.* These models are used in task force headquarters for planning the landing phases of amphibious operations. For this reason they are frequently called amphibious-assault models. Up-to-date reconnaissance photography is required for accurate representation.

(4) *Assault models.* These are large-scale models giving a particular representation of vegetation, lesser land-forms, and prominent manmade objects. They show a detailed representation of specific and sensitive objectives such as airfields, radar installations, and rocket-launching areas. These models are constructed for use in the study of amphibious operations, and in briefing assault forces. The production of these models is given security protection. These models emphasize the aspects of objects as seen from surface approach.

(5) *Airborne-landing models.* These models are used to brief air-transport crews and to orient airborne troops prior to their departure for the drop zone. These models emphasize the aspects of objects as seen from the air instead of from the ground.

(6) *Aerial-target models.* These models are used in the briefing of pilots and flight crews in preparation for aerial strikes and bombing missions.

b. Classification According to Scale. The horizontal scale is expressed in terms of a representative fraction in the same manner as that of any other military map. The scale, in general, is determined by the intended use of the model. Table I shows the scale of each type of model.

Section II. ADVANTAGES AND DISADVANTAGES OF RELIEF MODELS

5. General

Relief models help to facilitate the understanding of military problems in which topography is a major consideration. Models are more realistic visual aids than maps or sketches. Natural obstacles and approaches can be seen in relation to each other. They illustrate at a glance physical features not immediately perceived on a flat map. Vertical scale can be exaggerated to accent regional physiography.

6. Terrain Models

a. Advantages. Terrain models are ideal for broad overall planning. They give accurate outline of coastlines, show possible routes for troop and supply movement, and indicate natural obstacles and possible enemy strongholds. Some models show vegetation and culture. Other models emphasize outstanding landmarks which aid in planning an air attack or air supply mission. Terrain models are highly effective as visual aids in training.

b. Disadvantages. Terrain models are only as accurate as the topographic maps, aerial photos, or other information upon which they are based. Material makeup of the models creates a transportation problem. The amount of detail and hydrographic features are limited. For great detail and accuracy, model making requires a great deal of time in planning, gathering source material, and actual construction.

7. Plastic Relief Maps

a. Advantages. Plastic relief maps have the same general advantages as terrain models. In addition, they are durable and easy to transport and distribute. They can show all the information contained on a topographic map, and can be readily interpreted with little or no training in map reading. Once the master mold is made, they can be readily reproduced.

b. Disadvantages. The main disadvantage of plastic relief maps is their physical bulk. Additional disadvantages are the lapsed time required to make the master model before forming can be accomplished and the fact that a topographic map must be available for its production.

8. Molded Aerial Photographs

a. Advantages. A molded aerial photograph can be prepared from an average aerial photograph. Topographic maps and mapping photography are essential in order to obtain the contours. Contour lines and other pertinent information such as gun emplacements, battle lines, and roadblocks can be surprinted on the photograph prior to molding. They are durable and easy to transport and handle.

b. Disadvantages. The main disadvantage of the molded areial photograph is the possibility of inaccuracies incurred in the construction of the master model due to lack of adequate control of source material.

Section III. MATERIALS, SIZE, TYPE, AND TECHNIQUES

9. Materials

The source materials used in relief maps and model making consist of engineer intelligence data and aerial photographs, both mapping and reconnaissance. Maps provide the topographic information, and charts the hydrographic data. Aerial mapping photographs provide up-to-date changes in culture and terrain, while reconnaissance photographs provide the combat intelligence regarding disposition of forces both friendly and opposing. Large-scale contoured and gridded topographic maps furnish useful relief and control information. The basic materials used in terrain models are paints, plywood, cardboard, plaster, papier-mache, cheesecloth, and burlap. Other materials used are sawdust, cotton, wire, wood pegs, nails, and glue. These are usually available to field units preparing terrain models. In preparing plastic laminate, a vinyl chloride copolymer thermoplastic sheet material is used for printing the maps and aerial photographs.

10. Size

The size of the terrain model is determined by its proposed use and the time and materials available. In plastic relief maps and molded aerial photographs, size is determined by the scale and sheet size of topographic maps and aerial photos used as source material and the limitation of the molding equipment.

11. Type

The determining factors that influence types of models are the same as those that influence size. For tactical field operations a light durable model is required; therefore, a plastic relief map or molded aerial photograph is used.

12. Techniques

Certain techniques are common in the preparation of terrain models, plastic relief maps, and molded aerial photographs. Some of these are the master model plan, gathering source material, and contour transfer, which are all basic steps in preparing a model or mold. The next steps common to all three are the base construction, cutting of the laminae and contour, and developing of the surface.

PART TWO. CONSTRUCTION OF TERRAIN MODELS

CHAPTER 3

PLANNING

13. Preliminary Computations

A terrain model is only as accurate as the planning that has preceded it. Sometimes the specifications for a terrain model will state the type of model desired and how it will be used. Sometimes the exact scale will be given in the specifications; more often, however, the scale will have to be chosen by the model maker in the following manner.

a. Horizontal Model Scale. The classification and purpose of the terrain model will be the determining factor in the horizontal model scale (table I). This range may be narrowed down by considering the specific purpose of the model. For example, a tactical planning model is to be used in planning the invasion of a series of islands. The series consists of 6 islands and covers 100 miles. It is desired that the coastline and major terrain feature of the island appear clearly on the model. If an HMS (horizontal model scale) of 1:125,000 is chosen, the model will be 4.2 feet long and 1,000 feet of elevation will appear as 0.1 inch of relief on the model. At this scale only the general shape of the island will be discernible and the island terrain will appear almost flat. If the scale chosen is 1:25,000, the model will be 21.1 feet long, and 1,000 feet of elevation will appear as ½ inch relief. Details such as coves and inlets will be apparent in the coastline, and the ridge and drainage patterns will be visible as well as roads and buildings. Therefore, in this case the model scale should be as large as possible or as close to 1:25,000 as possible. For convenience in compiling the source material for the model, it is wise to have the model scale a round figure which is simply related to the scales of the source material.

b. Vertical Model Scale. In determining the vertical model scale (VMS) the factors to be considered are character of terrain, vertical detail required, and consideration of the horizontal scale. The thickness of available laminar materials may also have to be taken into consideration.

c. Vertical Exaggeration. The direct relation between vertical model scale and horizontal model scale is called vertical exaggeration (VE). Therefore, the definition of VE is a whole number representing the ratio VMS: HMS. If the VMS is to be the same as the HMS, the VE will be 1 or 1:1. If the VMS is to be 4 times as large as the HMS the VE will be 4 or 4:1 (fig. 2). Vertical exaggeration is determined by considering the HMS and the character of the terrain to be modeled. For example, at large scales (HMS of 1:10,000 or larger) rugged, well-defined terrain would have a VE of 1:1 (no exaggeration); at the same scale low, flat terrain would require a VE of 2:1 or 3:1 in order to emphasize the small vertical variation that does exist. At medium and small scales (HMS of 1:100,000 or smaller) even well-defined terrain would require a VE of 2:1 or 3:1; low flat terrain, at the same scale, might require a VE as large as 10:1. Contour interval for a terrain model is chosen by considering the accuracy of terrain desired at a given HMS. For example, a model with a large HMS would require a small contour interval (10 feet or less) if any great terrain accuracy is to be maintained. For models with small HMS, a large contour interval (100, 500, or even 1,000 feet) will give best results obtainable at such scales.

d. Laminae. Laminae represent the contour elevations of terrain on a 3-dimensional model. Lamina thickness represents the contour interval at the vertical scale of the model (fig. 3). In all computations all model scales (vertical and horizontal) are used in fractional form. For example, if the VMS of a model is 1:10,000, for computation VMS would appear as

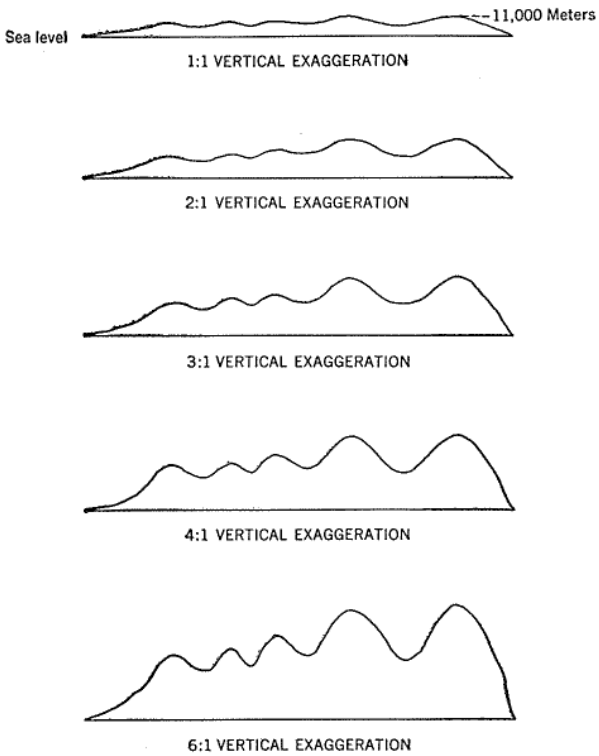


Figure 2. Comparison of vertical exaggerations at scale 1:250,000.

$\frac{1}{10,000}$. Lamina thickness (T) in feet equals the vertical model scale (VMS) multiplied by the contour interval (CI). T = VMS × CI.

EXAMPLE 1:

$$\text{Given: } \quad VMS = 1:15,000 \text{ or } \frac{1}{15,000}$$

$$CI = 20 \text{ feet}$$

Find T:

$$T = VMS\ (\frac{1}{15,000} \times CI\,(20) = \frac{20}{15,000} \text{ or}$$

$$20\overline{)15,000}^{\,750} = \frac{1}{750} \quad (750)\overline{1.0000)}^{\,0.0013}$$

$$T = 0.0013 \text{ feet}$$

The thickness of most materials that are used for laminae is given in inches; the lamina thickness for a model is also given in inches. Therefore, to obtain the lamina thickness in inches (t), the lamina thickness in feet (T) is multiplied by 12.

$$t = T \times 12$$

EXAMPLE 2: (referring to example 1)

$$\text{Given: } T = 0.0013 \text{ feet}$$

Find t:

$$t = T\,(0.0013) \times 12 \text{ or } \begin{array}{r} 0.0013 \\ \times 12 \\ \hline \end{array}$$

$$t = 0.0156 \text{ inches}$$

If none of the materials available for use as laminae correspond to the lamina thickness that was computed, the VMS must be changed to suit the fixed t (thickness of the available laminae material). To find thie new VMS, the relation t = VMS × CI × 12 is used. It is written:

$$VMS = t \div 12 \times CI$$

EXAMPLE 3:

$$CI = 20 \text{ feet}$$

$$t = 0.0185 \text{ inches}$$

Find: VMS

$$VMS = \frac{t}{12 \times CI} \text{ or } VMS = \frac{0.0185}{20 \times 12}$$

$$VMS = \frac{0.0185}{240} = \frac{\;\frac{0.0185}{0.0185}\;}{\;\frac{240}{0.0185}\;} = \frac{1}{13,000}$$

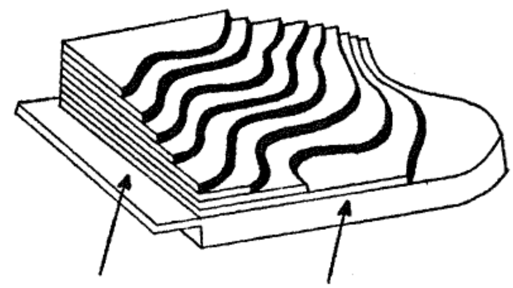


Figure 3. Laminae.

14. Master Model Plan

Once the preliminary computation has been completed, the master model plan for the model can be started. The preparation of the master model plan consists of assembling and evaluating all available source material on the area to be modeled, and of preparing and revising the master model plan manuscript.

a. Source Material.

(1) *Maps*

(*a*) Topographic maps supply topographic, manmade, hydrographic, and vegetative data. The completeness of the data will depend on the scale of the map and the use for which the map is intended.

(*b*) Planimetric maps such as town plans and road maps contain little or no topographic data, but may give reliable and thorough coverage of cultural, vegetative, and hydrographic data.

(*c*) Miscellaneous maps designed for special purposes, such as forestry maps, subsurface marine charts, and the like, may supply useful detail.

(2) *Aerial photography.* Aerial photography is used to obtain thorough, up-to-date coverage of an area. Its value is limited only because special equipment is necessary for the proper interpretation of certain types of data. Topographic detail can be accurately obtained from aerial photos by the use of stereoscopic plotting instruments. General landforms and rough form-lines can be obtained by visual inspection or stereoscopic analysis of aerial photos. Since this data can be taken with ease from the photos without special equipment, aerial photography can be used under emergency conditions as the primary source.

(3) *Surveyors and field party notes.* Any form of field reconnaissance notes may be used; however, the process of obtaining such notes is too costly and time consuming for them to be considered as major sources of data for terrain models. In practice their use is confined to two important purposes as follows:

(*a*) Accurate survey data is used to establish vertical and horizontal control for aerial photography.

(*b*) Rough reconnaissance notes may be obtained by the model maker on field trips whenever such trips are possible. Data obtained on such trips is used to supplement and to check data from other sources.

(4) *Intelligence information.* Intelligence information consists of combat intelligence regarding disposition, obstacles, and other information not available from other source materials.

(5) *Evaluating source material.* Accurate surveyors' notes are the most reliable source of map and terrain model data. Aerial photos are now widely used in flat map compilation and, since they are usually available, are a primary source for man made hydrographic and vegetative detail. Aerial photos are also an excellent source of topographic detail, if equipment for accurate photoanalysis is available. In general, however, aerial photos are used only to rough check other sources of topographic information. Topographic maps are useful sources, since they are reliable and readily available to model makers. All other details obtained from maps are considered less reliable than aerial photo data. Often the data from two sources will conflict. In this case the model maker must decide which source is more reliable and should be used for the model. Sometimes the source material available will not be accurate or complete enough for the type of model desired. This fact will have to be determined and corrected before work on the model proceeds. Another phase of source material evaluation is the evaluation of the agency or agencies responsible for the production of the source material. Familiarization with the various agencies and with the quality of their work can only be arrived at through experience with their products. Each agency evaluates its own products, stating the accuracy of the work and the methods and sources used in compiling it.

b. Master Model Manuscript. The manuscript consists of a sheet or sheets containing all the detail to be used on the model, and a data sheet containing all computed data necessary for the construction of the model. Once the source material has been collected and evaluated, and the detail to be used has been selected, this detail must be transferred from the various source sheets to the manuscript at the model scale. The model-to-map ratio is the ratio between the HMS of the model and the scale of each unit of source material. This ratio establishes a relation between linear distances on the source maps or photos and on the model. The data sheet for a terrain model project contains all basic data (computed and determined) necessary for the construction of the model. The master plan should be checked for completeness and for accuracy. No useful detail should be omitted and there should be no conflict between detail obtained from different sources.

(1) *Preparation of the master model plan manuscript.* This manuscript is a topographic map that is made to the same scale as the terrain to be constructed. It includes all the contours, culture, and vegetation that are found on the topographic map. In drawing this manuscript, the designated map areas are blown up to model size by several methods, of which the reflecting projector and copy camera, if available, are accurate and fast. The method normally used and available to a model making detachment is called the proportionate grid system.

(2) *Proportionate grid system.* The proportionate grid system is the process of transferring map and aerial photograph information to a drawing made to the size of the model being constructed. It is done by first enlarging a grid system drawn on the map or aerial photograph to the size required by the model-to-map ratio, and then drawing in all the detail.

(*a*) *Grid construction on map areas.* The first thing to be determined in drawing the grid squares on the assigned map areas is the size of the grid square. The smaller the grid square, the more accurate the enlargement will be. However, the size of the grid square should not be so small as to be impractical. On a 1:25,000 map a ¼-inch grid system will usually give all the accuracy desired. Therefore, with the use of an architect scale and triangle, ¼-inch points are marked off on the edges of the designated map areas, both horizontally and vertically. Then the lines are drawn in with a fine, sharp line.

(*b*) *Grid construction on manuscript.* After the grid squares have been laid out on the assigned map areas, the next step is to blow up the map area on the master model plan to the size required by the model-to-map ratio. For example, if it has been determined that the model is to be 8 times the size of the map, the size of the assigned map area is multiplied by 8, and these dimensions are laid out on a large sheet of drawing paper. This is the beginning of the manuscript. It is the actual border of the model to be constructed. After the borders of the model have been made, it is necessary to put in the proportionate grid squares. Here again the model-to-map ratio is 8:1, and the grid squares on the map are multiplied by the model-to-map ratio. Grid squares are ¼ inch on the map, so they would be 2 inches on the manuscript. These grid points are marked off on the manuscript in the same manner as on the map, and grid lines are then drawn.

(*c*) *Contour transfer.* After the proportionate grid system has been laid out on both the map and the manuscript, the contour lines must be drawn. If there are a large number of contours and they are close together, only every other contour will be drawn. However, if there is sufficient time, it is always better to use all contours. When drawing every other contour it is best to start with the lowest contour or sea level. Locate the lowest contour and its origin in a grid square on the edge of the map. Then locate the corresponding grid square on the manuscript. Determine by eye the point on the edge of the large grid square which corresponds to the point where the contour intersects the edge of the grid square on the map. From this point a line is drawn in the enlarged grid square as the contour line is to the sides of the small grid square. This process is continued in every grid square through which the contour line travels. The contour lines are to be drawn with a brown pencil.

(*d*) *Hydrographic features.* The next step in drawing the manuscript is to plot the hydrographic features, such as rivers, streams, and lakes. Their course is drawn in the same manner as the contour lines. In most cases stream widths must be determined through the use of aerial photographs, because on a map 1:25,000 or smaller, some streams can only be indicated and not drawn to scale. Lakes are transferred by drawing the shore lines in the corresponding grid squares, in the same manner as contours. All hydrographic features are drawn in blue pencil.

(*e*) *Vegetation.* After the contours and hydrographic features have been transferred to the manuscript, the vegetation is drawn in. This includes woods, orchards, shrubs, hedgerows, fields, and the like. After determining the boundries of the woodlands on the map, these outlines will be transferred in the same manner as the contours and hydrographic features. However, when drawing vegetation it is always best to use the most recent aerial photographs available, since vegetative growth may have changed because of forest fires, timber cutting, windfalls, and land cultivation. All vegetation is drawn in green pencil.

(*f*) *Culture.* The next things to be drawn on the manuscript are the cultural features, such as roads, buildings, bridges, and other manmade objects. Roads are transferred in the same manner as contours and streams. Buildings are oriented in corresponding grid squares. Here again, as in transferring the vegetation and water, aerial photographs should be used, the reason for this being that roads and buildings can only be indicated on a map and not drawn to scale. The cultural features are drawn in black.

(3) *Autofocusing reflecting projector.* Another, more accurate method of enlarging map and aerial information is the autofocusing reflecting projector. The map area or photo to be enlarged is placed in the projector's holder. A light source within the machine is projected upon the source sheet. This image is then picked up by the reflecting mirror which is fixed at a 45-degree angle. This in turn reflects the image into a photographic projection lens. The lens then projects the image to the table of the projector. The image is automatically adjusted to the correct size on the fixed table top by movement of the lens and projector body. This enables the image size to be enlarged to the desired dimensions. The limits of enlargement are 3 times the source sheet. (Example: If the holder will take a 9- by 9-inch source sheet, the largest image projected would be 27 inches.)

(4) *Press copy.* If a topographic or reproduction unit is available, it is desirable to submit the map sheet for reproduction of an enlarged copy. This copy may be a proof press run in monochrome, preferably of a color other than black to avoid confusion when tracing the contours on the laminae. A make-line or reproduction block, showing the scale desired, should be drafted on the margin of the map sheet submitted to assure obtaining a manuscript of the proper scale. Preparation of film positives and production of ozalid copies is another method of providing source material for model construction.

(5) *Profiles.* Profiles are required in the construction of terrain models whenever a model is to be built in more than one section. These profiles are

made of only the edges to be horizontally and vertically matched (fig. 4). This enables the two sections to be modeled from the same profiles, thereby assuring an accurate match. The profiles which are drawn from the adjacent manuscript edges will also include a step profile to aid in the stacking of the laminae.

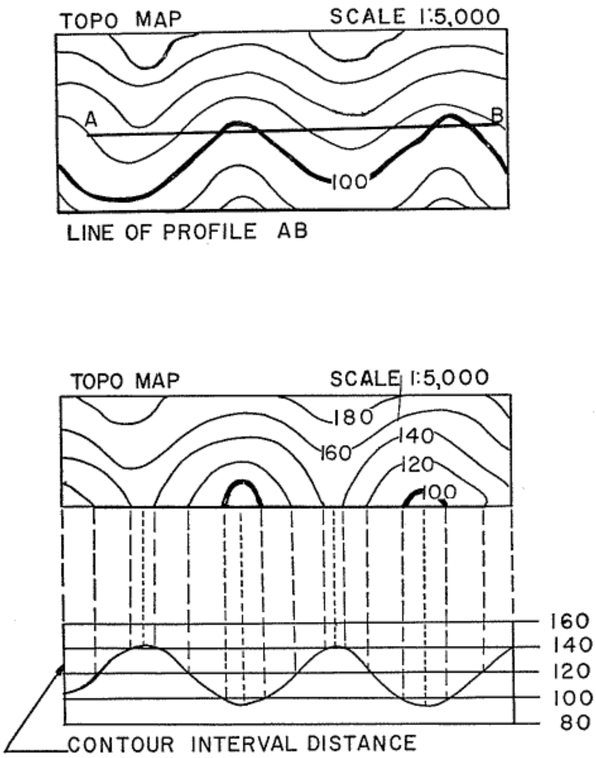


Figure 4. Typical profile.

15. Base Construction

The first step in constructing a terrain model base is the determination of the size of the base. This can be taken directly from the master model manuscript or made by measuring each side of the map area and multiplying each measurement by the map-to-model ratio. This will give the correct enlarged size. After the size of the base has been determined, it is carefully laid out on a sheet of plywood. If the base is extremely large, or of an unusual slope, more than one sheet of plywood may be necessary. The next step is to add reinforcement to the bottom. The size of the reinforcement is determined by the size of the base. On small models where light weight is an important factor, 1- by 1-inch or 1- by 2-inch wood strips may be used, but on larger models 2- by 2-inch or 2- by 4-inch strips are recommended (fig. 5). A good rule to follow is: If no side of the model exceeds 3 feet in length, the reinforcement is added to the edges of the model only. If the model exceeds 3 by 3 feet, then additional cross bracing should be used. Judgment must be used in applying reinforcing, taking into consideration such factors as the purpose of the model, weight of model, where it will be used, and how it is to be transported. The primary purpose of reinforcement is to prevent warping and sagging

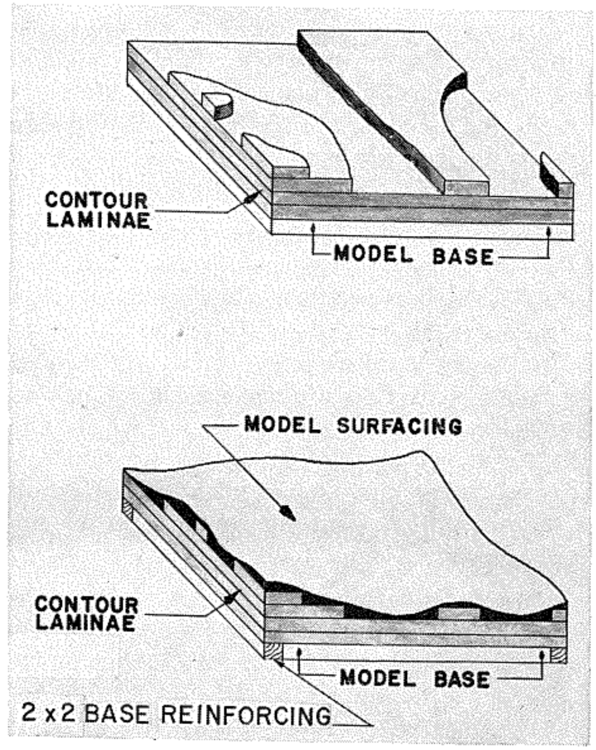


Figure 5. Base construction.

16. Preparation of Laminae

A lamina is defined as the representative scale of the vertical distance between contours. Plywood and cardboard are the two materials that are used most extensively in making terrain models.

a. Cutting Laminae to Size. Before the contours can be cut from the lamina material, certain factors must be determined. The first is the number of sheets to be cut. This will be determined by the method being used and by the number of contours. The next item to be determined is the thickness of the contour lamina sheets. This is done by using the methods explained in paragraph 13*d*. Now the model maker must decide upon the most suitable material to use for the laminae. Plywood should be used on a large model having a comparatively greater lamina thickness, while cardboard, a less stable material, is used when a smaller lamina thickness is required. The lamina sheets should be cut to a size large enough so that they slightly overlap the edge of the terrain base. They should be checked to make sure that all sheets have a slight overhang. Any undercut sheets must be removed and replaced by larger sheets. The stacked sheets are nailed temporarily to the base with enough nails to hold them securely in place. The next step is to cut or sand all edges to the same size as the base. In extremely large models the laminae should be precut to size and checked by stacking.

b. Marking Registration on the Laminae. After the laminae have been sanded or stacked so that the edges are flush with the base, registration marks are made on the edges. A registration mark is a line drawn vertically through the heights of the laminae to insure perfect alinement when the sheets are restacked after being removed and cut to the proper contours. For registration on contours that do not extend to the neatline, tick marks are made in the cutting process.

c. Tracing Contours onto Laminae. Normally carbon paper is placed on the laminae to cover the entire sheet. If the model is large, the master model manuscript can be penciled on the back and traced over to produce the contours on the laminae. Over this is placed the manuscript, which is lined up over the lamina sheet and taped or stapled securely in place. The particular contour is then traced directly onto the lamina. If a separate lamina sheet is to be used for each contour or every other contour, 1 corner of the lamina sheet is marked with the height of the contour being cut as an extra precaution. The particular contour is then traced on the lamina sheet in addition to the contour immediately above it, as an aid to registration. In the alternate step method, where only 2 lamina sheets are used, all contours are traced on both sheets. All even numbered contours are marked with an X across the contour lines on 1 sheet, and all odd numbered contours are marked on the second sheet.

d. Cutting the Contour. In cutting contours, it is best to begin by cutting the lowest contour first. In this way, the laminae can be temporarily stacked as they are cut, providing an aditional check on accuracy. Before any cutting is begun on the lamina sheets, it is always best to first practice on the jigsaw and bandsaw, using scrap pieces of plywood. In using the cutawl, the machine should be pulled toward the operator over the work. In using the jigsaw, the work should be pushed away from the operator. In this manner, the uncut portion of the contour can be seen by the operator at all times.

17. Stacking Laminae

After the contour laminae for a terrain model have been cut, they must be assembled to form the terrain base of the model. This procedure is known as stacking. Stacking consists of alining the laminae and of permanently fastening them in their proper position. When the stacking has been accomplished, the model surface can be developed.

a. Progress of Terrain Base Prior to Stacking. The following steps have to be completed prior to stacking.

(1) The model base has been constructed to the exact size of the model as described in paragraph 15.

(2) Lamina sheets have been cut to the exact size of the model base.

(3) Profile plates have been prepared for the edges of the model that are to be married to adjacent models.

(4) The necessary contour lines have been traced onto the lamina sheets and the model base.

(5) The contour laminae have been cut out as described in paragraph 16*d*.

b. Lamina Sheet Registration. The lamina sheets were cut to the exact size of the model base to insure that the lamina edges of contours extending beyond the model would be flush with the model base when stacking was completed. You then fasten the profile plates to the model base. The profile plates form a frame around the model base (fig. 6). If there are four profile plates, only three are fixed in place at this stage. The fourth plate will be fixed in place after all the sheets have been set as a final check on the alinement. The cut contour laminae are then set in their proper order on the model base and are flush against the profile plates (fig. 6).

c. Contour Registration. After the cut lamina sheets have been set inside the profile frame, the cut contour edge should be checked to make certain that the cut edge registers with the alinement contour outlined on the previously set sheet. If the cut contour edge is undercut, correction can be made by cutting away excess material. If the cut contour edge is overcut, the entire lamina sheet must be recut. Local contour laminae (i.e., laminae of contours that close within the limits of the model) are set in position solely by the method of contour registration.

d. Fastening the Cut Lamina Sheets. After the lamina sheets have been alined, they must be permanently fastened in position. This fastening must be accomplished in such a manner that when the model surfacing is applied, the terrain base will not be appreciably distorted by warping and loosening of lamina sheets.

(1) *Fastening rigid laminae.* Rigid laminae will not be appreciably distorted by the application of normal surfacing materials; therefore, fastening materials such as nails, screws, or pegs are used to fasten rigid laminae in position.

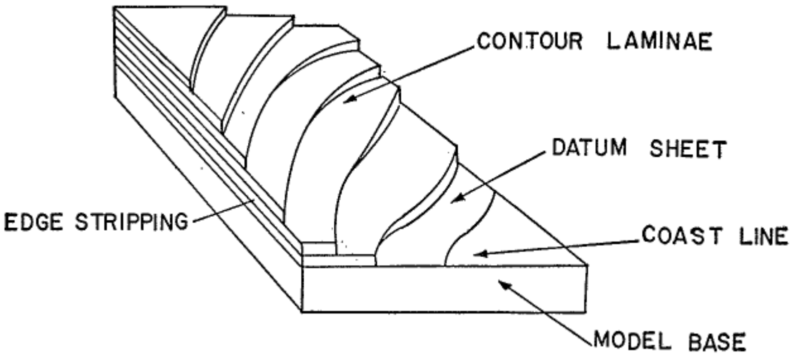
(2) *Fastening nonrigid laminae.* Nonrigid laminae, such as cardboard, tend to warp, swell, and separate when subjected to large quantities of moisture, or to surfacing materials containing water; therefore, special treatment before surfacing is required. Individual lamina sheets should be soaked in kerosene to prevent the absorption of water. The laminae should be fastened with the best waterproof cement available. Small flat-headed nails or tacks should be driven into the laminae to prevent the separation of the layers due to moisture swelling. The entire terrain base should then be coated with shellac to waterproof it further.

18. Methods

One of the first factors to be considered in making terrain models is the type of construction that should be employed. There are various methods which are more accurate than others and some lend themselves to faster construction. When time is not the most important factor and an accurate model is required, a more accurate method of construction can be employed.

19. Step Method

a. Construction Principles. The first step in actual construction is to make the base of the model. The size of the base is determined from the model manuscript. The type of construction will determine the type of base to employ. If the model is to be constructed of light material, a lightweight base can be used. If heavier materials like plaster are to be used, a heavier base with sufficient reinforcement must be used. Plywood or wallboard is a very desirable material for this purpose. In the step method of construction, one lamina per contour is used. The manuscript must be used to determine the total number of contour laminae of the model. The laminae are cut to size, then fastened temporarily to the base with small brads. The edges of the laminae are then sanded to conform with the base. The highest points on the outline are then determined from the manuscript and transferred to their corresponding position on the model. This is done by scribing tick marks on the laminae with a knife or chisel-pointed pencil. This system of marks aids in stacking the laminae after they have been cut. The laminae are then removed from the base The lamina sheets are kept in the same order and position in which they were sanded. The contours are now traced from the manuscript onto the laminae, beginning with the lowest contour. Carbon paper is used underneath the manuscript to make the transfer. The contours are now cut with either the cutawl or jigsaw. Care must be taken to cut accurately on the line. The bottom or lowest contour lamina is fas-



COMPLETED TERRAIN BASE

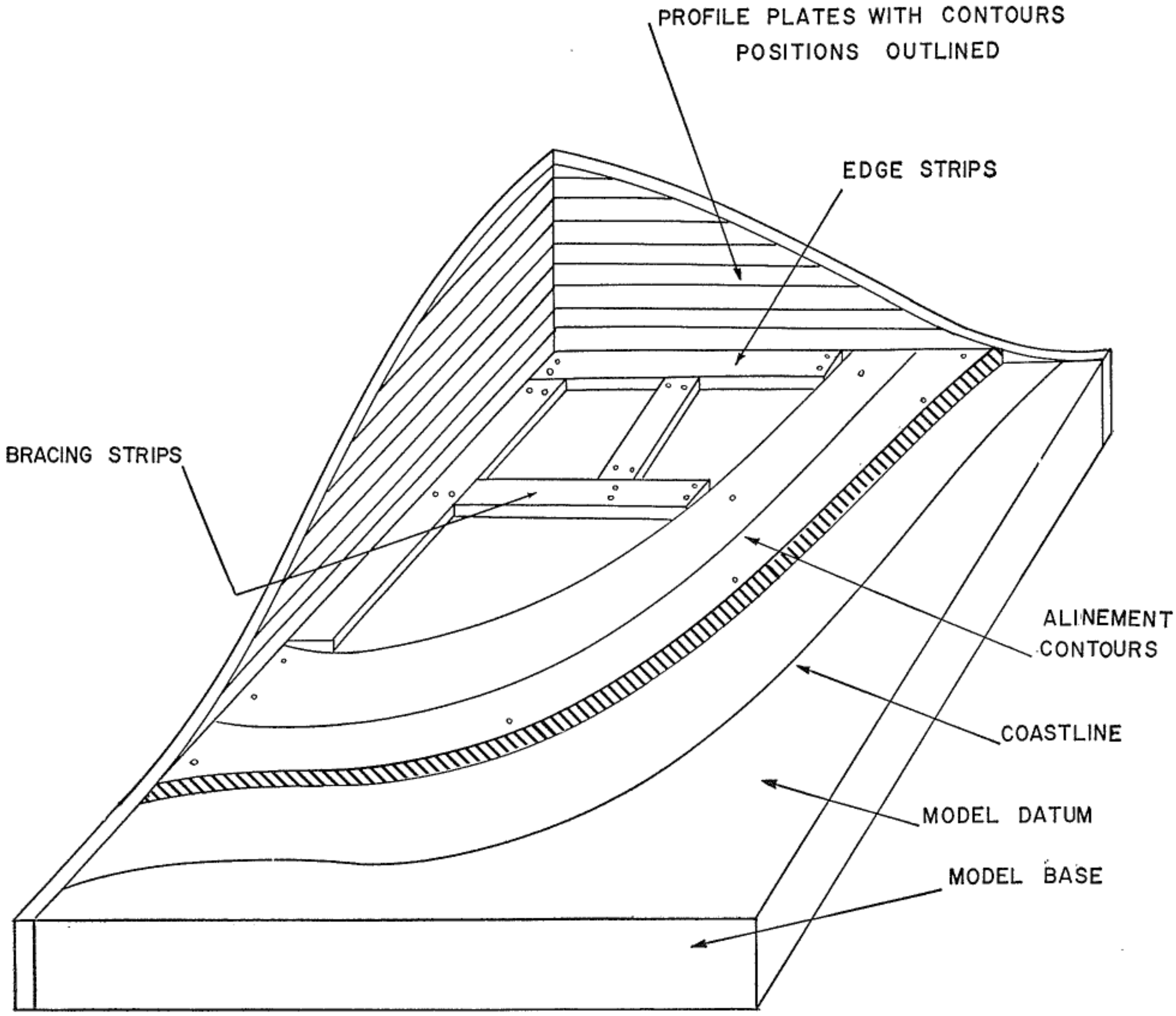


Figure 6. Stacking procedure.

tened to the base first with small wire nails, making sure the tick marks are properly alined. Each succeeding contour lamina is then positioned and nailed in place until the stacking is complete (fig. 7). Then the entire surface is covered with a thin coat of shellac to prevent moisture from seeping into the layer material when the model surface is developed.

terrain model construction, since a maximum amount of control is attainable. One disadvantage of this method of construction is that one lamina per contour level must be used, thus requiring more material than other methods. The step method is also considered one of the slower methods of terrain model construction.

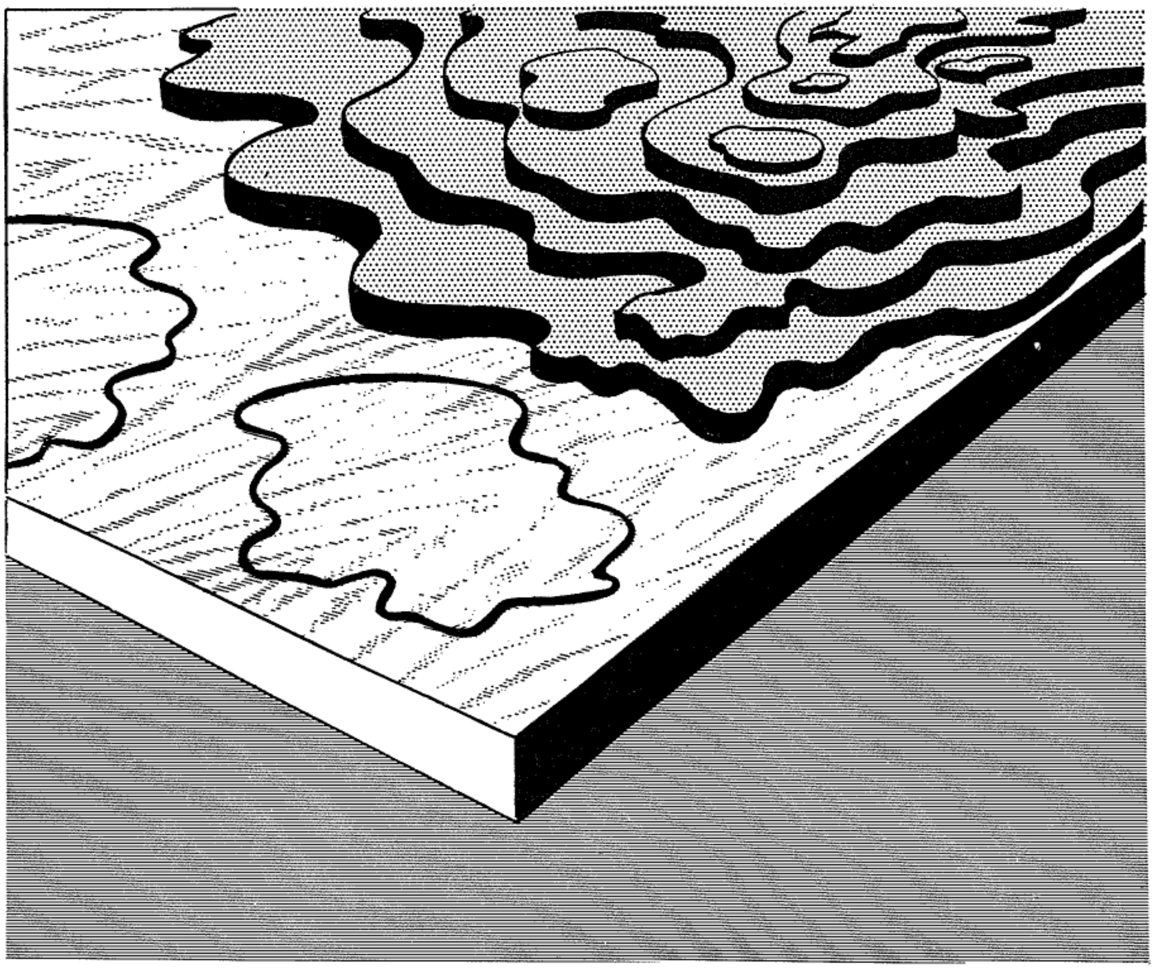


Figure 7. Step method.

b. Developing the Surface. The step method of terrain models can be developed by either the skin method or the solid-surface method, which are described in paragraphs 27 and 28. Another method employed on smaller scale models is to use molding clay, molding it directly on the model core. On larger scale models, papier-mache can be used for developing the surface in the same manner as hydrocol.

c. Advantages and Disadvantages. The step method is one of the most accurate methods of

20. Alternate Step Method

The alternate step method is a variation or alternate way of constructing a step model. The basic appearance and function of the 2 model cores is the same. The difference between the 2 methods is that alternate step construction requires only 2 lamina layers for the complete model whereas the step method requires 1 per contour level.

a. Contruction Principles. The base is prepared, taking into consideration the same factors, such as weight and reinforcement, as in the step method. The 2 laminae of the required thickness are then prepared. The edges of the laminae are sanded to conform with the edges of the base. The laminae are temporarily fastened to the base for this operation. Tick marks are then cut in the 4 corners of the manuscript for the purpose of orienting the manuscript accurately on both lamina sheets. The manuscript is then oriented on 1 lamina with a sheet of carbon paper underneath. All the contours on the manuscript are then traced onto the layer material. The second lamina is treated in the same manner. The laminae are now ready to be cut. On the first lamina, the lowest and the third contours are cut first. On the second lamina, the second and fourth contours are cut. All the odd numbered contours are cut on the first lamina sheet, and all the even numbered contours are cut on the second lamina sheet. This alternate cutting is continued until the final contour is cut. The laminae are stacked and nailed in position starting at the contour lamina of the lowest elevation. The next contour (the first one cut from the second lamina sheet) is alined over the traces of the contour below. The stacking is continued by alternating contours from one sheet to the other. Blocks must be used underneath the second and all succeeding contour laminae to maintain the proper vertical height from the base.

b. Developing the Surface. The model surface may be developed in the same manner as in the step method of construction, since the two model cores are identical.

c. Advantages and Disadvantages. The main advantage of the alternate step method is that only two lamina sheets are required to make the complete model, making it less expensive. Another advantage of this method is that fewer operations are required in preparing the contour laminae and orienting the model manuscript on the lamina sheets, thus cutting down the construction time. The main disadvantage is that a loss of accuracy is possible in stacking, since in this method the alinement of the contours depends almost solely on the trace of that contour on the one beneath.

21. Step-and-Block Method

This method derives its name from the fact that blocks are used to control the height of the contour laminae from the base instead of depending on the thickness of the laminae for vertical control.

a. Construction Principles. Construction is started in the same manner as described in paragraphs 19 and 20. The alternate step method of using only 2 lamina sheets is employed. Two laminae of any thickness are fastened to the base. The edges are sanded to conform with the edges of the base. All the contours from the manuscript are traced onto each lamina. The alternate step method of cutting the off numbered contours on 1 lamina sheet and the even numbered contours on the other. After the contours are cut, blocks are made to support the contour laminae to correct vertical height. These blocks are fastened to the base first and the contours are fastened to them. The contour line traced on the lower contour is used as a guide for stacking. Enough blocks are used to insure that each lamina has sufficient support.

b. Developing the Surface. The step-and-block method of terrain models can be best developed by use of the skin method which is described in paragraph 28.

c. Advantages and Disadvantages. This method of construction is used almost exclusively on large-scale models and also where the terrain to be represented has a large vertical distance between contours. Since this method of construction generally employs only two contour laminae, less material is used for construction. The disadvantage of this method is that stacking is more difficult than the other methods because of the blocks. The contour laminae cannot be positioned directly on top of the lower contour; they must be alined from the extension of the contour traced from the one directly below.

22. Egg-Crate Method

This method of construction obtains its name from the fact that the model core looks very similar to an egg crate (fig. 8).

a. Construction Principles. The first step in construction is to square off the model manuscript into as many squares as necessary to get sufficient coverage of the model area. When the terrain is rugged, more squares are necessary; less squares are needed for flat terrain. Some-

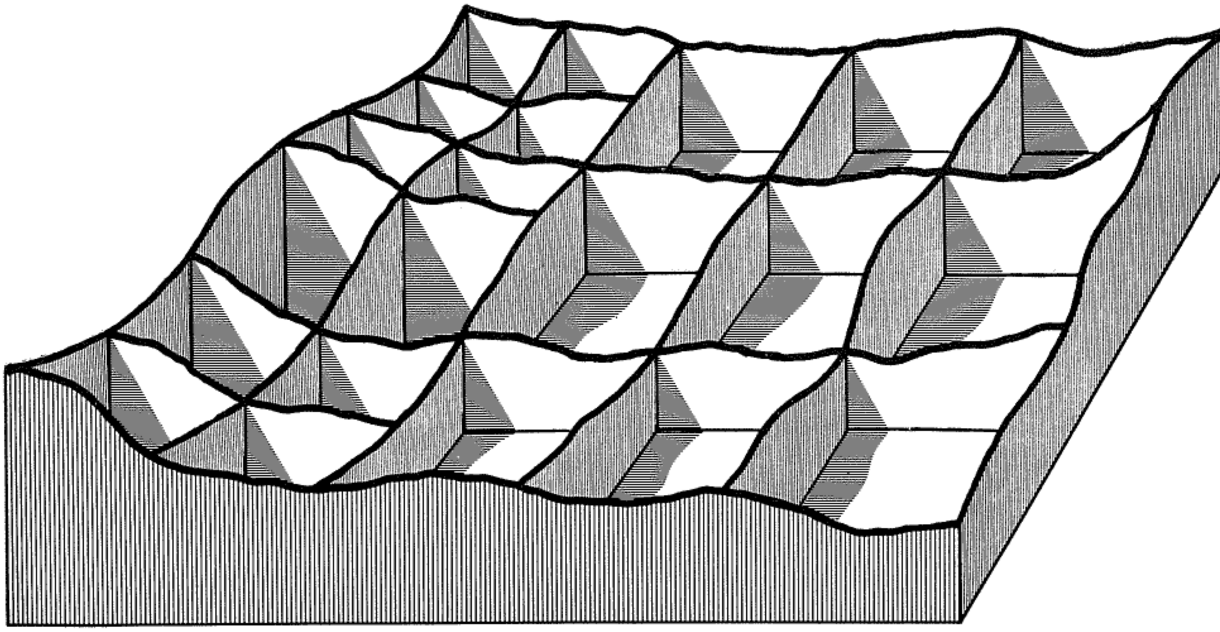


Figure 8. Egg-crate method.

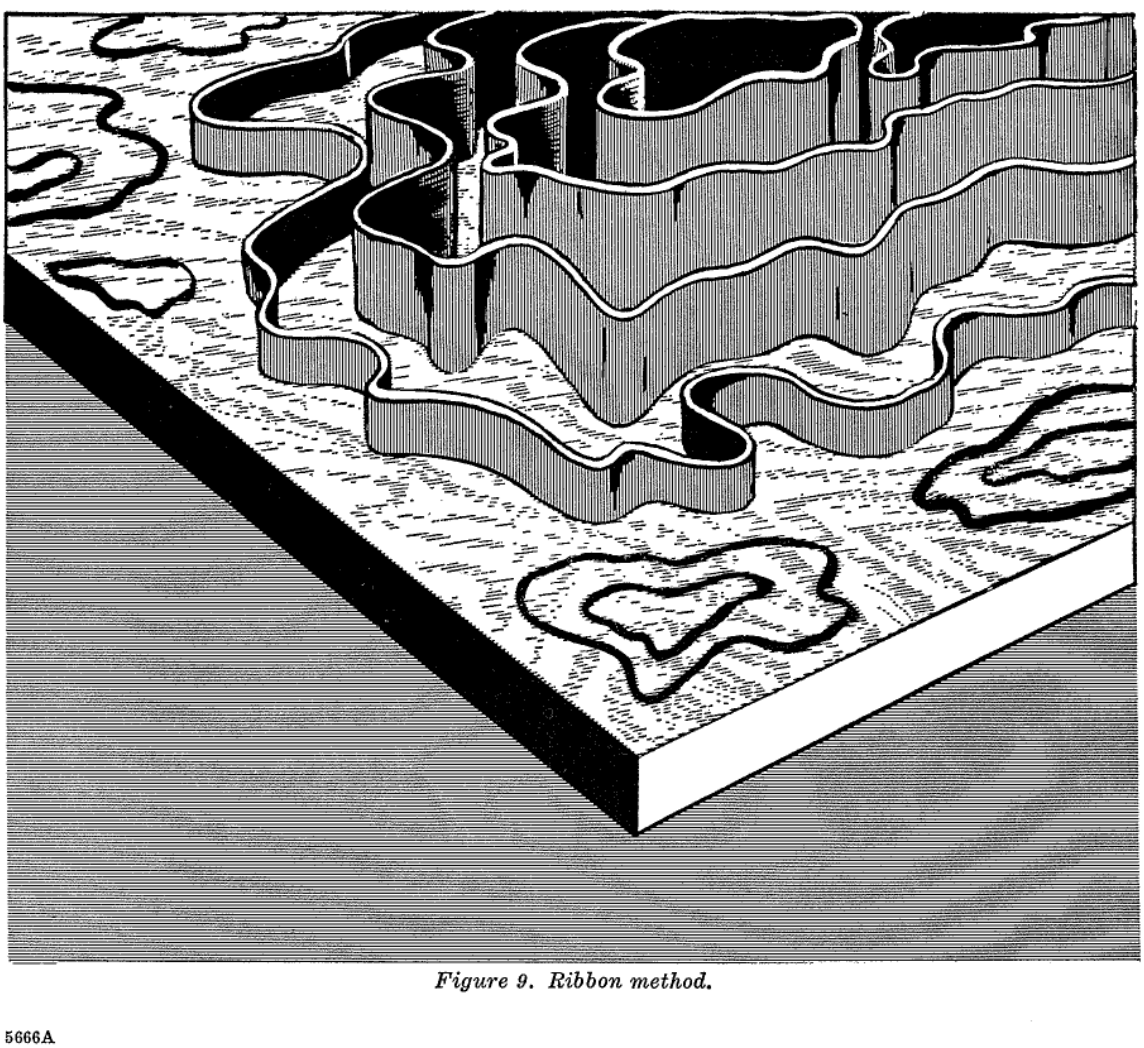


Figure 9. Ribbon method.

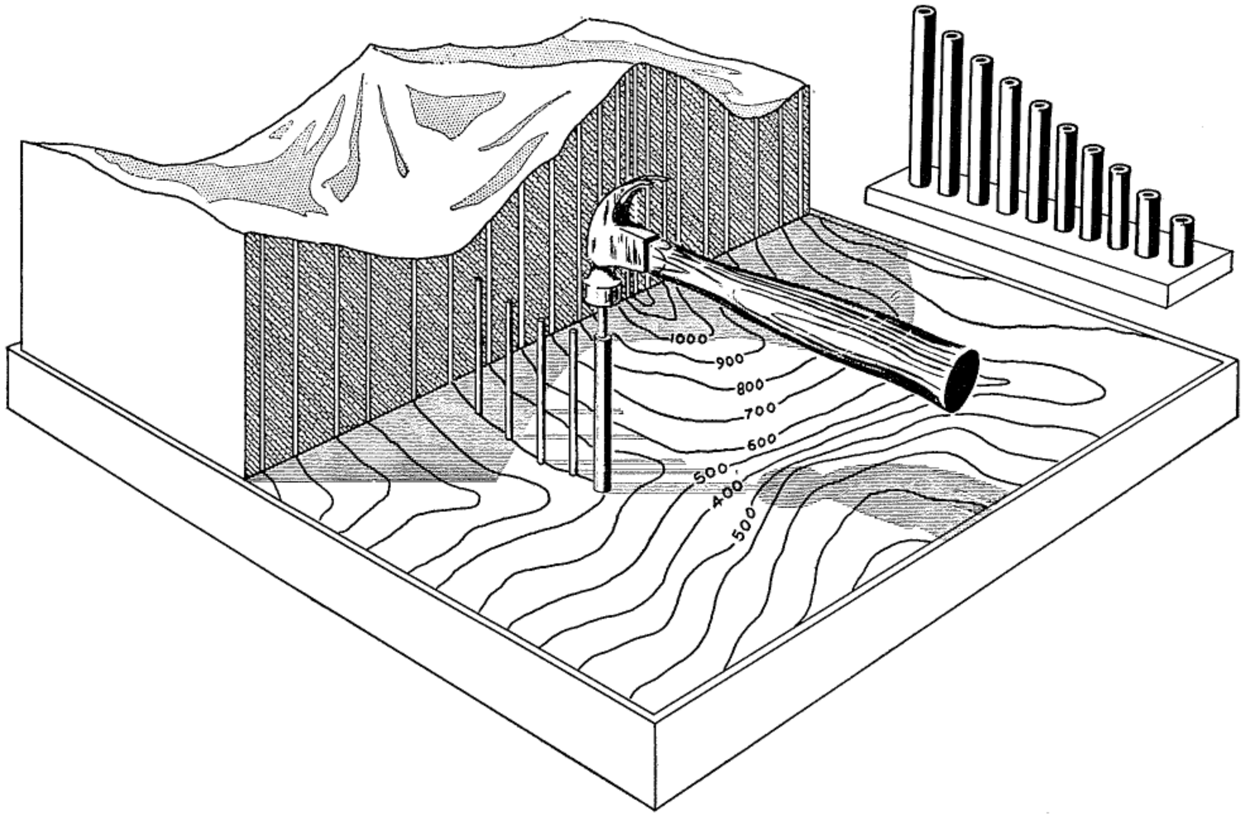


Figure 10. Nail-or-peg method.

times the grid system from the manuscript can be used for these lines. The lines should run parallel to the borders. For each of the squared off lines, a profile is constructed of a suitable material. On larger scale models, ¼-inch plywood is used for these sections. On smaller scale models, stiff cardboard is used. The profile sections conform exactly to the relief of the terrain.

b. Developing the Surface. The most common method of developing the surface of the egg-crate model core is the skin method which is described in paragraph 28. A less common but effective method of surface development is accomplished by using the solid-surface method and using the profile sections as control points. This method is described in paragraph 27.

c. Advantages and Disadvantages. The egg-crate method is one of the most accurate means of terrain model construction, since a maximum number of control points are obtainable. It also produces a lightweight model that is structurally sound. The main disadvantage of the egg-crate method is that it takes more time, materials, and tools to construct than other methods.

23. Ribbon Method

The ribbon method (fig. 9) is perhaps the easiest and quickest of the more expedient methods. The procedure is to trace the contour on the base and then from corrugated cardboard cut ribbons in widths corresponding to the scale height of the consecutive contours, keeping in mind that the channels in the cardboard must be vertical, when the ribbons are placed on the contour. The nails are placed on the contours and the cardboard ribbons fastened to the nails. The space between cardboard ribbons is then filled to within ¼ inch of the top of the ribbon, with such materials as sawdust, leaves, newspaper, or papier-mache. The ribbons can also be covered with cheesecloth, which is glued to the top edge of the cardboard ribbons. The next step is to apply hydrocol or papier-mache in the same manner as in the egg-crate method. The advantage of this method is that very little material and time is required. It also provides a very light model. The ribbon method can be used to the best advantage on a small-scale model and when no great amount of detail is required. The main disadvantage is the fact that the model is structurally weak and cracks very easily. Also control is at a minimum.

24. Nail-or-Peg Method

This method is similar to the ribbon method. The contours are traced on the base, and then nails or pegs are driven on the contour lines to a predetermined height. Jigs are normally made to insure driving the nails or pegs to the correct height. This method of construction can be developed by either the skin or solid surface methods which are described in paragraphs 27 and 28. The advantages of this method of construction are similar to those of the ribbon method; however, both depend on the availability of cardboard, nails, and pegs. The disadvantages are that there is very little control and the model is structurally weak and will support very little detail (fig. 10).

25. Sand Table and Blanket Methods

These two methods are more or less a last-resort method; however, they do have some value where time and materials are a limited factor. There is practically no control and the final product is only an approximate representation of the ground. However, where sufficient time and materials are available, plus initiative and ingenuity, these methods can be of great value for field orientation and training.

CHAPTER 4
SURFACE DEVELOPMENT

26. General

After the terrain base of a model has been completed, the surface of the model must be developed using the contour or profiles of the terrain base as guides to the shaping of the surface. The two common methods used to develop the surface of a terrain model are the solid-surface method and the skin method.

27. Solid-Surface Method

This method is ordinarily used on a model which is composed of a number of stacked laminae and which contains intricate terrain features. If the project to be modeled consists of plywood laminae, gypsum forming plaster or papier-mache is the best surfacing material to use.

a. Gypsum forming plaster is a moderately slow-drying substance which may be worked into shapes and forms with ease for approximately 15 minutes during the period of plasticity. The overall setting period is a minimum of 1 hour. After this material sets, it may be carved, sawed, or planed.

b. Papier-mache is lightweight and for this reason is used in constructing large models. It is slow drying; if applied in any thickness it usually takes 24 hours to dry. Papier-mache is also difficult to carve or plane after it has set. However, in constructing a model with gypsum forming plaster, if the plaster is setting too fast, papier-mache may be added to lengthen the period of plasticity. If the project to be modeled consists of cardboard laminae, plastilene modeling clay should be used as the surfacing material because it is nonhardening clay and very pliable.

c. In modeling plywood laminae it is necessary to drill holes in the laminae to insure a positive bond. These holes should be 1/4 inch to 3/8 inch, placed 1 to 2 inches apart. The first step in molding is to mix the forming plaster to the proper consistency. For application over contours, a mixture similar to a heavy paste is desired. In order to control the flow of plaster on extremely rugged terrain, a heavy mixture is used, whereas, if the model consists of slow, rolling terrain, a thiner mixture may be used. To attain the proper mixture, water is first placed in a mixing bowl. Plaster is then sifted into the water and mixed by hand, kneading out lumps in order to get a smooth mixture. There is usually no set pattern for applying plaster to a model because mixtures vary and the terrain features of various models differ, but in most cases it is applied first at the high point on the model because it tends to flow to the lower areas. The main problem in applying plaster is maintaining proper landform between the contours. This distance between the contours should be shaped with smoothly flowing curves. Since the contour edges are the only control points, it is necessary to barely cover them with a fine film of plaster. However, they should not be exposed to create a ridge effect. Therefore, it is best to shape small areas at a time, in order to work in proper landforms before the plaster sets. The plaster may be smoothed out with paint brush and water. Papier-mache is molded and applied in the same manner as forming plaster.

28. Skin Method

The skin method is used in the construction of models of considerable size which have simple land formations. In the skin method, instead of having the model surface composed of solid hydrocol or papier-mache, it is covered with either cheesecloth or burlap. Burlap is used on large-size models, cheesecloth on the smaller models. To give the model a hard surface a thin coat of hydrocol is applied on the fabric. The procedure for surfacing the different methods are as follows:

a. Surfacing the Step-and-Block Method. The step-and-block method is usually employed on large size models, therefore burlap is used as a surfacing material. After all contours have been cut and blocked in position, the burlap is tacked or stapled over the model. The burlap is first tacked in the high corner of the model. From this point it is stretched outward and down, being tacked alternately from edge to edge and along the edge of every successive lower contour, and it must be kept taut at all times. This process is followed until the model is completely covered. Any excess burlap extending over the edges of the model is trimmed off. The model is then ready to be surfaced with forming plaster. When the surface material is burlap, two coats of plaster should be applied. The first coat should be a thin mixture to enable the plaster to soak into the burlap. This creates a positive bond between the burlap and the plaster. This first coat will also shrink the burlap and take out any slack between the contours. After this first coat has set, the second may be applied. When putting on the second coat, the landforms are molded into smooth curves, as in the solid surface method. The total thickness of the plaster should be approximately $\frac{3}{16}$ inch. The finished surface may be smoothed out with paint brush and water.

b. Surfacing the Egg-Crate Method. The egg-crate method may be used on large plywood models covered with burlap or small cardboard models covered with cheesecloth. When burlap is used it is tacked on the profile in a manner similar to the surfacing in the step-and-block method. When cheesecloth is used it is glued on the edges of the profile instead of being tacked. A fast-drying glue is recommended. The pattern followed in gluing down the cheesecloth is the same as in the burlap applications. In surfacing the burlap-covered model, two coats of forming plaster are recommended. The procedure is the same as in the step-and-block method. The application of plaster to the cheesecloth varies slightly with the methods used in burlap surfacing. Two coats of plaster are required. The first coat is a very thin mixture, and is applied with a paint brush. This first coat will shrink any slack areas in the cheesecloth. The second coat is applied sparingly in order to create smooth landforms. This second coat may also be brushed on; in this case its consistency should be greater than the first.

c. Surfacing the Ribbon Method. This method consists of cardboard construction, therefore the surfacing material used is cheesecloth. The application of the cheesecloth and hydrocol is the same as for the egg-crate method.

d. Surfacing the Nail-or-Peg Method. This method may be developed with either the solid-surface method or the skin method. The solid-surface method is accomplished by simply filling the area between the base and the heads of the nails or pegs with plaster, papier-mache, sawdust, or some similar material, then using the heads of the nails or tops of the pegs as control points. Proper landforms are shaped as in any other method. The skin method is a little more difficult to use, but it does have a weight advantage. The first step is to connect the nails or pegs that fall on the same contour line with string or heavy twine, depending on the size of the model. The string is tied as close to the head of the nail or peg as possible and may be glued there to prevent slipping. This, then, has an appearance similar to the ribbon method. The cheesecloth may be either glued or sewn to the string. Plaster is then applied in the manner described in preceding paragraphs.

CHAPTER 5

FINISHING

29. General

In the finishing of a terrain model, texturing is the last and most important step. It transforms the barren plaster cast into the shape and color of the terrain that the model represents. The materials used to texture a model give it a certain degree of roughness to represent earth, fields, and wooded areas so the viewer can easily differentiate between them. Coloring a model helps to distinguish one type of field from another and adds realism to aid in the identity of objects, manmade or natural.

30. Materials Used

The materials listed in the following paragraphs will suggest the many materials available for finishing a terrain model. A very satisfactory model can be obtained through their use, but the result will depend upon the ingenuity of the person finishing the model. Most of these materials are available through normal supply sources.

a. Sawdust. The degree of coarseness of sawdust is determined by the size of equipment and blade used to produce it. Fine sawdust from a sanding machine is used to simulate short grass and dirt. The coarser the sawdust the denser the type of vegetation it will represent.

b. Sponge Rubber. Sponge rubber ground to different degrees of coarseness can be used instead of sawdust. Blocks of sponge rubber can be shaped to represent trees, bushes, and hedgerows. The sponge is dyed by dipping it into a container of the desired color and kneading to insure coloring throughout. The sponge will absorb the liquid color and swell up. If it were shaped before being colored it would swell to a size of a different scale forcing it to be reshaped. Due to the pigment entering into it, the sponge will not revert to its original shape after drying out. The sponge must be thoroughly dry if an adhesive is to hold it in place on the model.

c. Lichen. Lichen is a moss-like plant with a spongy appearance, which in its original form is brittle and hard. To make it more practical and useful, lichen is put through a curing process which softens it and makes it permanently pliable. The structure of lichen bears a strong resemblance to brush and dead trees. The formula for the ingredients that soften lichen is: 1 gallon of glycerin, ½ gallon of water, ½ gallon of alcohol, and 1 pint of kerosene. The alcohol and kerosene kill any existing bacteria in the lichen, thereby eliminating any plant decay. Glycerin penetrates the brittle nature of lichen rendering it permanently pliable. A mixture of this strength will last a year if the excess of each curing is retained. The method for curing is to let the raw lichen cook for 24 hours to insure thorough impregnation of the mixture. A weight may be kept on the lichen to keep it completely immersed. After it is thoroughly soaked, all of the excess mixture is squeezed out and this excess can be used again. The lichen is then spread on a piece of cheesecloth or screen and suspended over a rack to allow the air to reach all of the wet lichen. It is advisable to wear rubber gloves during the procedure because of the effect of the mixture on the skin.

d. Wood. Almost any type of wood can be used to construct the cultural features on a model. It is impossible to set any special type of wood as a must for this construction. Balso wood is desirable because of its convenience in forming. Bridge abutments of rock can be simulated with wood, but in some cases small stones can be used and will provide a more realistic result.

e. Fastening Materials. Model-making units are authorized a cellulose cement. This glue is quick drying and ideal for fastening vegetation and culture to the model. Brads and bank pins are used to support any flexible material that is used for detailing the vegetation and culture on a model. They are also used to fasten buildings and bridges to a model.

31. Method of Finishing Terrain Models

a. Sealing. The entire model is given a coat of shellac after the carving has been completed. This is to seal the plaster. When the first coat is dry, the second and following coats of shellac are applied on small areas, approximately 3 square inches at a time. While the shellac is still wet the texturing material is sprinkled on, enabling it to adhere to the model's surface. When areas of woods or heavy vegetation are applied to the model, several coats of shellac should be brushed on so that the heavy grade texture sticks to the model.

b. Texturing.

(1) Although the following method is dependent upon the scale of the model and is left to the discretion of the person doing the finishing, it is a very successful method of gaining accuracy in the insertion of cultural features. Before any texturing is begun, the culture is copied from the manuscript onto the model. All existing land formations, such as rivers, ridges, and valleys, are used as guides. Dividers are helpful in measuring and transferring distances. Once these are drawn on the model they are covered with masking tape. A fine grade of sawdust is then applied. This reduces the glare of the shellac that would ordinarily show through a heavy grade material. After the first layer of sawdust is applied, the second layer, which is the desired grade of texture that conforms to the scale of the model, is applied. The grades of texturing material are applied in a specific order. This order is simply a fine to a coarse grade of texturing material, and is followed throughout the texturing and color procedure. One can notice that this order conforms with nature to the extent that brush is formed below trees, grass under brush, and earth or sand under grass.

(2) If the model is of such a large scale that the trees average an inch or more in height, they are colored and added to the model along with the detail after all painting and coloring have been completed. In either case, when applying trees to wooded areas, one must be careful to observe and follow the degree of coverage shown on the manuscript. This area can be accurately drawn on the model by using all of the landforms and culture as control points. Trees generally thin out gradually along the edge of a forest. Very seldom do woods end abruptly on a field unless there is farmland or plowed field involved. When trees have been cleared in this manner, it will be obvious by the straight lines formed between wooded areas and cleared areas.

c. Coloring.

(1) Before any coloring is begun, the tape that marked the culture is removed. Removing the tape at this time permits any chips or defects, arising from the operation, to be corrected with paint. It also permits road shoulders to be painted on realistically. Coloring is done in the same order as the laying of the texture—from fine to coarse. Each area's woods, fields, or beaches are colored separately with a base coat that approximates their areas. Paint, when wet, will be much darker than when it dries. The dry pigment is close to what the color will be after it is mixed with the thinner and dries. Different colored pigments are added to the base coat mixture. These new colors will represent any ground discrepancies such as barren areas, green or dead grass areas. After the pigment has been added, it is blended into the base by brushing thinner over it.

(2) Blending two distinct areas together is basically the same process as coloring. It is done to eliminate the distinct line that otherwise would exist between the two areas. It is done by giving both areas their base coat and blending the two together with thinner. Blending

areas together is done only in specific instances; for example, between beaches and grass fields or dirt areas. Blending would not be used on such areas as forests or shore lines for in these instances a distinct line is necessary to designate where these areas end. Blending would be used within these areas to illustrate surf, breakers, and water depths in the case of shore lines and water. It would also be used within a wooded area to show burned-out sections or the fall coloring of trees.

(3) All textured areas of the model are colored with pigments mixed in the special thinner. Water areas can be colored with regular oil- or turpentine-based paints. The special thinner, composed of linseed oil, dryer, and turpentine keeps the texturing materials pliable for a long period.

(4) There are standard base-coat mixtures that are accepted for their close resemblance to natural terrain features. To represent dirt with a large percent of silt or clay, mix 1 part white, 1 part yellow ochre, 1 part burnt sienna, and 1 part burnt umber. To represent lighter dirt with a large percent of sand, mix 2 parts white, 1 part yellow ochre, and ¼ part burnt sienna. To represent sand along beaches, mix 3 parts white and ½ part yellow ochre. To represent grass and vegetated fields, mix 1 part white and 1 part chrome-green, light. A mixture that resembles the basic color of water is 1 part flat white, 2 parts chrome-green, medium, 1 part blue, and ¼ part burnt umber. The oil painting of hydrographic features is done after all the texturing and coloring with pigments are completed. This keeps the adhesive nature of the set paint free of foreign matter. Before applying oil paint on a water area, the base should be shellacked enough to bring out a high gloss when painted. Very often oil or enamel paint is not available, and pigments must be used to color the water areas. When coloring water areas with pigments it is best to shellac the base before and after coloring to insure a realistic gloss. It is well to rely on pigments to color water areas since oil-base and enamel paints are not included in the model-making kit.

(5) The formulas given are only base coats for certain features on a model. There are many variations both lighter and darker, to represent different types of fields, trees, and water depths. To derive these other shades, ingenuity must be used. An aid in representing these shades is a collection of photos or pictures, depicting different seasons or areas, clipped from magazines. A field would never be a solid, unblemished color unless it were a golf green. In this case, care must be taken not to make the green look too artificial. Color principles are shown in figure 11.

d. Detailing.

(1) After all the texturing, coloring, and painting have been completed, the next step is to add the detail. This is a very intricate step, requiring patience, care, and accuracy. Details such as roads, cement or asphalt areas, and airfield runways are drawn or painted on first. These must be accurate for they serve as a guide to all other manmade features that appear on the model. Such features as telephone lines, guard rails, street lights, houses and bridges depend on roads as a guide. These features are temporarily placed on the model until they are located as accurately as possible. Then they are permanently glued down.

(2) On a terrain model that has vertical exaggeration the bridges, dams, and features that fit between some land formations are exaggerated vertically. The horizontal scale of the bridge or dam would not change, leaving features distorted which in this case cannot be avoided in any way.

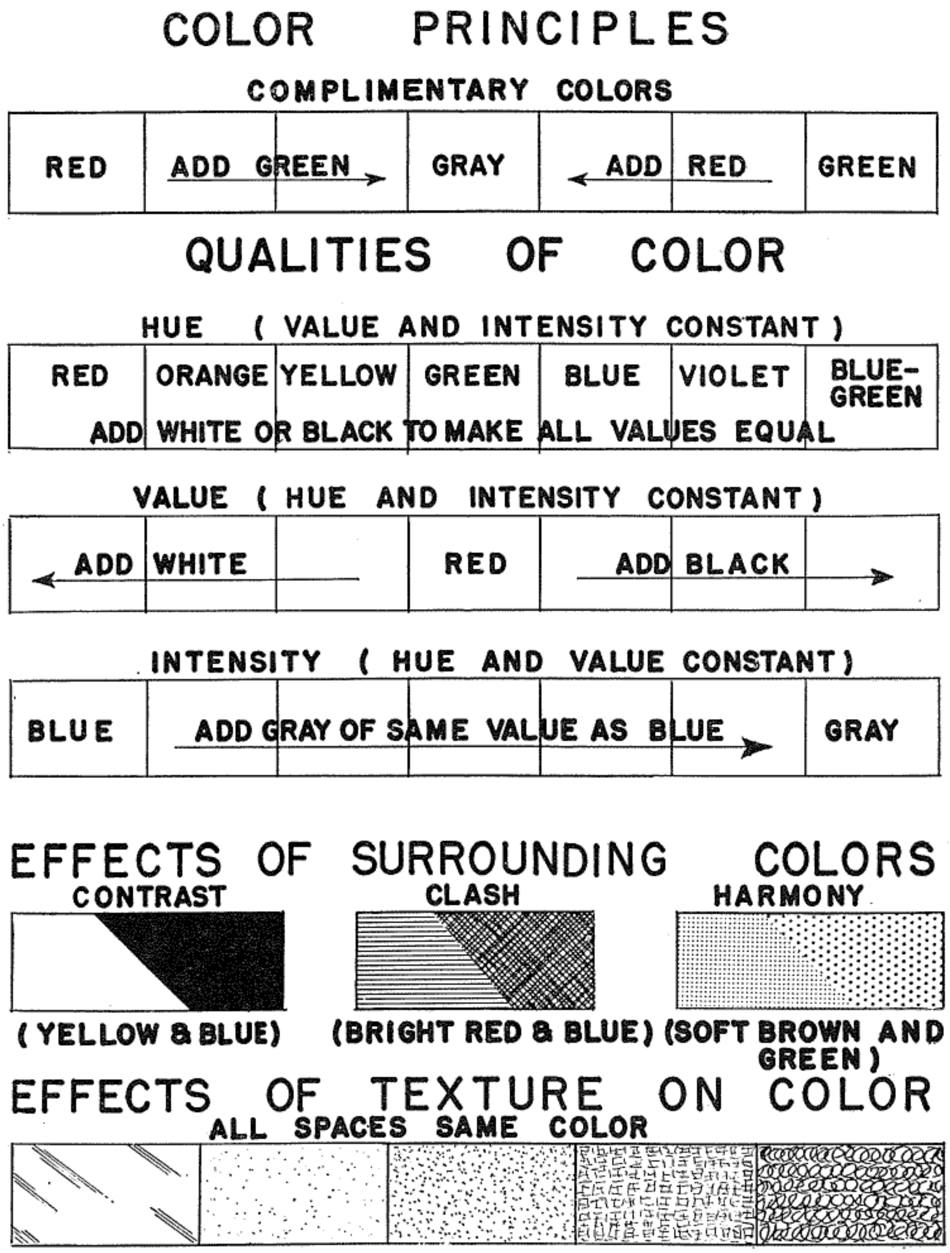


Figure 11. Color principles.

(3) The material used in constructing the detail is composed of whatever is available at the time. All of the materials used and how they are used is left entirely to the imagination of the individual. Desirable materials would be balsa wood, white pine, and rubber, all of which can be cut easily with a knife if power tools are not available. If proper tools are on hand, most any type of wood, tin, or plastic would be suitable. Paper, cardboard, nails, wire, and toothpicks can be used for bridges, telephone lines, and similar features. There is no limit to the materials that can be used.

(4) The most important point in fastening the detail to the model is to get a strong bond between the article and the base. This can be done with either strong glue or nails. In some cases parts of the model have to be chipped

away so that a bridge or dam may be fitted into place. The surface has to be scraped when a road is to be indicated. The road surface is generally smooth or a cut may have to be made on the side of a hill. Holes may be drilled in the model to insure a good bond and support for lamp posts, telephone lines, or guard rails. Any method may be used, but it must be durable.

e. Trim. The final step in completing a model is to paint the border and exposed sides of the base. Slate black produces a pleasing result by complementing the colors on the model. All pertinent model information is printed on the base. Such information includes the name of the model (taken from its map location), the type of model, the horizontal and vertical scale, and finally the title block. This is made up of the unit and the date the model was made. This printing can be done with a lettering set. The paint used in the scriber has to be well thinned to permit its use in the pen.

CHAPTER 6
CASTING

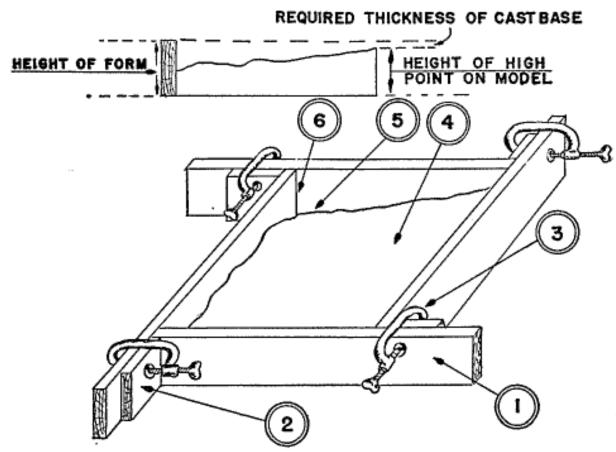
32. General

In the production of terrain models, it is often necessary to make more than one model. The process of duplicating a model is known as reproduction. Models are reproduced by casting in cement. Casts of a model may have to be made either when the terrain base of the model has been completed, or after the surface of the model has been developed. The overall process for reproducing models is the same as that used for reproducing statuettes or other forms in plaster or cement. When the model reaches the stage in production at which it is desired to have reproduction made, a negative cast of the model is made. From this negative cast, any number of positive reproductions of the model may be cast.

33. Preparing the Mold for Casting

a. Sealing the Mold. Before a cast is made, the model to be reproduced must be sealed. Sealing prevents the mold from absorbing moisture from the poured cement. If a terrain base is being cast, moisture will warp and distort the laminae. If a cement or plaster surface is being cast, the moisture absorbed by the model is subtracted from the moisture in the poured cement, and may result in a weakened cast. Cut shellac is used to seal the mold before casting. The shellac should be cut with pure, denatured alcohol only. It should be cut thin enough so that the first coat will be completely absorbed by the mold, and 2 or 3 coats will be required to seal it completely.

b. Forms for the Mold. Wooden forms are clamped in place with C-clamps to form a frame around the model to be cast. These forms, which will contain the poured cement, must be high enough to provide a base of sufficient strength and thickness for the desired model cast (fig. 12). Each time the forms are set, they should be sealed with a coat of cut shellac. After the forms have been clamped in position, any gaps between the forms and the model must be filled in with clay to keep the poured cement from seeping into the gaps.



1. FORM BOARDS
2. CLAMPING BLOCKS ATTACHED TO FORMS
3. C CLAMPS
4. SURFACED MODEL (FORM TO BE CAST)
5 & 6. GAPS SEALED WITH PLASTILENE CLAY

Figure 12. Casting forms.

c. Separating Compound. To facilitate the separation of the cement cast from the model mold, after the cement has set, the entire mold is covered with a separating compound. The separating compound forms a thin film over the mold and prevents cohesions between the mold and the cast. Some of the separating compounds normally available are—stearic acid, cut petroleum jelly, lard oil, light lubricating oil, and spirits of camphor. A thin, uniform coat of separating compound is all that is required to produce the desired results. This coat can be obtained by applying the compound with a 1-inch paintbrush. The separating compound should be applied 20 to 30 minutes before the cast is poured.

34. Making the Cast

a. Mixing the Cement. A molding plaster or cement, such as Hydrocol B-11 or equivalent, that has a low setting expansion rate, a low moisture absorption rate, and remains plastic for quite a while before the initial set, should be used to make the cast. The strength and hardness of a cast will depend directly on the amount of water used to produce a given amount of mix. If specific directions are not available for the plaster or cement that is being used, several test casts should be made to assure that the best results possible are obtained.

b. Pouring the Cast. The plaster or cement should be poured immediately after the mixing has been completed. The prepared mold should be placed on a loose-legged table so the mold can be vibrated well while being poured. This vibration eliminates air gaps and air spaces which would normally form between the mold and the freshly poured cement. The mix is poured into the mold through a strainer to prevent any lumps that form in the mix from getting into the cast. The mix should be poured into the mold from one corner and allowed to flow freely over the mold. After sufficient mix has been poured to cover the entire surface of the model being cast, it is no longer necessary to vibrate the table. The mold should then be filled until the level of the mix is slightly higher than the top of the framing forms. Just before the initial set, the cement should be leveled flush with the top of the framing forms by drawing a straightedge across the top. The straightedge should rest on two opposite forms and be drawn across them with a side-to-side motion. This will insure a uniformly level base for the cast to rest on.

c. Reinforcing the Cast. It is sometimes desirable to reinforce the cast in order to increase the tensile strength (fig. 13). Commonly used reinforcing materials are burlap and matted straw or fiber sheets. These sheets should be cut 1 inch less than the dimensions of the cast to be poured. For model casts 2 or 3 reinforcement sheets should be used. When enough mix has been poured to fill the mold to within 1/4 inch of the top of the forms, the sheets of reinforcement should be set into the mix in the mold, making sure that the sheets do not touch the mold at any point, and that they are set in the center of the mold so that their edges will not be seen after the cast has been pulled. After the reinforcing sheets have been placed, the remainder of the mix can be poured into the mold.

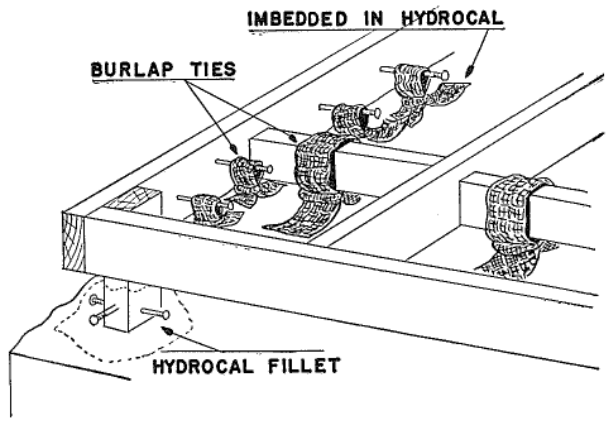


Figure 13. Cast reinforcing.

d. Pulling the Cast. After the cast has had sufficient time to set, remove the framing forms. Adjustable hand-screw clamps are then attached to the cast, and the cast lifted vertically from the mold. If the cast does not come loose immediately, a few light taps on the cast, with a leather or wooden mallet will loosen it. When the cast has been separated from the mold, it should be left to dry for several hours. After this drying period, the cast may be used as a mold for further casting, as a model, or stored for future use.

PART THREE. BASE PLANT CONSTRUCTION METHODS

CHAPTER 7

PLASTIC RELIEF MAPS

35. Modeling Criteria

a. Certain basic criteria must be met before the start of a plastic-relief mapping project. Failure to observe these criteria will result in a map that does not present a visual advantage to the map user.

b. (1) The criteria described below apply to plastic relief maps at 1:25,000, 1:50,000, 1:100,000, 1:250,000 and 1:1,000,000 scales and are intended as a guide only. Individual requests, including special-use models at these scales or models at other scales, should be examined from the standpoint of proposed usage and the position of an individual sheet with respect to other sheets within the project. In most cases, because vertical heights shown at true horizontal scale are extremely low and of little aid, the relief cartographer, while accepting the horizontal scale of the flat map, finds it necessary to exaggerate the vertical scale over the horizontal, in order to accentuate the terrain.

(2) The exact amount of exaggeration is largely a matter of judgment taking into consideration the intended use of the map. For example, for small-scale maps such as 1:1,000,000 used for operational planning purposes, exaggeration of the vertical scale serves to emphasize relief which might otherwise be imperceptible since, at this scale, 1,000 feet of elevation measures only 0.012 inch at a 1:1 ratio. On the other hand, large-scale maps, used for orientation and briefing purposes in local areas, to be of value must depict the terrain features as realistically as possible. Therefore, any exaggeration of the vertical scale over the horizontal may falsify the terrain to such an extent as to be confusing to the user.

(3) One other factor to be considered in the final decision as to the degree of vertical exaggeration is the material limitation, that is, the amount of draw to which the plastic material can be subjected and still give acceptable register. Experience has proved that, in almost all cases, following the exaggeration of the vertical over the horizontal scales as set forth below, desired material behavior will result and most use requirements will be met.

Horizontal scale	Recommended exaggeration of vertical scale
1:25,000	None to 2:1
1:50,000	None to 2:1
1:100,000	2:1
1:250,000	2:1 to 3:1
1:1,000,000	4:1

(4) Figure 2 shows a comparison of vertical exaggerations at 1:250,000 scale. Of those shown, the 3:1 exaggeration is the most reasonable. In areas of extremely rugged terrain the standard vertical exaggeration may be decreased to accommodate material limitations, but these variations should be held to a minimum so as not to destroy the comparison of relative heights within a project area.

c. In order to establish uniform procedure for examining a sheet, it is necessary to check the relief within a sheet on a grid square or comparable basis. Elevation variation is the difference between the lowest elevation and highest elevation, at the vertical exaggeration decided upon, within the grid square or sheet limits as specified.

d. When determining the practicability of preparing molded plastic relief maps covering any desired area, the following prerequisites should be considered:

(1) A minimum elevation variation of at least 0.15 inch is required within 10 percent of the grid square covering the *land area* of the sheet. The square should measure approximately 1.5 inches on a side. For example, a 1:25,000 scale sheet, measuring 17.5 inches by 20 inches, contains approximately 143 1,000-meter squares which measure 1.53 inches on each side. In order to meet the minimum criterion, at least 14 of these squares must contain relief whose vertical variation, at the accepted vertical exaggeration, is 0.15 inch or more.

(2) For simplicity the following scales and unit squares or equivalent may be used:

Scale	*Unit* (meter square)
1:25,000	1,000
1:50,000	2,000
1:100,000	4,000
1:250,000	10,000
1:1,000,000	variable (as indicated below)

(3) At 1:1,000,000 scale the N–S measurement for the unit shall be 20 minutes and the E–W measurement shall vary as indicated in the following table:

Latitude band	*E–W unit*
0°—27°	20 minutes
28°—43°	25 minutes
44°—55°	30 minutes
56°—59°	35 minutes
60°—63°	40 minutes
64°—67°	50 minutes
68°—71°	1 degree
72°—75°	1 degree 30 minutes
76°—80°	2 degrees

(4) If upon examination a desired sheet does not meet the criteria as outlined above, it should be checked for over-all elevation variations. If a uniform slope with an elevation variation between highest and lowest points of more than 0.50 inch exists, the sheet should be molded. This is a situation which would occur in many coastal areas and the 0.50 inch variation would appreciably affect the mosaicking of adjacent plastic relief maps.

e. The plastic material used for the relief map has certain physical limitations which necessitate changes in the design of the map and control the technique used in the construction and reproduction of the master model. This material is a chloride-acetate vinyl copolymer thermoplastic 0.015 inch thick, purchased in sheet form. When subjected to heat, the sheets will contract about 30 percent in the longitudinal direction and expand about 10 percent transversely unless rigidly clamped in position. The softening point of this material is approximately 135° F., the forming temperature 175° F. The material is limited in the amount of stretch or draw to which it can be subjected. These features must be given careful consideration in the preparation of construction and reproduction materials.

36. Cartographic Procedures

a. Source Materials. Existing reproduction material is used whenever possible for the printing of plastic maps. Should any revisions to the map detail be considered necessary, they are made on film positives of the appropriate drawing. Changes may also be made in the format in order to meet equipment capabilities. Oversize sheets are divided into smaller sheets; if sheets are small, they may be combined into one sheet, thus saving time and materials in the printing, casting, and forming operations. Where possible, island sheets and sheets with minor land areas are incorporated into adjoining sheets. These changes are made by cutting and mosaicking film positives to new sheet lines. New press plates, incorporating all revised copy, are made for the plastic printing.

b. Marginal Data Layout.

(1) Marginal data appearing in the existing flat map must be redesigned for the plastic printing into a more compact form because of equipment and material limitations. Figure 14 shows a comparison between the arrangement of the border data of the exist-

ing paper map and the plastic edition. The limits of the marginal data are dependent upon the size of the forming equipment. In forming over a positive model a certain amount of material must be allowed for trim off, since the edges of the sheet are clamped between a clamping frame and side walls of the box containing the model. To obtain proper register of line work, the height of these walls must be nearly as high as the highest landform on the model, and that portion of the sheet which is drawn from the side walls to datum must be trimmed off as shown in figure 15. Therefore, should any of the information appear in the trim-off area, it must be shifted elsewhere in the margins.

(2) The design of the marginal data is also affected by the neatline positioning within the limits of the plastic sheet. Because of the limitations of the plastic material, the position often varies for individual sheets, depending upon

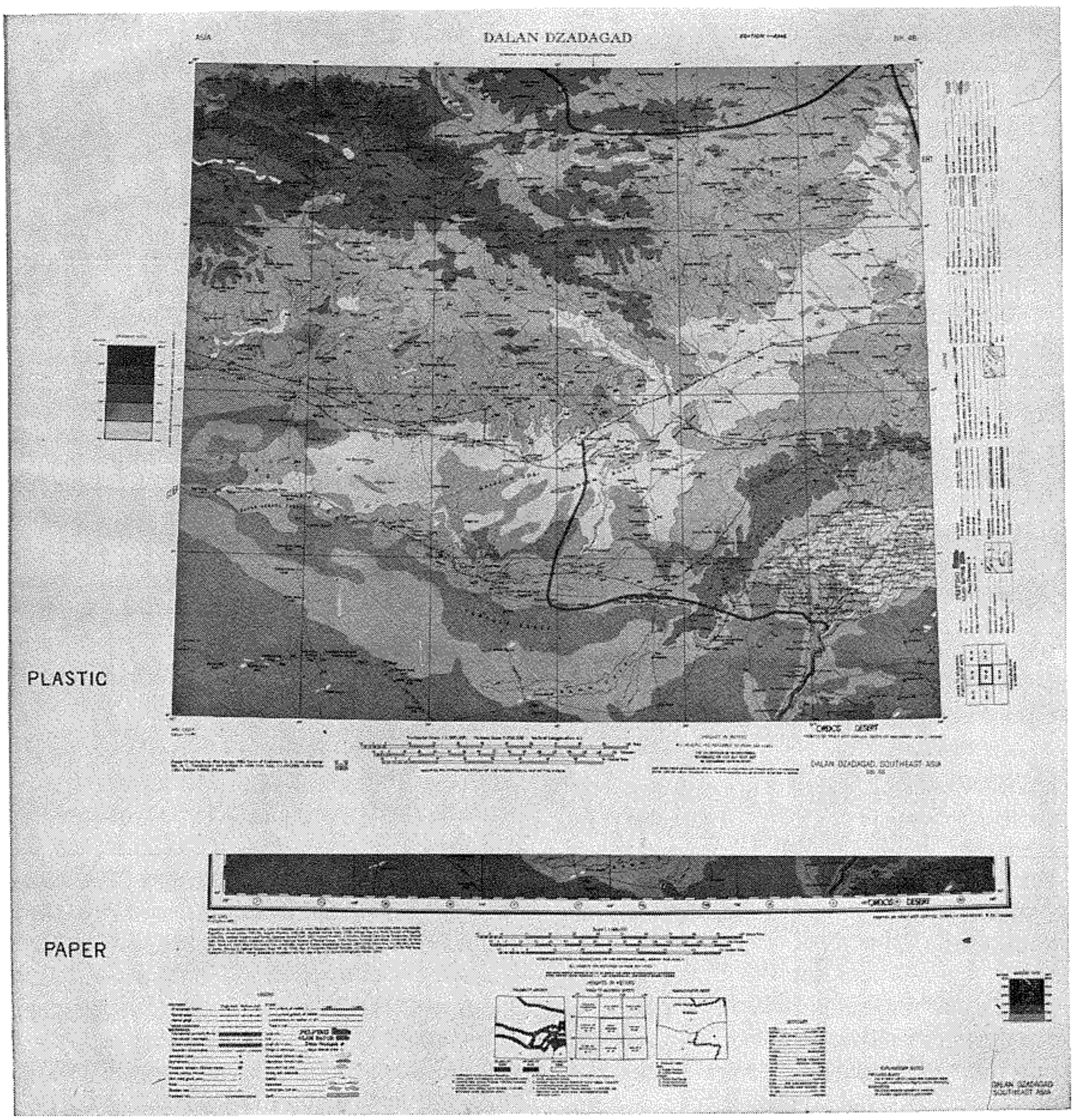


Figure 14. Comparison of marginal data layout of plastic map and corresponding paper map.

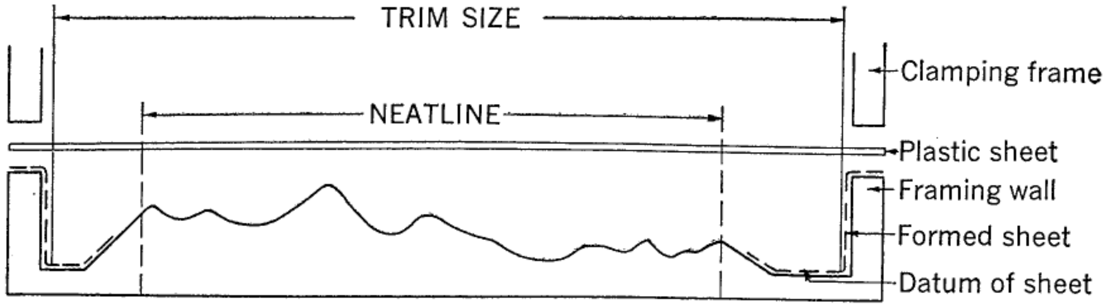


Figure 15. Trim size of formed plastic sheet.

the nature of the terrain. When the terrain heights are consistent throughout the model, best register can be obtained by centering the neatline on plastic sheet, thus allowing the maximum amount of material outside the neatline on all sides where the greatest draw to datum occurs. Should high relief be concentrated on one side, the neatline is offset to allow more material on the high side and provide enough material to accommodate the draw.

(3) In the rearrangement, the marginal information is placed as close as possible to the neatlines and is usually positioned to read from the neatline to the sheet edge on all margins except the north margin where it is positioned to read from the bottom of the sheet. Information not pertinent to the plastic relief map is deleted (fig. 14). The revisions are made on a blueline Dyrite copy of the culture plate, and again the revised copy is used in making new press plates for the plastic printing.

c. Relief Drawing. Various guides may be used in the pantograph cutting of the terrain base. For most expedient cutting, an etching of the contour drawing is made on zinc which usually necessitates color-separation material being available. Otherwise, any etched lines intersecting the contours present difficulties in guiding the tracing needle. If the existing map is a monochrome, cutting may be done from a stable base material such as Dyrite. In the absence of either zinc or Dyrite, a paper map can be used for the guide although this is unsatisfactory since stability of the paper is uncertain. In any case, special treatment of relief detail is required. Continuous and clearly defined contour lines are necessary to insure expedient cutting and avoid confusing the cutting operator. Upon a Dyrite copy of the contour drawing, all broken lines are connected and contours are interpolated and drafted through all glaciated and unsurveyed areas. In flat areas where carving often proves most difficult, intermediate contours are plotted and drafted. Coastal shorelines and, in some instances, internal water body shorelines are transferred to the Dyrite. If the Dyrite is to be used as the cutting guide, the contour intervals are colored, where the line work is confusing, to facilitate cutting.

d. Cutting Positive. The cutting positive is a printing on glass of the revised Dyrite copy described in paragraph *c* above, from which, by a photoengraving process or photolithographic processes, the etched zinc plate is made. The glass plate is retained for checking the stepped terrain base upon completion of cutting. This plate may be washed and reused after the check has been made.

e. Checking Positive. The checking positive is a composite printing on glass of the contour and drainage drawings. It is obtained by the same means as the cutting positive although different topographic detail is added to the composite Dyrite copy. The compilers annotate on this copy such relief symbols as will aid the carver in the interpretation of landforms—ridge lines, spot heights, cuts, fills, and cliffs. The section or marriage lines are also marked. Sufficient copies are prepared to serve as carving guides. From one of these annotated copies, the composite glass plate is made for use on the editing device as described in paragraph 37*c*.

37. Construction Methods

a. Plastic Block.

(1) Prior to preparation of the plastic block, or laminate, the datum plane of the series, the number of cuts, the thickness of laminae, the width of flowline (app. III), and the sheet sizes must be established. As an example in determining these figures, assume a series of maps at 1:250,000, a contour interval of 100 feet, a high contour in the series of 5,000 feet, a high elevation of 5,000 feet along any neatline, and a low at sea level. The model will be constructed at a vertical exaggeration of 3:1. The datum plane is established for the set, in this case sea level; from this is figured the number of laminae required for each sheet. For those sheets where the lowest contour is several intervals higher than datum, additional laminae must be allowed for the number of intervals to datum (fig. 16). In this case, the greatest number of laminae for any one sheet would be 51.

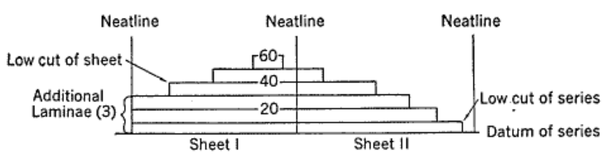


Figure 16. Additional laminae allowance for intervals to datum.

(2) The thickness of laminae is figured according to the scale, contour interval, and vertical exaggeration of the model. For instance, using the example in (1) above, 1 foot at 3:1 is equal to 0.00015 inch, making 100 feet or each lamina 0.015-inch thick.

(3) The width of the flowline is established for the series, and being as wide as the highest neatline contour is high, would be 0.00015 inch x 5,000, or 0.75 inch for all sheets. This width must be added to the overall size of the neatline area, when cutting the laminae preparatory to stacking. If the model is to be cut in sections (par. 37*b*.(1)), separate laminates are prepared for each section.

(4) Cellulose acetate sheet material is used in the preparation of the laminate, each sheet representing 1 contour interval. Sheets are selected according to the specified thickness and cut 1 inch larger than the specified size; for example, a nominal 12- by 18-inch sheet is cut 13- by 19-inches. All sheets are cleaned to remove dust and grease and given 2 spray applications of a pressure-sensitive adhesive, which is strong yet allows the sheets to be easily stripped as required in the construction of the base. Three formulas recommended for use with this material are given below in the order of their suitability. All solutions must be thoroughly blended.

(*a*) 1 gallon O/R 36 Permakote
3¼ gallons Methyl Eythyl Ketone (MEK)
¾ gallon Hytrol–O (Cyclohexanone)

(*b*) 2 gallons O/R 17 Permakote
2 gallons MEK
½ gallon Hytrol–O (Cyclohexanone)

(*c*) 1 gallon E. C. 870
8 to 10 gallons Toluene or MEK

(5) When the adhesive has set to the point where it is not tacky to the touch, all sheets, except the bottom one, are slit as shown in figure 17 to preclude the formation of air bubbles during stacking.

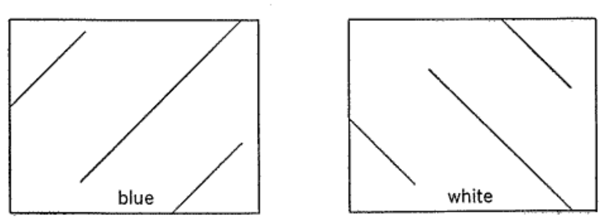


Figure 17. Alternating colors and slits in cellulose acetate sheets.

(6) The sheets are stacked, alternating colors and slits, and placed under a pressure of approximately 25 to 30 psi for ½ hour. Upon removal the laminate is cut to the proper overall size, mounted on a plywood board or metal plate to prevent warping, and again subjected to pressure for 10 to 15 minutes.

b. Cutting of Terrain Base.

(1) Construction of a model may be expedited by dividing the neatline area into several sections, cutting and carving the individual sections, and rejoining or marrying them to the original size. If this is done, the zinc plate and the laminate must be prepared accordingly.

(2) The cutting of the terrain base is accomplished on the two-dimensional pantograph shown in figure 18. The routing or cutting arm is suspended above and traverses the left-hand table; the tracing arm is suspended above and traverses the right-hand table. The pantographic action causes the router blade to cut the same configuration being traced by the point of the tracing arm. The tracing arm may be raised or lowered in order to be adjusted to the height of the table; the cutting arm may be adjusted vertically to accommodate the thickness of the block; and the cutting depth of the blade may be adjusted.

(3) The plastic block is mounted securely on the left-hand table and the etched zinc plate oriented on the right-hand table by first placing the tracing point of the router on the upper left corner tick of the zinc plate and moving the plate until the router blade is positioned the width of the flowline in from the left and top edge of the laminate and, second, placing the tracing point on the upper right corner tick and swinging the plate until the router blade is positioned the same distance

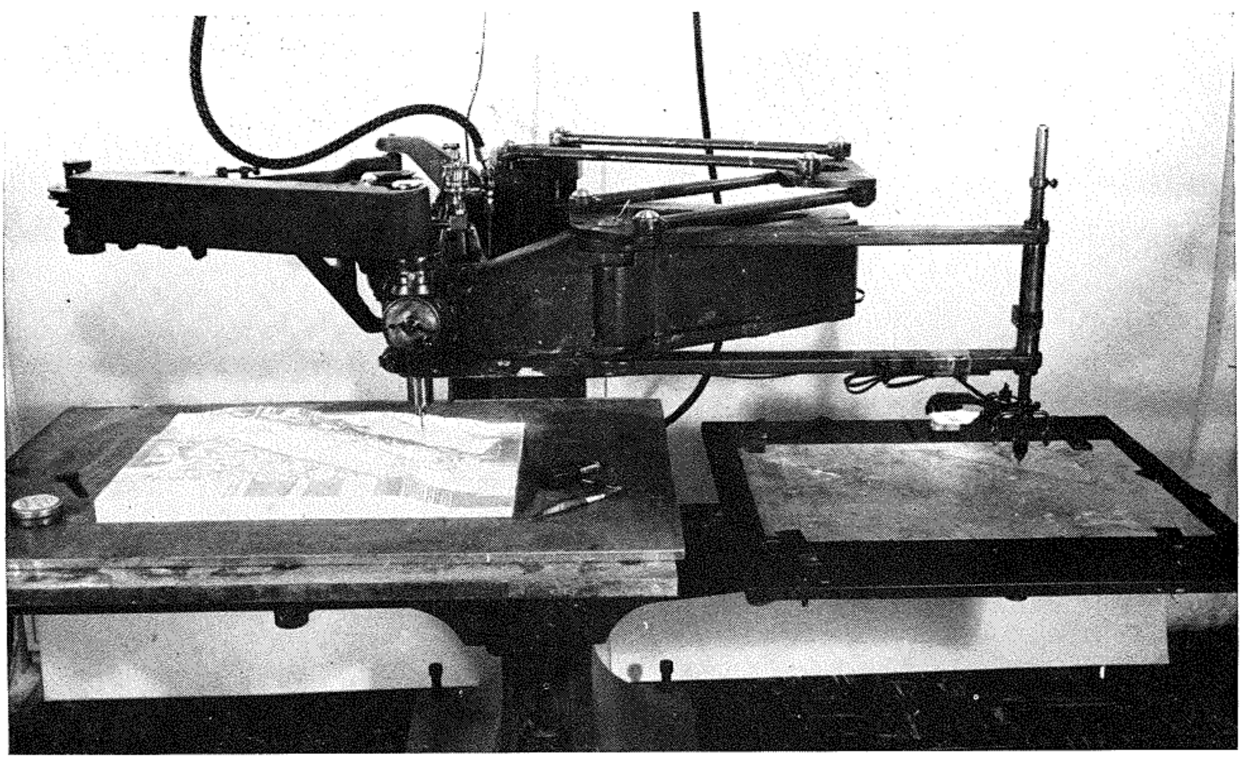


Figure 18. Two-dimensional pantograph with cut plastic terrain base on the left-hand table and zinc plate on the right-hand table.

from the top edge. When proper orientation has been achieved, the zinc plate is clamped securely to the table.

(4) If the zinc plate is produced by photoengraving techniques, before it is clamped onto the table a red oil pigment is rubbed evenly into the contours using a cloth adequately moistened with turpentine to thin the pigment sufficiently for air drying. If it is produced by photolithographic process, a red press ink is applied before the gum stencil is removed. The red dye serves as a guide in cutting so that, as each contour is traced, the pigment is pushed out and permits the operator to see readily which contours have been cut. The plate is then grained to remove the glare of the metal. The contours are labeled at the neatline and an overlapping strip is attached on the marriage line.

(5) In the cutting operation, the operator places the tracing needle in the groove of the highest contour and adjusts the router blade to cut through one lamina. He then traces the contour outline. The pantographic action causes the cutting blade to cut the same outline on the laminate. After all contours at one level have been cut, the excess material is stripped off, leaving just the raised contour outline in a step form. This procedure is continued, proceeding from the highest to the lowest contour, with the cutting blade being lowered for each successive level until all contours have been cut. The stepped terrain base is then ready for a negative step cast. If the model is being cut in sections, the marriage line and neatline are scribed after the cutting is completed. The stepped base is then checked against the cutting positive for completeness of cutting as shown in figure 19.

c. Shadow Projector.

(1) The shadow projector is an optional device based on a parallel optical system, developed at AMS to provide a means of insuring dimensional accuracy throughout the construction and reproduction phases. Standard cameras and projectors cannot be used since their optically divergent and convergent (conical) image projection systems enlarge the image of the contour map as it is projected into the depths of the model.

(2) As shown in figure 20 the projector consists of two main parts—the light source and projector (A), and an objective lens or parabolic mirror (B). The light emanating from the projector strikes the mirror, which bends and transmits the rays in a parallel or collimated beam. The composite glass plate (par. 36*e*) is positioned 4 to 6 inches above the model. The parallel rays passing through cast the shadows of the counter lines perpendicularly to the datum of the model regardless of the amount of relief. The diameter of the mirror determines the size of the model area covered, the largest at present being 16 inches. However, the glass plate and model are contained in a movable cradle which can be shifted to bring any portion of the model under the collimated beam.

(3) The shadow projector is used to check the following:

(*a*) Accuracy of plaster step terrain bases, both negative and positive.

(*b*) Details and accuracy of carving.

(*c*) Scale fidelity in subsequent negative and positive molds.

(*d*) Marrying sections of a model into the original neatline measurements.

d. Step Casts.

(1) Several factors determine the type casting plasters to be used in the several casting operations required, the most important being the maintenance of size to insure proper register of the preprinted plastic maps with the mold. Hydrocol B-11, Densite K-12, or Densite K-13, because

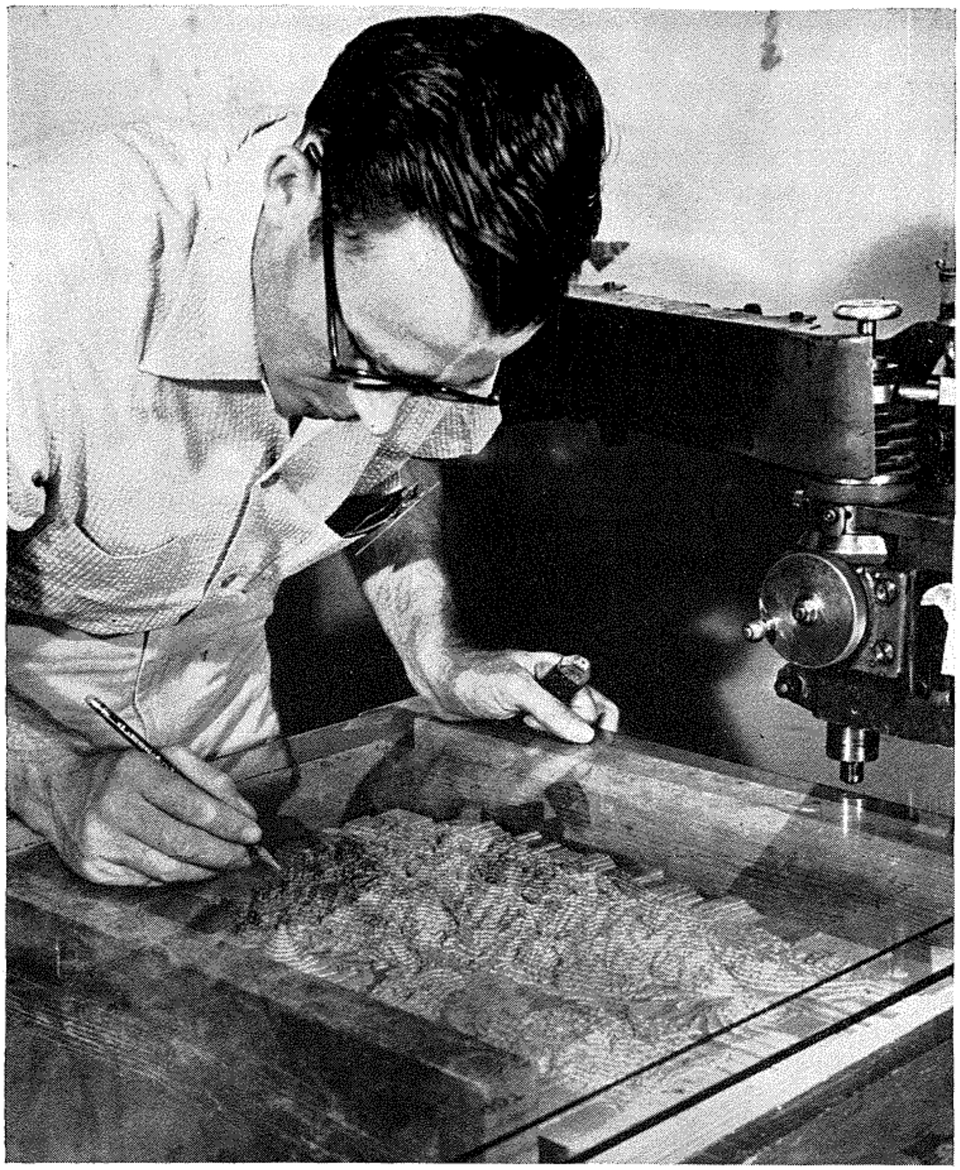


Figure 19. Checking the stepped terrain base through the glass cutting positive.

of their low expansion qualities, are especially adapted to the production of dimensionally stable models. These plasters are further characterized by a surface hardness 2 to 4 times greater than ordinary plasters, a quality necessary for withstanding the wear and tear of the reproduction run. Because the plaster after the initial set increases in temperature, casting into molds made from media affected by heat is not recommended.

(2) Before carving the terrain base, 2 plaster casting operations are necessary. These are the step negative and step positive. In preparing any mold for casting there are several preparatory procedures necessary. The mold is clamped onto a marble-topped casting table equipped with an electric vibrator and, with the exception of the plastic laminate base, is sealed with a thin layer of shellac. Side rails are then affixed around the mold for containing the plaster and the cracks between the two are sealed with modeling clay. The flowline is clayed in to the proper width. Plaster re-

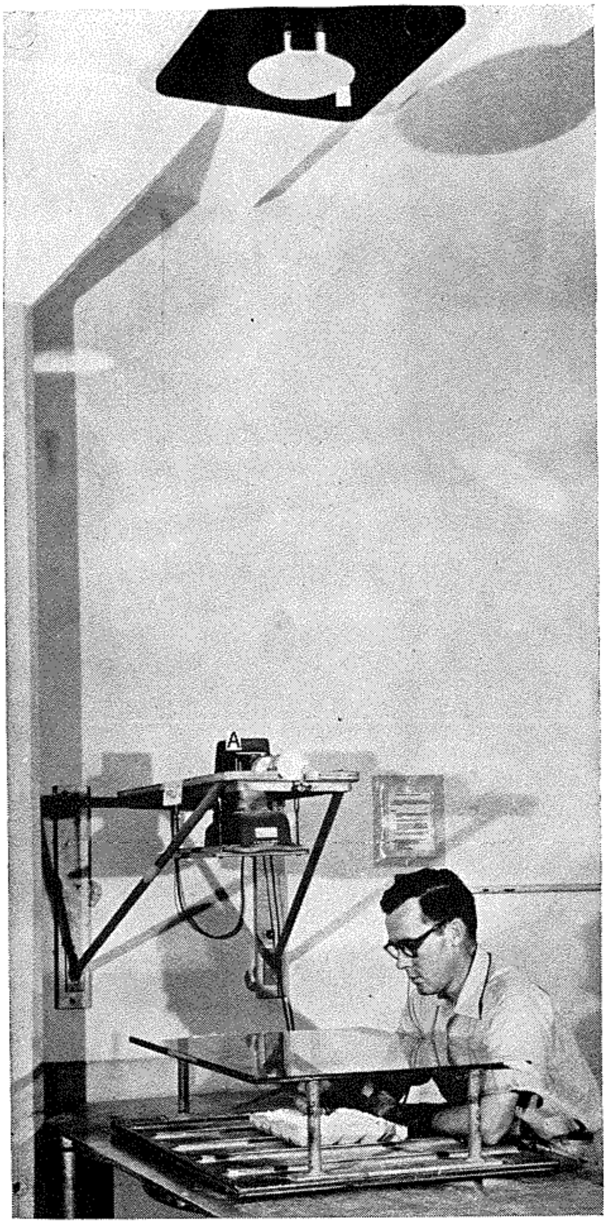


Figure 20. Checking landforms of model through the composite glass checking positive under the shadow projector.

lease is brushed onto the mold and side rails, and a final coating of a detergent or mold dressing is added to relieve surface tension and reduce the formation of blowholes. The Hydrocal B-11 is mixed distilled water in a 2:1 ratio, allowed to soak undisturbed for 2 minutes, and then stirred in a mechanical mixer for 1 minute. If Densite K-12 or K-13 are used, they are mixed at a ratio of 36 and 40 pounds of plaster to 100 pounds of water, respectively. With the table under constant vibration, the plaster is poured slowly over a cast or into a mold, beginning at the corner where there is the least topography (fig. 21). When the plaster is about ½ inch from the top of the rails the pouring is discontinued; 3 sheets of 5-ounce burlap or 1 sheet of ⅛- to ¼-inch hardware cloth are inserted for reinforcement, and the pouring is continued to the proper depth. Procedures applying to each particular stage will be described as that stage is reached.

(3) In casting the negative step mold from the original base, outside dimensions are not important so long as a protion of the datum plane appears on all 4 sides. In this case, the plaster will be poured to a depth of ½ to ¾ inch over the highest peaks. After cooling to room temperature, approximately 2 hours, the negative mold is removed and alined with the composite glass plate under the shadow projector to check the horizontal accuracy. All step edges extending beyond the projected contour line image are carved back to agree with the image. Step edges falling short of the image are corrected in the step positive.

(4) In casting the positive step cast from the negative, the outside dimensions are still unimportant although care is taken to include some datum surface on all 4 sides. One important factor to note at this stage is to pour the plaster to a depth of 1 inch above the datum plane, if the model was cut in sections, to provide a common model base for marrying of sections (par. 37*f*). After setting for 1 hour the step cast is removed from the mold and alined with the composite glass plate under the shadow projector. In the positive, the projected contour line must coincide with the

Figure 21. Pouring plaster over mold.

base of the step. Where it does not, the step is carved back the required amount. At this point the major drainage pattern and such relief symbols as will serve as a guide in landform interpretation in the carving stage are delineated on the surface of the step cast.

e. Carving. Preparatory to carving, the step positive is coated with an ocher dye, a mixture of ocher pigment and alcohol. As each plaster step is carved away, a thin line of the ocher is retained at the base to represent the contour and so serve as a guide in editing the model (fig. 22). In developing the model surface, the most expedient procedure is to establish the stream gradients before attempting to develop the valley slopes, peaks, and ridges. The carver locates the lowest valley point on the model and, by cutting away the plaster toward the next highest contour, develops the river gradient along the delineated course. Each cut takes away less materials until, at the intersection of the river and the base of the next step, there exists a fine ocher line. With the entire drainage system completed in this manner, the carver proceeds, working from the established gradient and from the lowest contour to the highest, to develop the terrain of the model. Care should be taken to carve the slopes smoothly and avoid a scooped out or humped appearance between the contours. Crest lines and peaks, not clearly defined by drainage or spot heights, should be carved to conform to the slope of the ridges. Accuracy can be obtained only by skillful handwork and careful interpretation of the landforms as represented on the flat map.

f. Marriage of Sections.

(1) If the model has been constructed in two or more sections, these sections must be joined or married into one panel before further work can be performed toward reproducing the original. When the model is constructed as a whole from the beginning, this phase is omitted.

(2) The sections are trimmed along the marriage line which was scored in the cutting operation, and a 45° bevel is cut approximately ½ inch below the topography along the marriage edges to provide a channel for pouring plaster. Notches are chipped at inter-

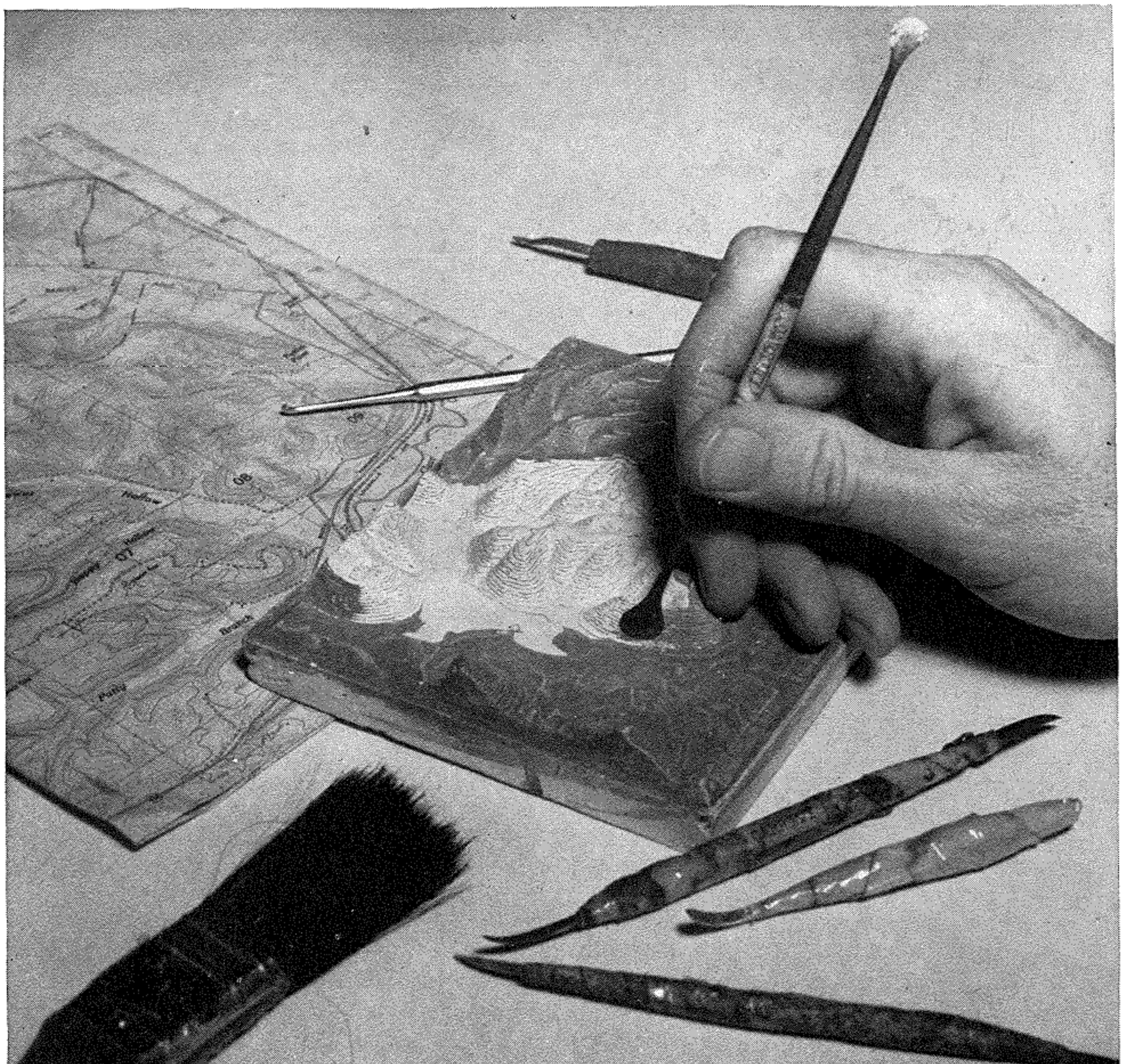


Figure 22. Development of model surface by hand carving.

vals around all 4 sides of each section to insure secure locking of the sections when joined. The edges and bottoms are shellacked, the sections placed together on 1 board, and a level datum established. Here the importance of the 1-inch thickness beyond datum specified in casting the step positive (par. 37*d*(4)) can be seen. Should a discrepancy between the datum planes be noticed, however, corrective action is taken by shimming the lower section to the proper height. A wooden frame ½-inch high is affixed around the assembly to contain the plaster.

(3) Before the plaster is poured to join the sections, the assembled model is placed under the shadow projector to assure proper alinement of the entire model with the composite glass plate. The plaster is poured to the ½-inch level of the frame and allowed to set. The plaster for the remainder of the marriage line is applied with a brush or eyedropper to the proper level and the terrain tied across. Final blending of this strip is accomplished in the negative.

(4) Further carving is performed with the model alined under the shadow projector to acquire further accuracy of landforms. Where the projected contour line does not coincide with the ocher line left in carving, correction may be made by carving away excess material. If the error is caused by overcarving, the area can be built up by adding plaster or can be corrected in the negative.

38. Reproduction

a. Library Mold

(1) The reproduction of the original model for forming over a positive mold is achieved in 2 plaster casting operations. The first of these, termed the library negative mold, results from casting over the original model and serves as the basic source for casting the reproduction positive. The library negative is also retained in file for making new reproduction positives, should they deteriorate during the plastic forming, or positive reproductions for special uses such as model photography. The mold is cast as previously explained, the thickness being ½ to ¾ inch above the highest point of the original model. The mold is given a final check under the shadow projector to complete all corrections considered too difficult to perform on the original model. The entire neatline is reinscribed at this stage so it will appear in all subsequent castings. This is important for the following reasons:

(*a*) To facilitate cutting of plaster models in order to mosaic for special formats.

(*b*) To provide a raised line in the reproduction positive to serve as a guide in the control of plastic stretch during forming. This stretch is critical at the neatline, because of the depth of draw to datum and up to the framing wall. The raised neatline is deleted before forming the sheet.

(2) Heretofore the overall size of the model has not been important; it has been necessary only to include the flowline and a portion of the datum surface beyond the neatline limits. Before the reproduction positive can be produced, however, it is necessary that the negative be "brought to size," or that the flat datum plane be extended to accommodate the size of the plastic sheet and so fit within the vacuum box over which the map is formed. Since a 24- by 36-inch sheet is most commonly used, these measurements are used in describing this step. The inside dimensions of the vacuum box are 22 by 34 inches; the margins of the mold are extended to 21¾ by 33¾ inches to allow for later fine adjustments in obtaining proper register. The edges are shellacked and nails set in to insure a firm bond. Since the neatline is sometimes printed off center, a plastic press proof is

used as a guide to obtain proper positioning of the neatline limits within the extended mold. One and one-eighth inches are trimmed from each edge of the sheet and the intersecting corners of the neatline cut out. The sheet is placed on the mold, face down, and registered to the inscribed neatline of the mold through the cutout corners. Side rails are placed around the mold to the size of the sheet and plaster poured within the limits of the rails.

b. Reproduction Positive.

(1) The second and final casting, made from the above mold, is termed the reproduction positive and is the model used for forming the plastic maps. In casting, the plaster is poured to a minimum depth of 1 inch and a maximum of 1¼ inches above the datum plane. One sheet of ¼-inch or ½-inch wire screen is inserted for reinforcement. It is imperative that the cast be perfectly level to prevent breakage when mounted and clamped within the vacuum box. This cast must be thoroughly dried in a low temperature (125° to 150° F.) oven; if an oven is lacking, the mold should be cast 6 to 7 days before used.

(2) Before the production positive is mounted on the forming machine, it is drilled through with several hundred minute holes by means of a radial drill press using a No. 60 drill (fig. 23). The holes are for evacuation of air from beneath the plastic sheet so that atmospheric pressure may be effective in pressing the plastic sheet against the mold surface. They are placed in all valleys and low areas since these are the last features formed, thereby making the holes effective for the longest possible times.

c. Forming.

(1) Figure 24 shows one type of machine used for forming plastic relief maps. It consists of a radiant heater (A), which is mounted on an overhead track and can be pulled alternately over the 2 mold tables (B). The mold is inclosed in a vacuum box frame (C), designed to hold its own vacuum unit. The floor of the box is an aluminum plate which supports the mold and whose waffle design permits rapid evacuation of air from beneath the plastic sheet through the holes in the mold. Insurance against leakage is gained by placing the assembly upon a rubber mat. An opening in the side of the box is connected to a vacuum pump or surge tank. The table supporting the vacuum box assembly is a die-lift scissor type which, when raised, presses the box, supporting the plastic sheet, tightly against a clamping frame (D). Stripes of rubber ¼-inch thick, glued to the bottom of the clamping frame and the top of the vacuum box, provide greater flexibility and more equalized pressure when the edges of the plastic sheet are gripped.

(2) In mounting the vacuum box unit upon the table, the mold is positioned so that the more rugged terrain is toward the heater, where it will be subjected to a second or two more of heat, and the hightest peaks extend slightly above the side walls. If necessary, the model may be raised within the frame by inserting plywood of proper thickness under the waffle board. In the case of a model with extremely high terrain on one side and low on the other, the mold may be tilted in the box by placing tapered layers of plywood under the waffle board. This procedure, by bringing the low terrain closer to the top of the box, subjects the heated sheet to a lesser degree of stretch and thus permits closer register. The mold is secured lightly within the box frame by means of 6 padded clamps located in the sides of the frame. In this position the cast is thoroughly warmed, a lay sheet is clamped over it under partial vacuum, and the heater placed over it for 10 seconds at which time full vacuum is applied. Under full vacuum the clamps are tightened to

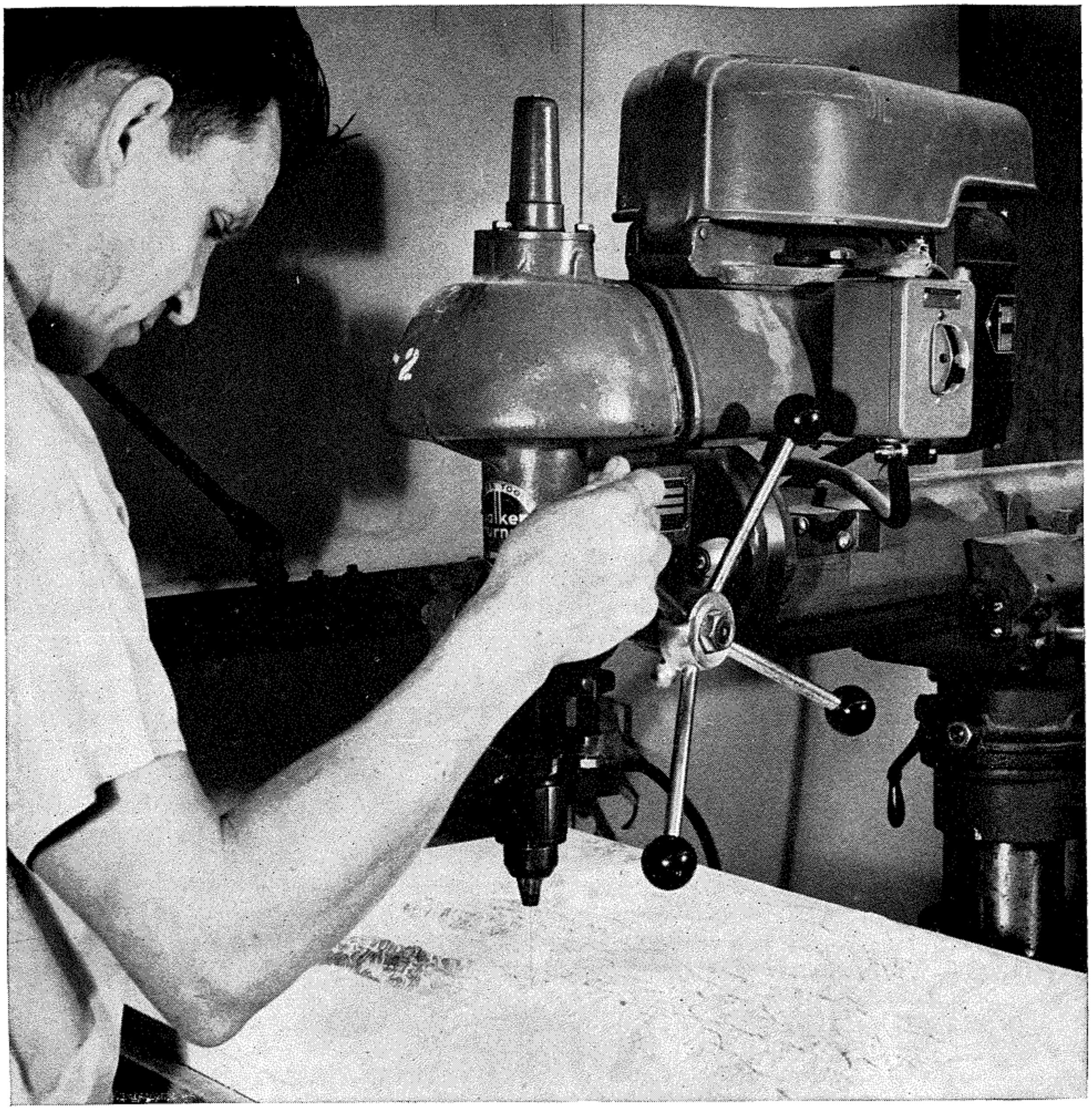


Figure 23. Drilling vacuum holes in the reproduction positive mold.

prevent the mold from slipping. The space between the positive and the frame is sealed with tape to direct the evacuation of air through the holes in the mold and so prevent too great a pull on the sheet in the marginal area. A final check is made for leakage of air. Before register trials are begun the flowlines are carved on all edges to conform to the landforms of the adjoining formed plastic sheets.

(3) In the printing operation, grippers on 1 long edge aline the sheet squarely along that edge and position 1 short edge against guides so the neatline limits will appear in the same position on each sheet. In the forming operation, 3 register screws are attached to the top of the vacuum box frame, in a position relative to these grippers and guides, 2 on the long edge and 1 on the short. These screws

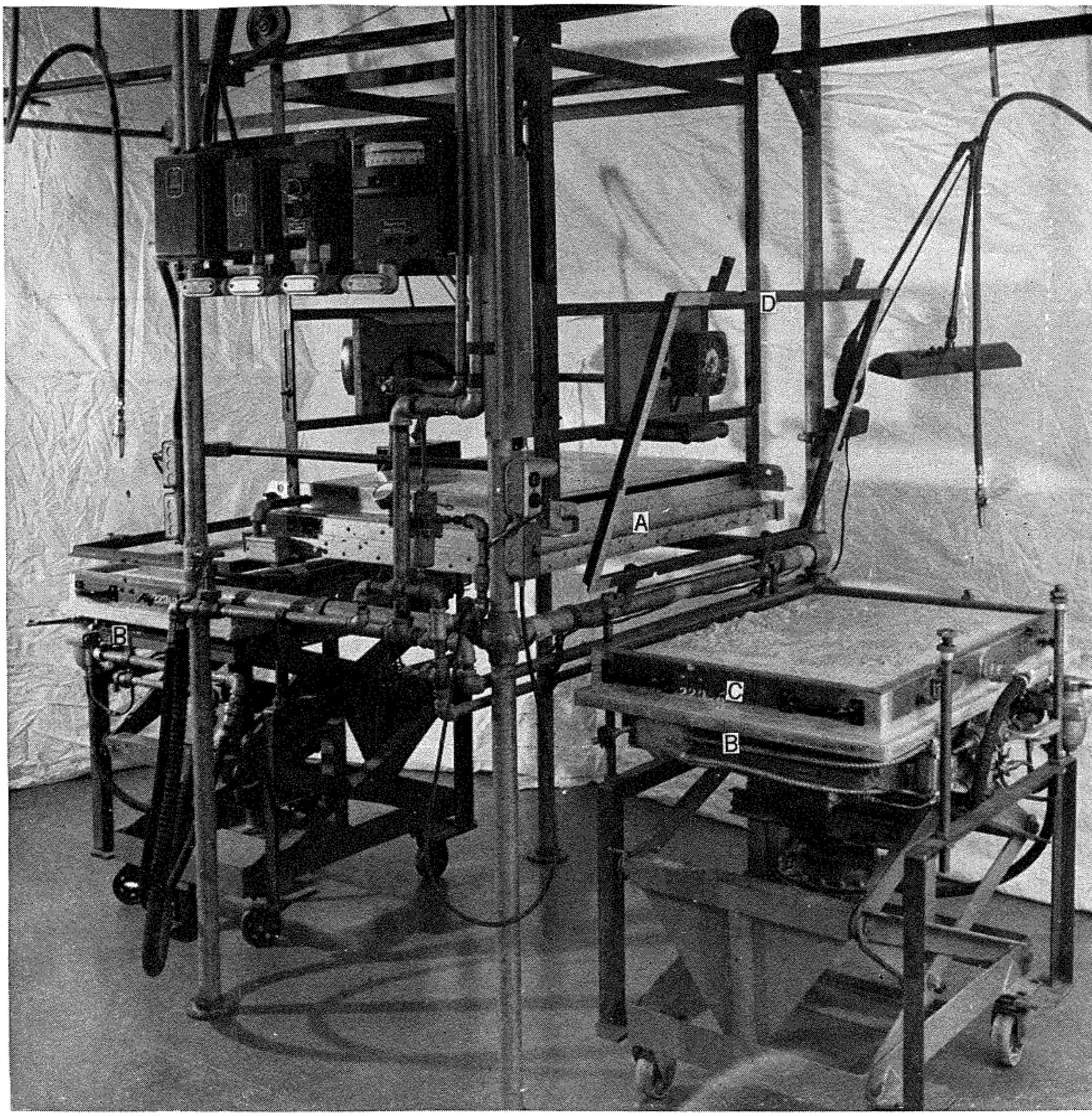


Figure 24. Vacuum forming equipment.

serve as guides for alinement of the neatline limits of the map with those of the mold. To obtain the first setting of the screws, a measurement is taken from the neatline to the edge of the sheet and the screws set to correspond to this measurement. Another method is to cut the highest peaks from the sheet, place the sheet over the mold matching the cut out areas with the landforms, and set the register screws according to the location of the sheet. Neither method will give perfect register the first time.

(4) Obtaining proper register is mainly an empirical procedure due to the expansion and contraction tendencies of the plastic sheet. This problem is overcome in large part by creating a

partial vacuum beneath the sheet at the instant of clamping. As the sheet reaches its softening point and starts to stretch, the light draw holds the sheet in register against the major peaks and crest lines until the forming temperature is reached. At this point full and instant vacuum is applied which completely forms the sheet over the landforms of the mold. The degree of partial vacuum and the length of the heating cycle will vary with each model depending upon the type of terrain, and only by trial runs will the proper combination of the two be determined. For the first test an average 4 to 5 inches of mercury and heat cycle of 8 to 10 seconds may be used and adjusted as necessary to accommodate the register. When the best possible overall register is obtained, the register screws are locked in place. If, during the register trials, it is noted that the contour lines are falling consistently to one side, slight adjustment of the register screws may correct the fault. Wrinkles in the formed sheet usually signify too little partial vacuum, too long a heating cycle, or both; if caused by abrupt changes in topography screening of the area may be required. Misregister or breakthrough of peaks may be caused by two strong a partical vacuum, too short a heating cycle, or both. If misregister should occur in isolated areas, landforms of the mold may be altered slightly by either undercarving or building up a portion in plaster. For this building-up process, Savogran is mixed with water to a heavy consistency, and a very small amount of white plastic glue added to the mixture. Small amounts should be mixed at one time because of the rapid thickening property of the plastic glue.

(5) One final preparation is made before the final forming is begun. To supplement the surface hardness of the mold and so prevent excessive deterioration during forming, and to provide added protection against moisture, the mold surface is given a coating of a rubber base compound. One formula recommended is a mixture of 9 parts of Paracoat with 1 part catalyst (10% solution of sulphuric acid). After mixing thoroughly dilute with 3 parts Methyl Ethyl Ketone. The mixture should be applied after the mold is thoroughly heated and dried, with heat being applied from 10 to 15 minutes.

(6) In the reproduction run, each sheet is alined against the register screws and clamped. At the instant of clamping the partial vacuum is created and the heater drawn over the sheet for the predetermined lenth of time. Upon completion of the time cycle, full vacuum is created, completely forming the softened sheet over the landforms of the reproduction positive, and the heater is removed. Full vacuum is maintained until the sheet has been cooled below its forming temperature. This is accomplished by directing several blasts of compressed air to the surface of the sheet. The sheet is then unclamped, breaking the vacuum seal, and removed from the mold. Applying compressed air between the sheet and the mold will help release the sheet. The average time in the production cycle, from the placement of the sheet until its removal, is approximately 2 minutes. During the run a constant check is made for changes occurring in register, wrinkles or holes suddenly appearing, and damage to the mold. At the completion, the formed sheets are trimmed to size, stacked, and counted.

(7) Reproducing the original model by vacuum forming of preprinted plastic sheets can be done by two methods. The sheet can be formed over a position mold which is a duplicate of the original model, or it can be formed into a negative mold which is the reverse of the original. Neither meth-

od will give perfect register because of the limitations of the plastic material; therefore, the selection of method is dependent upon the results desired in the end product. In either method the stretch of the heated materail occurs in the unsupported portions of the sheet, that is, those portions not in contact with any part of the mold surface. Consequently, those areas formed first in the production cycle will be strongest, those formed last, characterized by thinning. Preprinted information will react accordingly, remaining true in the areas of little stretch and becoming illegible in the thinnest parts.

(8) The relief map is a product produced as a supplement to the conventional paper map and used in general for planning and briefing purposes. Therefore, the peaks, ridges, and major drains are of the greatest importance to the users. In positive forming, the peaks and ridges of the mold are the first in contact with the sheet and are formed earliest in the cycle. Consequently, they are the strongest portion of the map and are in best register because of little material stretch. So far as the contact is limited to these areas with the major portions of the sheet unsupported, the stretch is distributed more uniformly throughout the sheet, precluding excessive thinning and providing better register. Conversely, in negative forming the lowlands are the first features in contact with the sheet, hence are strongest and in best register; the peaks and ridges are the last features formed, material is available for stretching and they end up tissue thin or broken, incompletely formed, and illegible. From this it can be seen that negative forming should be limited to areas of low relief.

(9) Excessive thinning and distortion of major valleys due to abrupt changes in relief can be controlled in positive forming by full or partial masking of the valley floors. This technique will limit the heating, and consequently the stretch, of these selected portions, and force the distortion into the valley walls which are of lesser importance. This is practical since the majority of valleys are continuous over a fairly extensive area and one mask may be cut for an entire sheet.

(10) It is possible but impractical to mask a sheet for negative forming because each peak must be masked individually, a time-consuming process; and with the printing on the face of the sheet toward the mold, proper orientation of the masks is difficult. Positive forming, therefore, is recommended because of the accuracy and material fidelity of the end product and the fact that this method lends itself more readily to varied topography. A final factor, never to be overlooked in production, is the psychological ease of working with right reading copy.

39. Tolerances

If the original model is accurate and size is maintained throughout casting of the molds, 90 percent of all points on an average model should fall within $\pm$ 0.02 inch of correct position as shown on the basic source material.

CHAPTER 8
MOLDED AERIAL PHOTOGRAPHS

40. Cutting Guides

If topographic maps of an area are available, contours for model construction can be obtained by enlarging or reducing such sources to the scale of the photographs. The contours are then traced onto transparent material such as acetate or vinyl. If contour information is not available, form lines may be traced on an overlay using a stereoscope and stereo pairs of photographs. Since most aerial photographic scales used for reconnaissance are larger than 1:25,000, it is recommended that there be no exaggeration of the vertical scale of the model in relation to the horizontal. Exaggeration of vertical scales of large-scale models (1:2,000 to 1:25,000) falsifies the relief to such an extent as to make orientation in the field difficult. The terrian base is prepared and cut as described in paragraph 37 *a* and *b*, with the contour overlay used as the cutting guide instead of the zinc plate. Cutting of the base may be accomplished by use of the cutawl or jigsaw.

41. Photo Overprint

A second contour base, identical to the cutting guide, is prepared for overprinting the aerial photograph. Onto this base other desired information, such as spot heights, military symbols, and military intelligence information, is annotated (fig. 25). These annotations should be kept to a minimum to avoid obliterating the photo detail. The annotated base is registered with the negative of the aerial print and a composite negative of the two is prepared photographically.

42. Marginal Data Drawing

The marginal data drawing shows such information as the horizontal and vertical scales of the photograph, vertical exaggeration if any, contour interval, north arrow, and any other pertinent information. This information may be added to the photo overprint as shown in figure 26.

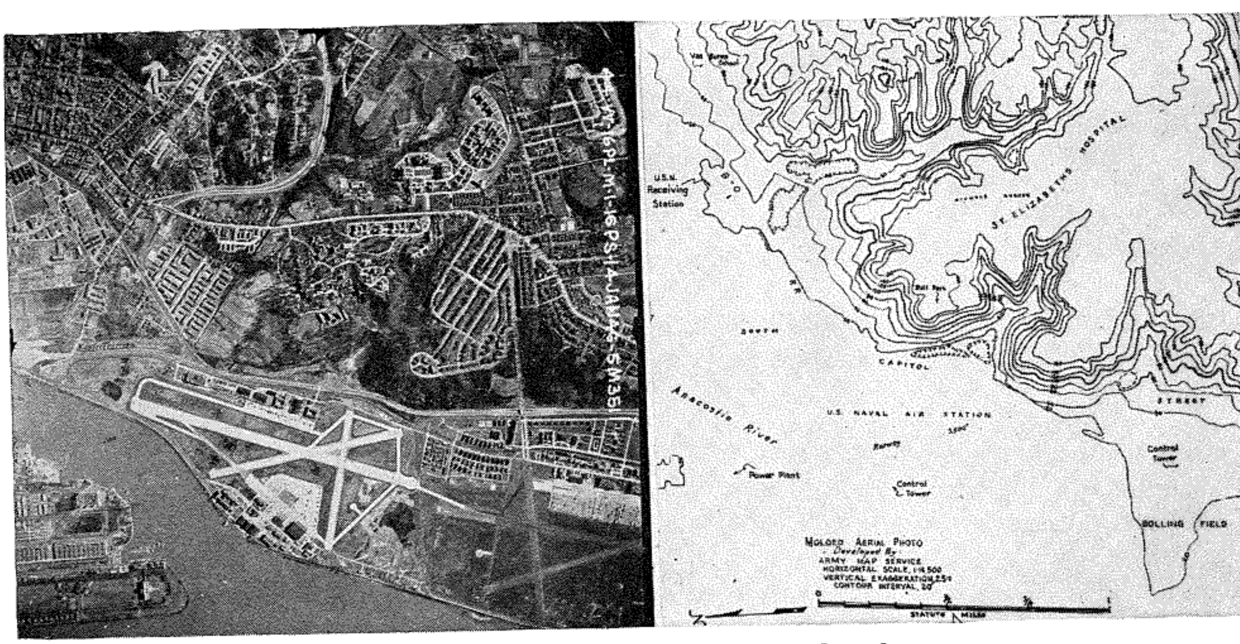


Figure 25. Aerial photograph and annotated overlay.

43. Rectification

If excessive errors due to tip and tilt are inherent in the prints, rectification of the photographs, if print rectifiers are available, should be done prior to contour compiling.

44. Reproduction

a. Ammonia Process. First, a negative is made from the rectified aerial photograph. The desired cultural and military annotations are drafted on a transparent overlay with black India ink. The aerial negative and the annotated overlay are registered and a composite continuous tone or 300-line halftone wrong-reading positive is produced. For the continuous tone, commercial Ortho Film is used; for the halftone, Photo Mechanical Film. The aerial positive can be processed by a map reproduction unit. Diazo coated plastic material can be obtained commercially for this process. The sensitized plastic is exposed in a vacuum frame with the emulsion side of the plastic in contact with the emulsion side of the positive. Exposure should be made with a carbon arc or high intensity ultraviolet light. It is not recommended that the exposure be made in the ammonia vapor machine. The plastic print is then developed in an ammonia vapor machine at a temperature not to exceed 100° F. It should be noted that the shelf life of the diazo coated material is only 3 to 6 months. In addition, diazo images may fade rapidly in sunlight.

b. Photomechanical Method. Although the ammonia process is more rapid, the photomechanical method may be used in the absence of an ammonia vapor machine. This process, known as the gum-reversal process is accomplished in the following steps:

(1) After being scoured in pumice powder and water to remove grease, the opaque white calendered vinyl is coated with a deep etch plate coating (bichromated gum).

(2) It is exposed to a halftone positive in a vacuum frame.

(3) It is developed with a deep etch developer in order to remove all the unexposed bichromated gum. Following development, the excess developer is removed.

(4) The image is formed by applying a black dye composed of a mixture of oil-soluble dyes, which contains a vinyl solvent. The following formulae are used in preparing the dye and the solvent:

(*a*)	Sudan yellow	0.90 grams
	Dupont blue	1.30 grams
	Dupont red	0.65 grams
(*b*)	Toluene	60 mls
	Methyl isobutyl Ketone	50 mls
	Varsol	30 mls

The black dye is dissolved in the solvent and stirred with an electric mixer. After a visible image is formed, the dye is allowed to dry. Surplus dye should be removed by an additional application of developer.

(5) The deep etch stencil is removed by scrubbing with a medium-hard brush in warm water. The temperature of the water should not exceed 100° F. or a permanent distortion of the vinylite is likely to occur. The end result is a halftone print, possessing a very durable image, on opaque white calendered stock, which is not affected by heat in forming.

c. Large Quantity Runs. If a large quantity of photos is needed, they may be reproduced by ordinary photolithographic halftone methods. The thickness of the plastic should be comparable to the capability of the press. Several images may be processed on a press plate for rotary presses for very rapid quantity production of halftone prints.

45. Forming

Forming is accomplished as described in paragraph 38.

CHAPTER 9
MISCELLANEOUS

46. Trimming

The excess plastic is trimmed from the relief map by the use of paper cutters or heavy shears, the point of trimming being near the junction of the datum plane and the framing wall as shown in figure 16. One copy of a particular map is trimmed and taped to the cutting table to serve as the trim guide. The untrimmed copies are nested on top of this guide, one at a time, and each edge trimmed. Figure 26 shows a comparison between a trimmed and an untrimmed sheet.

47. Grommets

Metal grommets may be mechanically inserted after trimming, for ease in hanging (fig. 27).

48. Mosaicking

a. Plastic relief maps are so designed and prepared that they may be easily mosaicked to produce a continuous panel of adjoining sheets. This is accomplished by trimming the north and west edges at the neatline end positioning these edges over the south and east edges of adjoining sheets. In most instances the sheets carry notes in the north and west margins, reading "TO MOSAIC, CUT ALONG THIS NEATLINE AND OVERLAP ADJACENT MARGIN". The trimming may be done with a pocket knife or shears. If the mosaic is to be hung on a wall, the plastic sheets are mounted on a

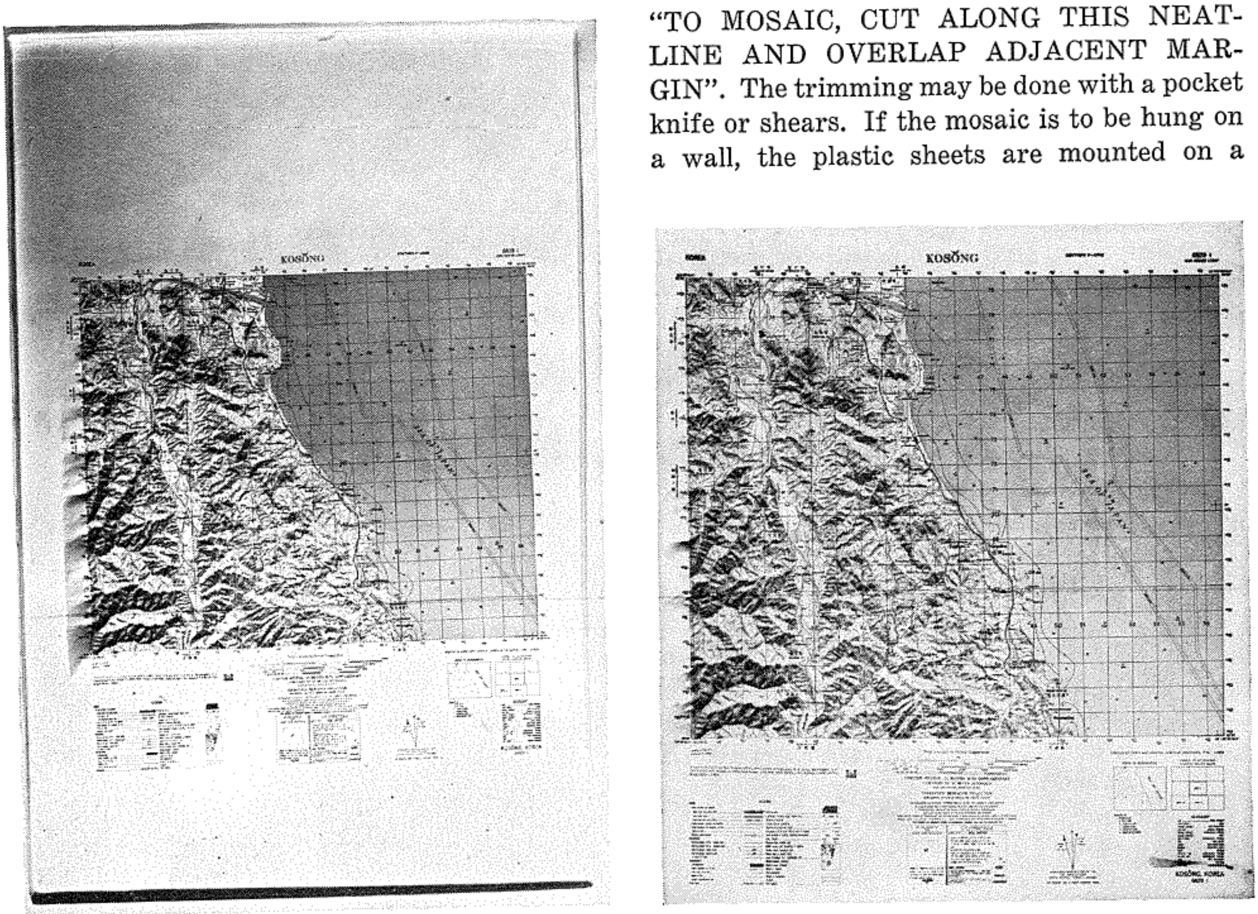


Figure 26. Plastic relief map before and after trimming.

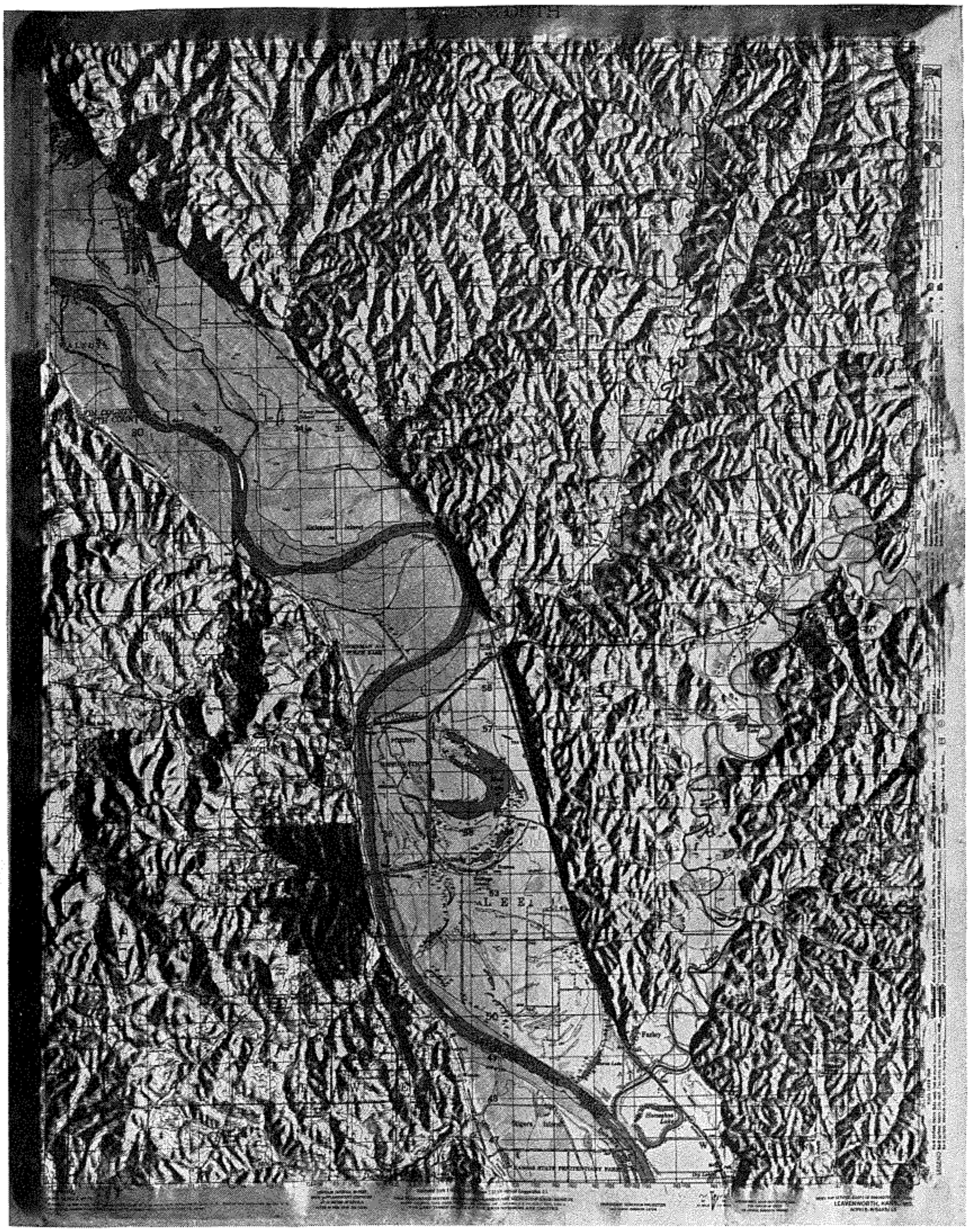


Figure 27. Plastic relief map with metal grommets inserted for ease in hanging.

rigid background such as wallboard or plywood using tacks, brads, or gun staples for fasteners.

b. In positioning maps on the mounting board, the convergence of the east and west neatlines and the curvature of the north and south neatlines should be taken into consideration, particularly in the smaller scale series. Maps should be trimmed and laid out in order to determine the size of the mounting board. Outside edges of the perimeter sheets of the mosaic should not be trimmed. A central line is plotted on the board perpendicular to the south edge. The central meridian of the mosaic is positioned along this line and the north band of

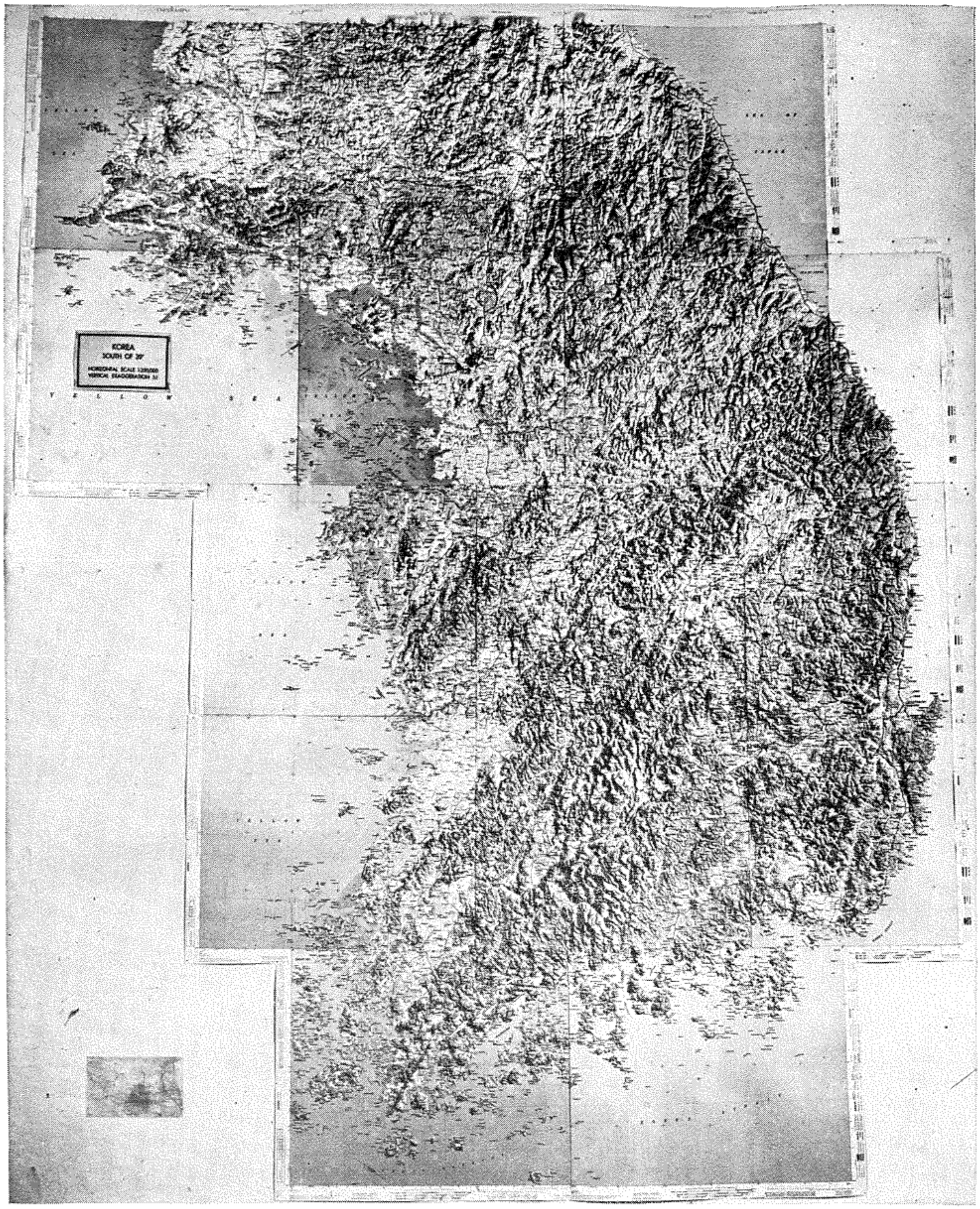


Figure 28. Wall mosaic of plastic relief maps at 1:250,000 scale.

maps positioned westward. The extreme northwest sheet is then stapled to the board. The sheets east of this sheet are then positioned and stapled to the board in consecutive order. Small-headed brads are used along junction lines to prevent gaps. When the entire top row is completed, the western sheet of the second band is positioned and the remaining sheets affixed in the same manner. A more pleasing appearance of the mosaic results when the outside edges of the entire mosaic are trimmed parallel to the neatline on all edges. Care should be exercised to establish trim line so that it falls outside the flowline (area sloping from neatline to datum plane). Excess or duplicate border data may be elected by scratching off with a razor blade. Figure 28 shows a completed mosaic.

49. Packing and Shipping

a. Plastic relief maps which are to be shipped locally or for domestic users shall be packed in standard fiberboard containers with sheets of creped cellulose wadding inserted between different relief maps. It is not necessary to use any packing material between identical plastic relief maps. The fiberboard containers are bound with a Scotch filament tape No. 880 or equivalent, or with metal strapping.

b. Oversea shipment of plastic relief maps requires more detailed packing precautions. The relief maps are packed in wooden containers with layers of creped cellulose wadding being inserted between relief maps of different areas. For convenience in handling, the wooden crates are limited to 200 pounds or less.

c. Whether the shipment is a local one or for oversea users, labels are prominently affixed to each container indicating that the contents are: FRAGILE—DO NOT CRUSH.

APPENDIX I
REFERENCES

FM 21–26, Map Reading.
FM 21–30, Military Symbols.
FM 21–31, Topographic Symbols.
TM 5–230, General Drafting.
TM 5–240, A Guide to the Compilation and Revision of Maps.
ACIC Technical Report No. 67.

APPENDIX II
THE GSR[2] MODEL
Graphically Simulated Relief

1. General

a. The GSR Model provides a means of depicting areas and objects, at predetermined scale, graphically and in three dimensions, by use of an assembly comprised of a number of layers of transparent plastic sheeting.

b. A typical "Model" has the superficial appearance of a solid block of transparent plastic within which the features of an area or structure appear to be suspended, each in its proper horizontal and vertical position (fig. 29). Actually, the "block" is made up of a number of layers, or sheets, held firmly together. Each sheet represents a predetermined height or altitude, and the various features are pictured or symbolized on the surfaces of the sheets, according to their elevation. When the plastic layer represent ground levels, natural features such as hills, valleys, ravines and descending drainage can be portrayed in realistic relief. When a structure is represented, cross-sections of the structure are repeated on consecutive layers until it is "built up" to its relative height and/or typical appearance. The concept does not require that the plastic layers be in contact with each other. They may be separated by spaces, and this may be a preferred arrangement for some purposes.

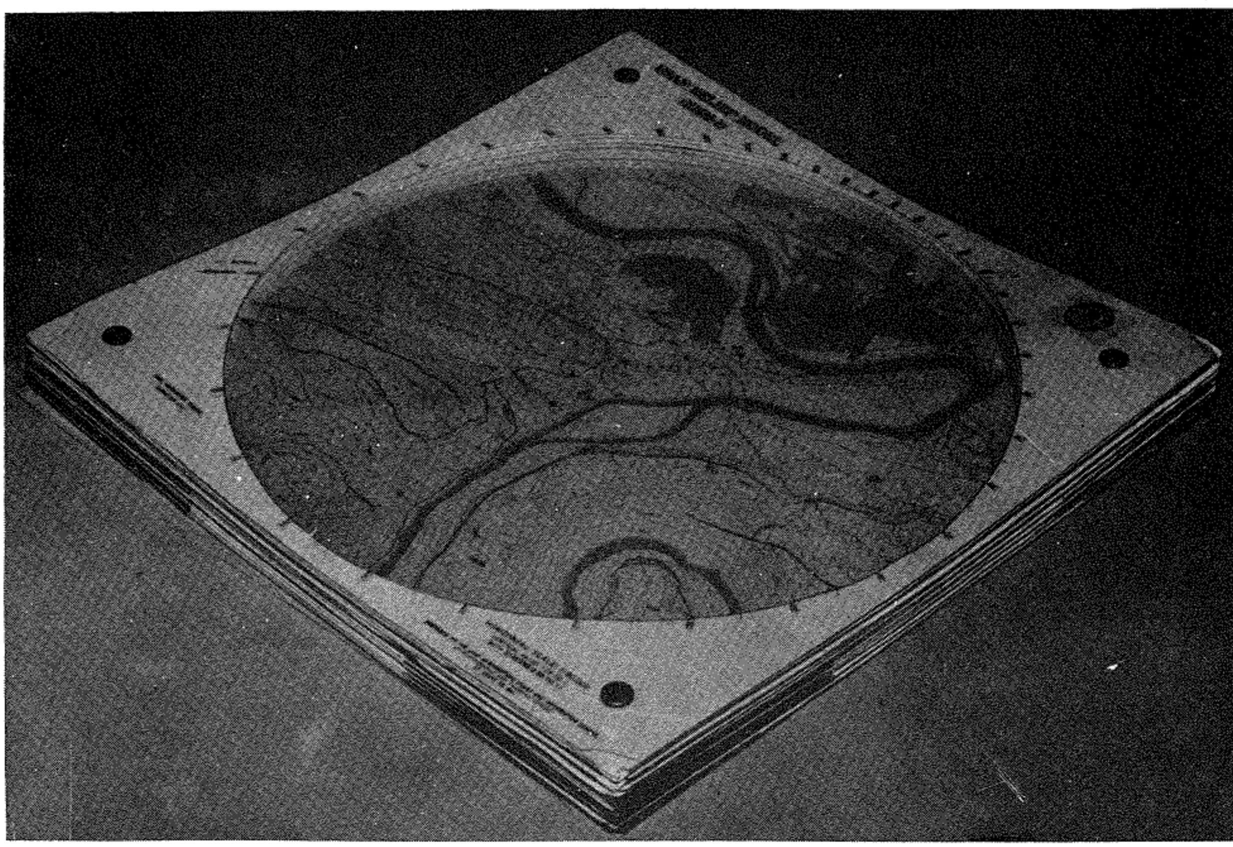


Figure 29. Typical finished Model.

[2] This information has been taken from ACIC Technical Report No. 67 THE GSR MODEL prepared in May 1955.

2. Scale and Size Relationships

Inasmuch as the GSR Model portrays both vertical and horizontal dimensions, consideration must be given to scale in both of these directions.

a. Horizontal Scale. Horizontal scale offers no special considerations not paralleled by normal map construction. The planimetric dimensions of a Model are readily determined by the extent of ground area to be portrayed and the scale at which it is desired to represent it. The actual sheet sizes must be somewhat larger than the area to be represented to allow for border and binding.

b. Vertical Scale.

(1) Vertical scale is directly related to the thickness of the sheets used to build the Model, and the spaces, if any, between sheets of the assembly. For example, each sheet may be made to represent a single contour interval, a predetermined number of feet or yards of height, one story of a building, or a single cross-section of a structure. The most satisfactory material so far tested (Plexiglas) is available in a standard thickness (0.06 inch) which lends itself to the representation of certain common scale relationships, as indicated by the following table (based on sheet thickness of 0.06 inch):

Horizontal Scale	*Contour Interval*	*Vertical Ratio*
1:25,000	62½ feet	2 to 1
1:25,000	125 "	1 to 1
1:50,000	100 "	2½ to 1
1:50,000	250 "	1 to 1
1:100,000	100 "	5 to 1
1:100,000	250 "	2 to 1

(2) The number of sheets required for any given Model depends on the interval selected and the range between the lowest and highest point of the area or structure being portrayed. That is, there will normally be one sheet for each interval, plus one for detail below the lowest interval, and an extra sheet on the top for protection. For example, if the lowest elevation of the area is 537 feet, while the highest is 1,123 feet, and the contour interval selected is 100 feet, then eight (8) sheets of plastic will be needed; one for the detail which lies below 600 feet; one each for the 600 to 700; 700 to 800; 800 to 900; 900 to 1,000; 1,000 to 1,100; and the 1,100 and over, intervals; and a top cover sheet. At 1:50,000 scale, this example gives a vertical scale ratio of 2½ to 1; that is, features appear 2½ times their true scale height. When thicker or thinner sheets are used, the vertical scale will vary accordingly. The use of 0.12-inch sheets, in the example above, would have produced a vertical scale of five to one. In addition, the sheets may be separated by uniform spaces for purpose of increasing the vertical scale exaggeration, or to produce special effects.

3. Materials and Equipment

a. Sheet Plastic. Plexiglas is recommended, primarily on the basis of clarity. Other transparent plastics can be used, but many types tend to lose clarity when a number of surfaces are placed in contact with each other as must be done in the assembled unit. This loss of clarity can be compensated for, at least partly, by back-lighting the unit. As previously mentioned, the standard 0.06-inch material is suitable thickness for use in portraying areas, at certain scales. The plastic must be perfectly clean, and great care must be exercised not to mar the surface, as any soiling or roughening drastically affects the clarity of the finished Model. The protective paper covering should not be removed until actual drafting is started.

b. Binding. Posts, extending through holes in the assembly, are the most commonly used and simplest means of binding it together. These may be placed, one in each of the four corners, if a rectangular assembly is being made, or at whatever locations are most effective, for other shapes. "Binder posts," of the type used to fasten the covers of loose-leaf ledgers and the like, are recommended. Other means of binding the assembly together may be used, such as bolts, screws, or clamps.

c. Drawing Mediums.

(1) Colored ink is the most effective medium for line work. Inks which do not

etch the surface are preferable in most cases, since they can be removed with a minimum of damage in the event that revision, or complete re-use of the plastic, is expected. "Foster-ite" drawing inks have been employed successfully. India ink is unsatisfactory, as it tends to chip on this surface, although it can be used. Other drawing mediums include grease pencil and crayon. These will be found of value in situations where the refinements of ink drafting are not required, when time is limited, or where personnel are unskilled in handling the formal drafting instruments.

(2) Prepared "stick-up" symbols, in the form of thin transparent sheets bearing printed images of the features to be depicted, and coated on the back with a wax adhesive, are of considerable assistance. These provide uniform representation, save time over drawing individual symbols by hand, and have better appearance than unskilled hand work. The desired symbol is cut out of the sheet on which it is printed, and pressed down upon the surface of the plastic sheet in its proper position. The wax adhesive holdes it firmly in place. Printed symbols may be obtained for a variety of features, such as marsh, orchard, sand area, various kinds of forest, mud flats, scattered buildings, and cross-hatching and other mechanical patterns, as well as type for names and descriptive notes. The use of tinted symbols of this kind will enhance the appearance and clarity of the model.

d. Tools.

(1) *Drill and Drill Points.* A hand drill may be used. However, if more than a few Models are to be produced, a power drill is more effective. A No. 12 twist drill is the proper size for standard binder posts mentioned above. To reduce danger of chipping the plastic, the drill point should be sharpened for plastics drilling, by grinding the point to a sharper angle of penetration.

(2) *Knife and Straight-Edge.* The use of knife and straight-edge for scoring Plexiglas is illustrated in figures 2 and 3. Knife is needed also for cutting out printed symbols.

(3) *Drawing Instruments and Pens.* Standard drafting sets and quill pens are adequate. Triangles, scales and the like should also be available.

4. Construction Steps

a. Source Material. The most convenient method of obtaining detail is to trace it from an existing chart or map of the same scale as that selected for the Model. This is accomplished by placing the individual sheets of the Model, one after another, over the source chart, and tracing off all the desired features which lie in the elevation range represented by each individual plastic sheet. However, a single chart containing all the types of features desired may not be available. In this case, it is advantangeous to first combine the desired data from several sources on a separate sheet, or "compilation", at the same scale as the Model, and trace from this. If the source chart, or the compilation, happens to be at a scale different from that selected for the Model, tracing may be performed over a photographic or mechanical reduction or enlargement of the source.

b. Preparing the Plastic.

(1) Once the physical dimensions have been decided, the required number of plastic sheets are cut to size. The plastic is scored, not cut through, with a knife, or other sharp object,

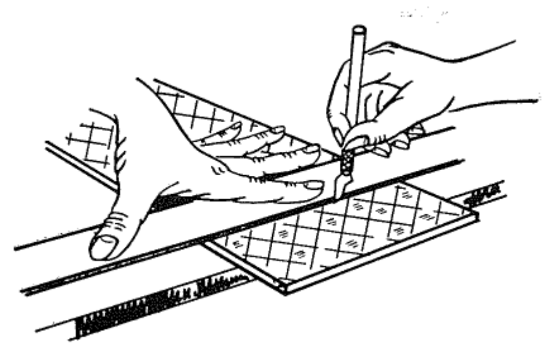


Figure 30. Scoring of plastic.

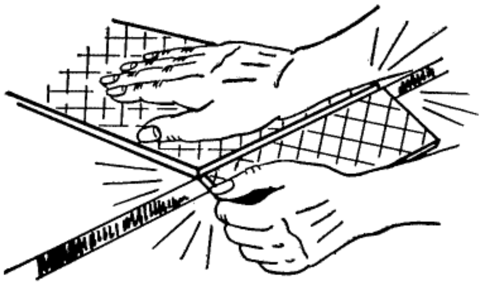


Figure 31. Breaking of plastic.

such as stylus. The material is then broken in a single, swift motion (figs. 30 and 31). These sheets are then assembled into a stack and clamped together, preparatory to drilling the holes for the binding posts.

(2) A typical drilling operation is shown in figure 32. A piece of plywood placed on top and bottom of the stack protects the plastic and insures flatness. The protective paper covering of the plastic is not removed, as this helps avoid chipping, and prevents the sheets from fusing together during drilling.

(3) It is of the greatest importance that the holes be perfectly vertical through the stack of sheets. Since the detail on each sheet is separately and individually traced from the source material, any sloping of the binding holes will affect the registration of detail from sheet to sheet. Misregistration from this cause will be progessively worse with each higher level of the assembled unit.

c. Registering to Source Material.

(1) Insertion of the binding posts through

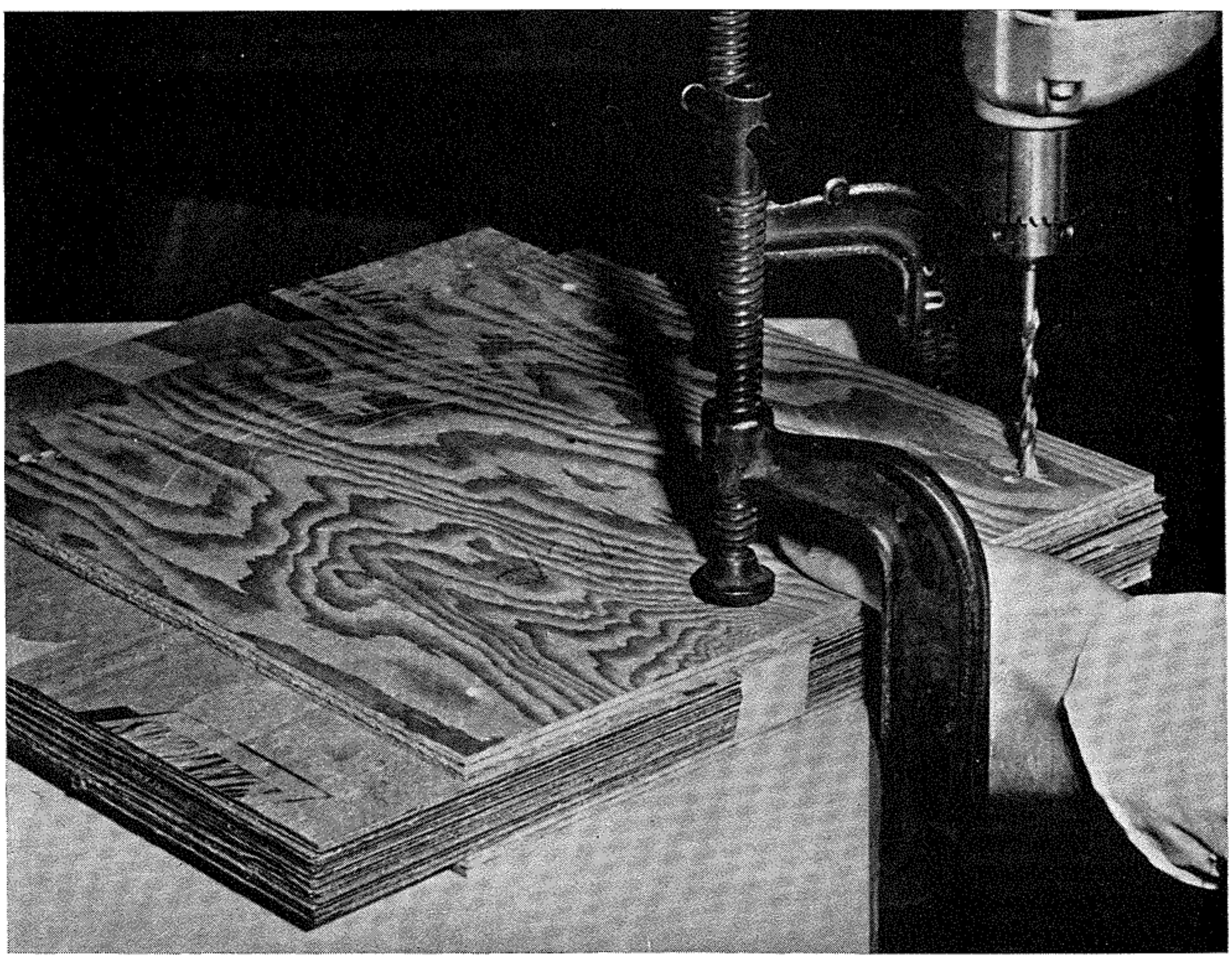


Figure 32. Drilling binder holes.

the drilled holes automatically registers the individual sheets of the Model to each other. However, some provision is necessary to provide control during tracing from the source material. If the source material is a compilation on a semi-rigid sheet of plastic (such as vinyl), it may be drilled along with the stack of assembled sheets. Insertion of the binder posts in the holes of the compilation and dropping the individual sheets of the assembly over the posts provides adequate control under these circumstances.

(2) If the source material consists of an existing chart, maintaining registration by use of binding posts is less satisfactory, due to the flexibility and relative fragility of the chart paper. However, with due care, holes and binder posts may be used. An alternate method is to use one of the drilled sheets as a template and trace penciled circles on the chart source corresponding to the holes in the plastic sheet. Holes in each succeeding sheet may then be registered to these circles for control while tracing detail.

(3) A further alternative would be to mount the chart source on a sheet of the plastic and stack it along with the other sheets for the drilling operation.

d. Tracing the Detail.

(1) The lowest sheet of the Model is drafted first. This sheet will contain all the desired detail which lies *below* the *lowest contour* of the area being portrayed. For instance, in the example previously cited, in which the lowest contour is 600 feet while the lowest elevation is 536 feet, the lowest sheet would contain all detail lying between 536 and 600 feet. The 600 foot contour is *not* drafted on this sheet, but on the next sheet above.

(2) Figure 33 shows a typical set-up for tracing detail on this first sheet from chart source. The sheet of paper under the draftsman's hands, in the illustration, is for protection of the plastic surface, a prime consideration at all times. In this illustration, a large circle has been drawn on the source chart to include the area of which a Model is to be made. Such a circle may be used as the starting point for positioning, but sheet by sheet registration cannot ordinarily be adequately controlled by markings alone, since the thickness of the plastic sheets prevents accurate alinement of line over line.

(3) After the first-level (lowest) sheet has been completed, it is left in position and the next higher sheet is laid over it. On this sheet all detail lying between the 600-foot contour and the 700-foot contour is traced, including the 600-foot contour line, but *not* the 700-foot line. The first sheet has been left in position so that detail drafted on the next higher sheet—in this example, the 600-foot level—can be matched to it.

(4) After the second-level sheet has been completed, both sheets are removed and the second-level sheet replaced. The third-level sheet is now placed over this and detail at this level is traced. In the example we have been following, this would be the detail lying between 700 and 800 feet altitude, and the 700-foot contour line would be drawn, but *not* the 800-foot line.

(5) When the third-level has been completed, both sheets are removed, as before, the third-level sheet is replaced, and now covered with the fourth-level sheet. On the latter is now traced all detail which it is desired to show at this level.

(6) In this manner, the Model is drafted, sheet by sheet, from bottom upward. It will have been noted that only *two* sheets are used at a time, the sheet on which detail is being drafted and the sheet of the level next below it, already completed. This procedure permits matching of detail from sheet to

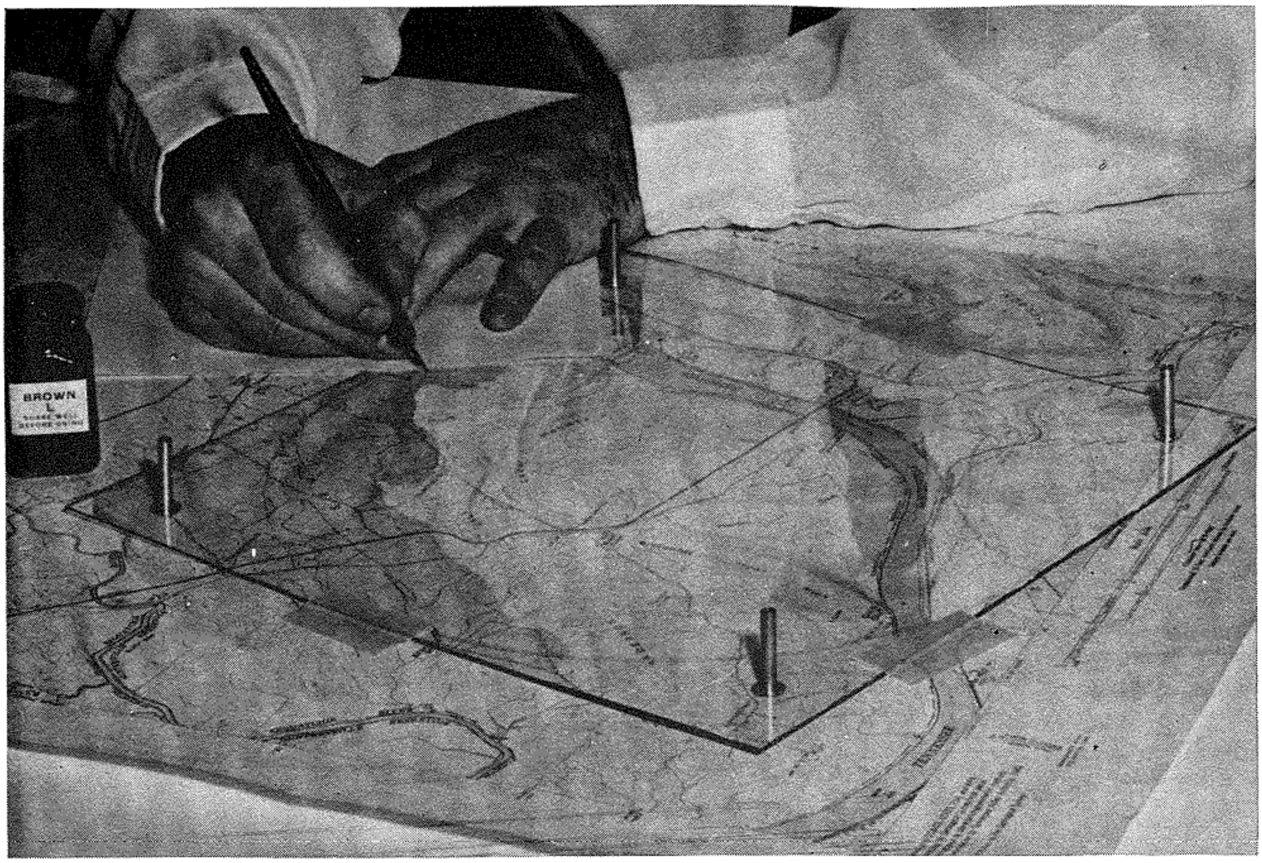


Figure 33. Tracing the detail.

sheet, at the same time avoiding the piling up of a large number of sheets over the source chart or compilation, which would make tracing and registration more difficult. The drawing surface is separated from the source material by only two thicknesses of the plastic at any one time.

(7) The topmost sheet on which any detail appears contains the final contour line of the area and all the detail which lies above that line. In our example, this would be the 1,100-foot contour. It is practical to add an extra cover sheet to protect the surface of the topmost drafted sheet.

(8) Whatever the type of vertical interval employed — contour intervals, floors of a building, girder levels of a bridge — the order of tracing detail will be the same.

e. Assembling the Model.

(1) After drafting has been completed on all sheets and symbol stick-up and names have been added (see next section), the Model is assembled. This is done by stacking the sheets in proper order on the binder posts, and tightening the binder post cap screws. The Model is now ready for use.

(2) Assembling is illustrated in figures 34 and 35. Arrow near center of figure 6 points to junction where a large stream "drops" from one sheet to the next. The complex dark mass on the upper sheet is a lake. Near its outlet, the river crosses a contour line (not visible on this photograph) and has therefore been dropped from this sheet at this point, and picked up and continued on the next sheet below.

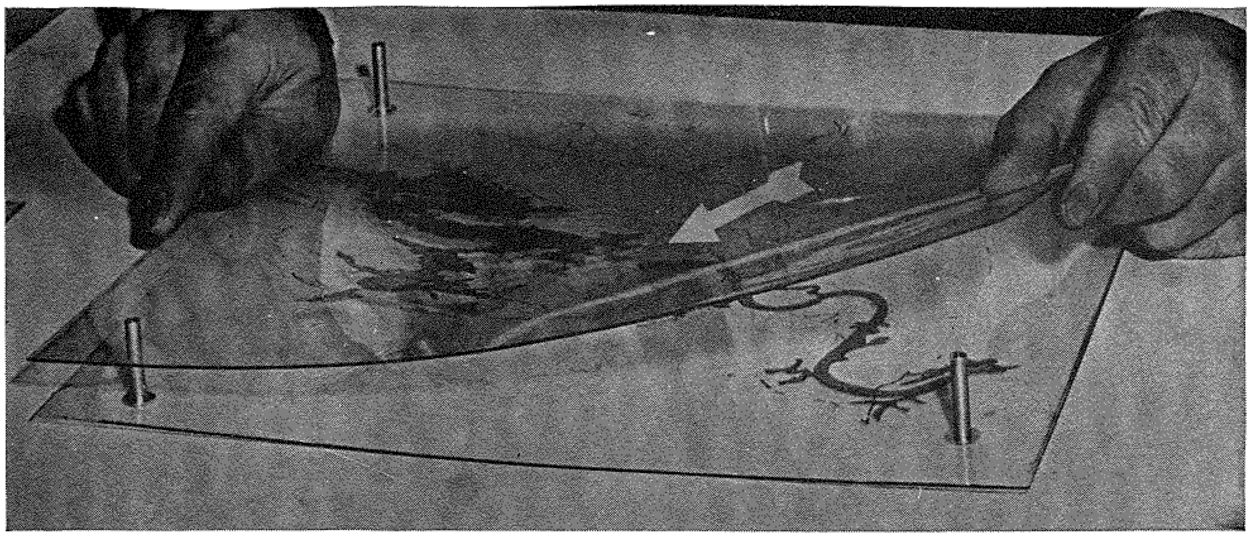


Figure 34. Typical detail junction.

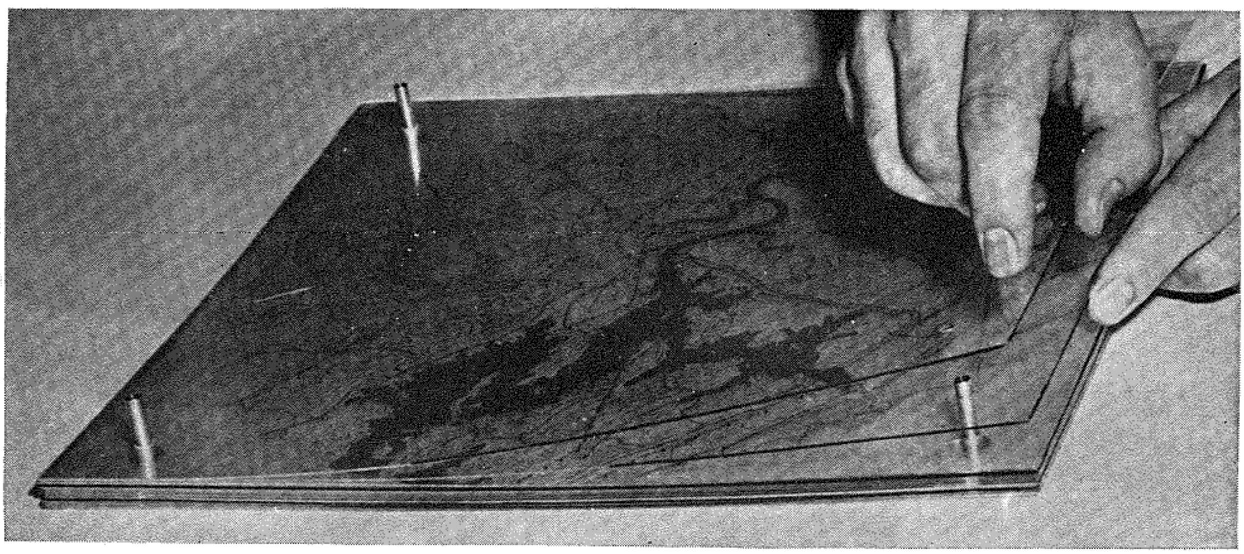


Figure 35. Assembling.

5. Typical Considerations

a. Natural Features.

(1) As has been demonstrated (fig. 34), drainage is "dropped" from sheet to sheet as it progresses downward to lower levels. A contour line, of course, is not carried from one sheet to another, since a contour line represents a constant level. Contours are usually utilized as division lines, and wherever a feature crosses a contour line, the feature must be dropped to the next sheet below, or raised to the next sheet above, depending on whether the contour indicates a descending or an ascending slope at that particular place.

(2) All natural features are drafted on the sheet which represents the level on which they lie, unless they are individually taller than a single level. In the latter case, the symbol or image may be repeated on successive layers with such modifications as seem desirable until they are shown in their proper height. Trees and bushes are

treated in this manner in large scale Models. In small scale Models, vegetation is perhaps better shown by solid tints, or stick-up patterns.

(3) An interesting sidelight is the possible delineation of interiors, such as caverns, inside features of depots and such, the structures of which have tactical significance. If the measurements of an interior are known, this feature can be shown with intriguing realism, and the technique permits the examination and study of such a subject from an "outside-inside" viewpoint, so to speak.

b. Cultural Features.

(1) *Roads, Railroads, Transmission Lines.*

(*a*) Cultural features which follow the profile of the terrain across country are treated in the same manner as natural features. The most common features of this type are roads, railroads, and electric transmission lines. The last named merits special note, for besides the individual poles or towers, which stand up above the ground surface, the connecting wires also are above the surface. While it is unlikely that the scales height of these would exactly correspond to the selected contour interval, this fact can be ignored in order to portray this feature realistically. By placing a dot at ground level to symbolize the base of the pole, and superimposing another dot directly above it on the next higher level to symbolize the top of the pole, and connecting all the superimposed dots by a line to symbolize the wire, a highly realistic portrayal of a transmission line with wires above the surface is created.

(*b*) If the scale is sufficiently large to show steel transmission towers to scale, the actual structure of these features can be approximated, by repeating the symbol, with modifications to show tapering toward the top, on several layers.

(2) *Bridges and Other Structures.* Such features as bridges can be most dramatically portrayed at large scale by repeating the image, with modifications to make it conform to varying structural patterns at various levels, on several layers (fig. 36). The same technique can be adopted to other structures of significant heights.

(3) *Underwater Features.* Submerged features, such as piling, cables, and the submerged portions of marine railways, can be realistically portrayed by reserving a number of the lowermost layers of the Model for underwater features, before land features are begun. Thus, for example, the first, lowermost, layer can be used to show features lying within the 20- to 30-foot depth; the second layer, detail within the 10- to 20-foot depth; the third layer, detail between the surface of the water and the 10-foot depth. Not until the fourth layer would land features be represented. On this layer is shown all detail lying between the water's edge and the first contour line. From then on upward, the usual terrain methods are followed. This system can be expanded to include as many underwater levels as desired, and to portray a wide variety of submarine objects and hazards.

(4) *Tunnels.* A light dashed line indicating the tunnel is shown on the level where the portals of the tunnel occur, and the line is stepped up or down from level to level as necessary to connect the two portals, passing under any intervening layers.

(5) *Names and Descriptive Notes.* Names and notes are positioned according to the same general rules as apply in the case of a conventional chart. However, for optimum legibility, a name of note is placed on the layer above that on which the feature referred to is located. This has an additional advantage in that feature detail is obscured to a lesser degree than would be the

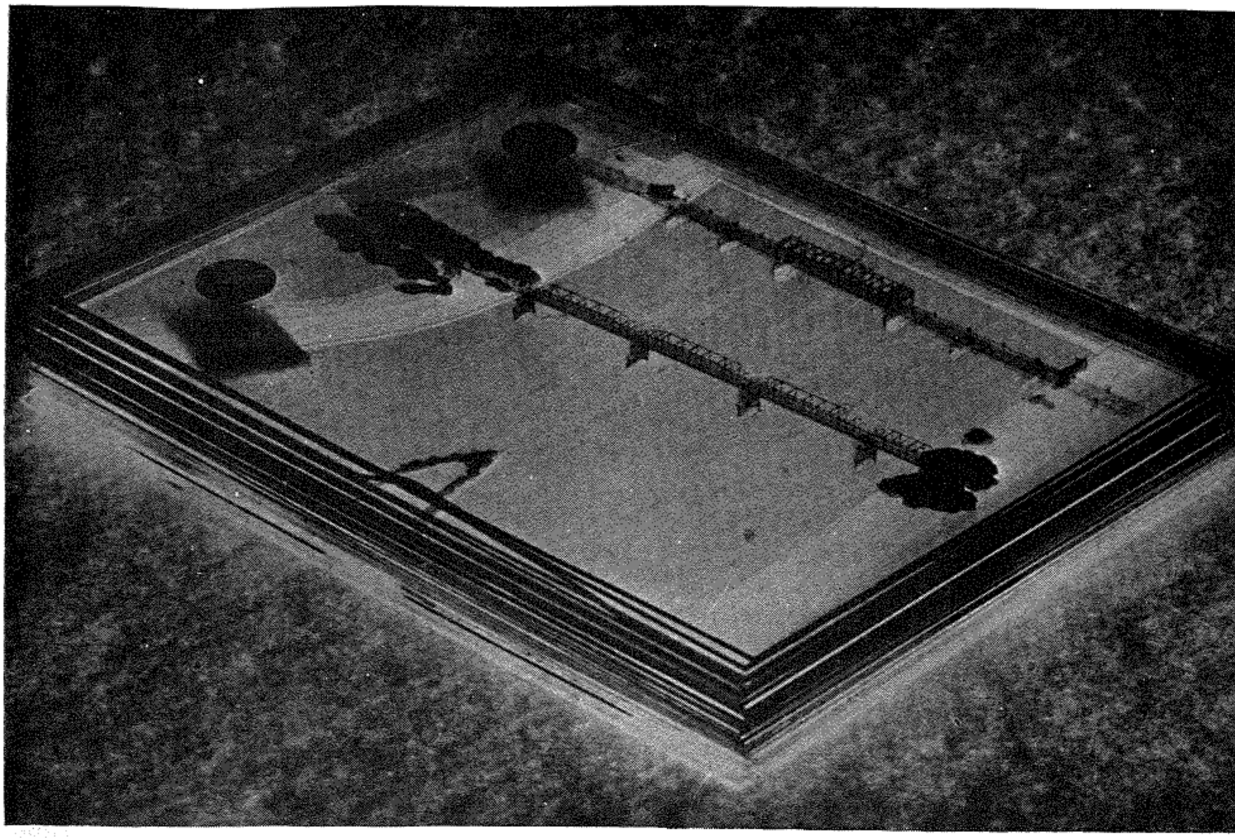


Figure 36. Typical structure treatment.

case if the name or note were laid directly on the images.

(6) *Increasing the Vertical Ratio.* Vertical ratio can be increased by separating the sheets of the unit with "spacers" of sheet plastic or other suitable material. Spacers the same thickness as the sheets making up the Model have the effect of doubling the vertical ratio, since there will be twice the distance between levels as there was before the spacers were inserted. Similar results can be achieved by use of collars on the binding posts, such as metal or plastic washers.

(7) *Reduction of Terrace Effect.*

(*a*) Inasmuch as the Model is made up of layers, some degree of terrace, or "stair-step," effect is inherent. This may be lessened by using thinner plastic sheets and dividing the portrayed features into shorter sections, with correspondingly shorter "steps" from section to section.

(*b*) When the sheets of a Model are separated by spacers, the stair-step effect is increased. If the separation is such that vertical scale is doubled thereby, the stair-step effect can be reduced by shifting one-half of the detail from the top surface of each sheet to its own bottom surface. This has the effect of adding an intermediate contour interval (although an auxiliary contour line is not necessarily actually drawn), with the detail within this auxiliary level being shown on the undersides of the sheets. For example, if the selected contour interval is 20 feet, the detail falling within the first 10 feet of each interval would be placed on the underside of a sheet, while detail lying in the upper 10 feet of the interval would be placed on the upper side of the same sheet. The same effect can be attained by shifting the upper half of the detail on a given level to the underside of the sheet next above, and continuing this practice uniformly throughout the Model.

c. Stereo Pairs.

(1) Although an assembled unit is itself three-dimensional, ordinary photographs, naturally, fail to do it justice in this regard, since they portray only in two dimensions. However, by making two pictures of the same unit, from slightly different angles, a stereo pair may be obtained.. Such a stereo pair is reproduced in figure 37.

(2) The amount of depth obtained in a stereo pair is governed by the angles at which the pictures are taken. The greater the angle the greater the impression of depth in the "fused" image—within limits. Too much angle produces a pair which cannot be fused at all, even with optical assistance.

(3) By printing one picture of the stereo pair in red and the other in blue-green, or other suitable color combination, an anaglyph can be produced, which, when viewed through appropriately tinted spectacles, recreates the original three-dimensional effect. It is also contemplated that the two views may be assembled in the form of a Vectograph three-dimensional photographic print, for viewing with polarized spectacles.

(4) Stereo reproductions may be considered for use as substitutes for the original plastic Model in circumstances where the bulk of the latter would be a disadvantage, or to permit use of the data by a greater number of persons at one time.

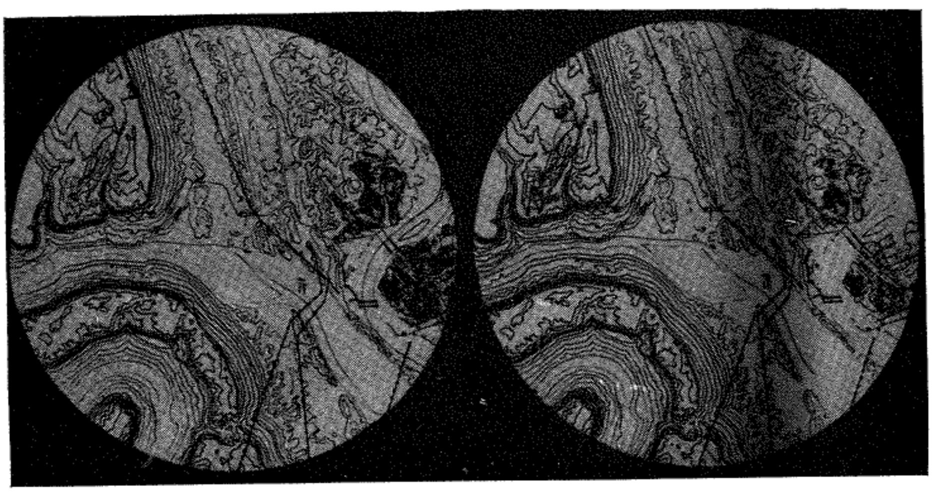


Figure 37. A stereo pair.

APPENDIX III

FLOWLINE TREATMENTS

1. Definition of Flowline

In molding preprinted plastic lithos over a master model it is extremely difficult to achieve a 90° bend at the neatline (sheet edge) without causing misregister of line work. Therefore, it is necessary that the master model be constructed so that the plastic sheet will be formed over a slope which extends from the height along the model edge to the datum plane of the model. This slope area is called the *flowline.*

2. Flowline Width

When several molded plastic maps are to be reproduced and used in conjunction with each other, it is necessary that all flowlines be of a consistent width for all the maps in the group. The angle of the flowline slope should be not greater than 45° from the horizontal datum plane. Therefore, the width of the flowline should be as wide as the height above datum (at the vertical scale of the model) or the highest landform on any neatline in the group of maps (fig. 38).

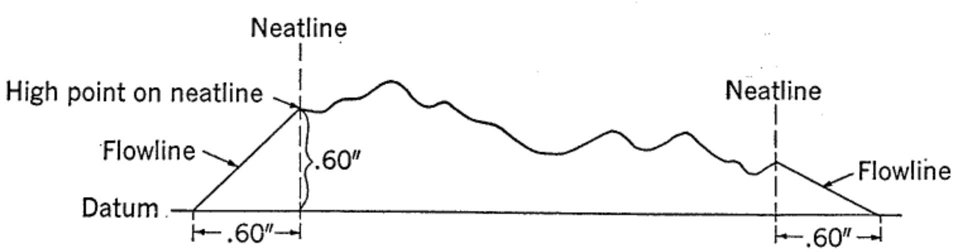


Figure 38. Flowline width.

3. Datum

In the construction of relief maps, it is necessary that the several adjoining maps of a group or *set* have a common datum plane in order that maps may be abutted and retain proper relative heights. In medium- or small-scale relief map construction (1:250,000 or smaller) where continental coverage may be anticipated, sea level is generally established as datum. However, in constructing sets of larger-scale relief maps, where the probability of constructing maps of adjoining areas is remote, it is common practice to establish an elevation one contour interval below contour appearing on *any* map within the set as the datum for that particular set. This necessitates the stacking of additional laminae where the low contour of an individual map is higher than the low contour of the map set. Negative and positive stacking, of additional laminae are illustrated in figure 39. In negative stacking, the laminae stacked above the low cut of the individual map to maintain datum are referred to as *collar sheets.*

4. Trimming

Mosaics of molded plastic maps are achieved by trimming the maps along 2 neatlines, generally the north and west positions, so that the trimmed edges can be positioned over the flowline of the adjoining sheets. In order that the trimmed edge of 1 map will meet properly over the adjoining flowline, it is necessary that areas lower than uniform slope to datum be incorporated into the flowline areas as illustrated in figure 40.

5. Types of Flowlines

Flowlines with incorporated detail are referred to as *developed flowlines.* Flowlines on edges which are to be trimmed off and outside

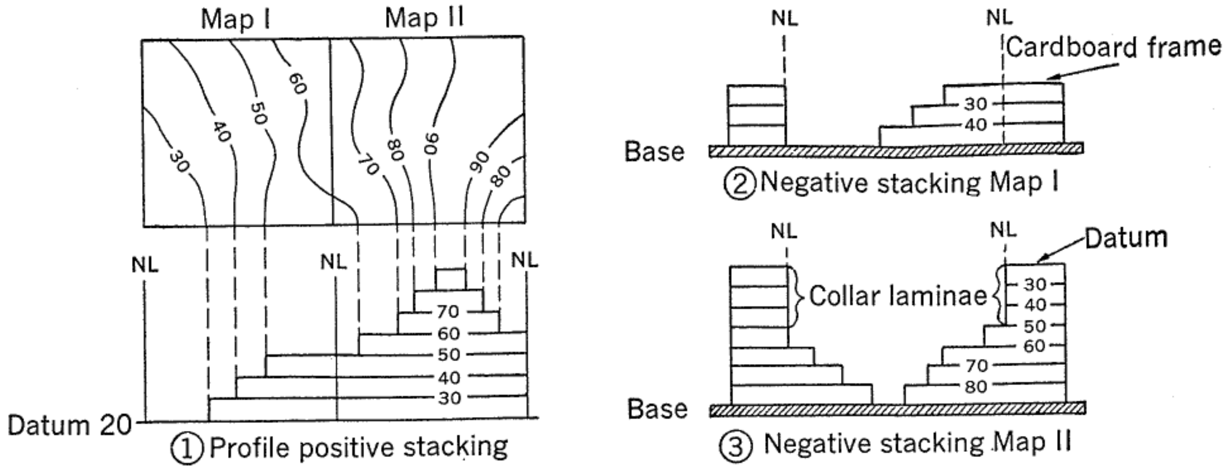
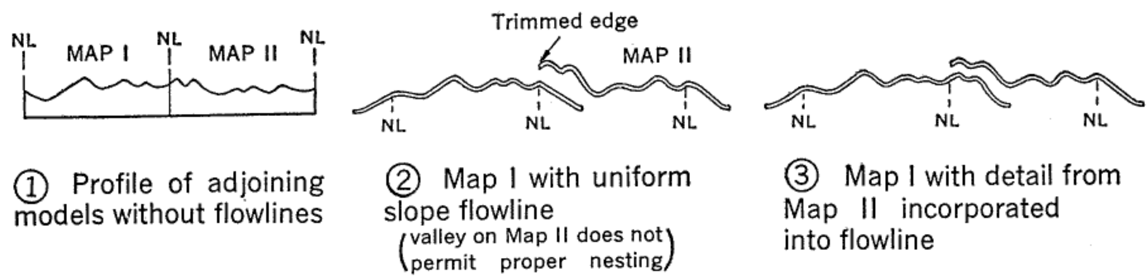


Figure 39. Positive and negative stacking of additional laminae to accommodate datum.



(It will be noted that it is not necessary to incorporate areas higher than the uniform slope flowline into the flowline area as they do not interfere with proper nesting.)

Figure 40. Incorporating low areas into flowline.

edges of a model set do not require such detail, and are modeled as uniform slope from the edges of the models to the datum plane of the model set. These flowlines are referred to as *normal flowlines*. However, to insure neatline register of line work in molding operations, contours will be extended to a line 0.10 inch outside and parallel to the neatline on edges to be constructed with normal flowlines. This 0.10-inch area is referred to as *false topo* (false topography). See 1, figure 41.

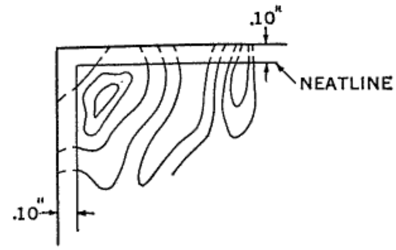
6. Transferring Detail for Developed Flowlines

The additional detail for developed flowlines is achieved by transferring contours from adjoining maps to the contour cutting base in the following manner. The flowline width is plotted parallel to map neatlines. The width on each side is divided into the same number of units as there are contours on that specific edge (from low cut of model set to highest cut intersecting the neatline). The lines dividing the width are numbered with the contour interval numbers. Line work is then traced from the adjoining map into the flowline area until it intersects the line carrying the same value. The contour is then tied back on that line, either closing upon itself or intersecting a line of the same value on another edge. See 2, figure 41.

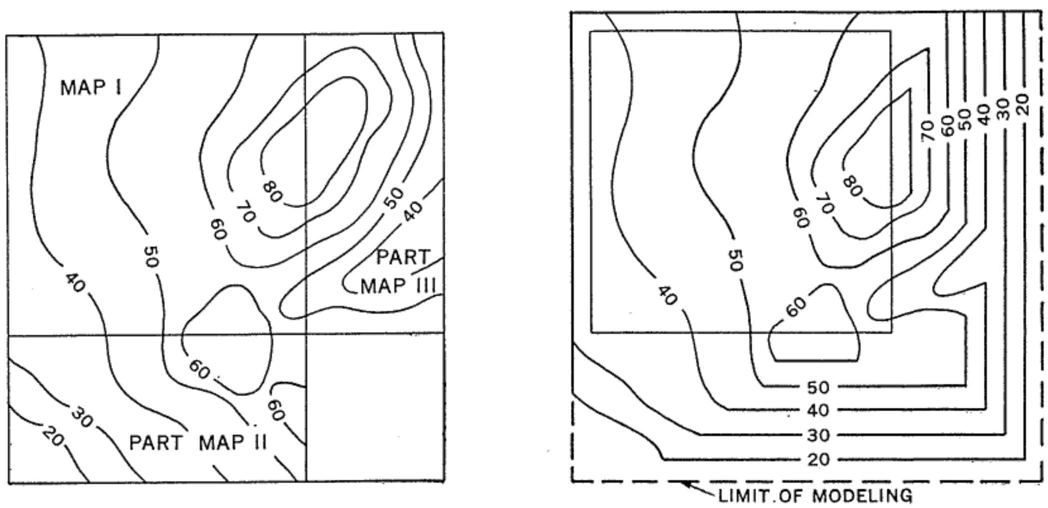
7. Transferring Detail for Normal Flowlines

a. Normal flowlines may be treated in the same manner as explained for developed flowlines by extending a line perpendicular to the neatline from the intersection of the contour with the neatline until it intersects the plotted line of the same value within the flowline, as illustrated in 3, figure 41.

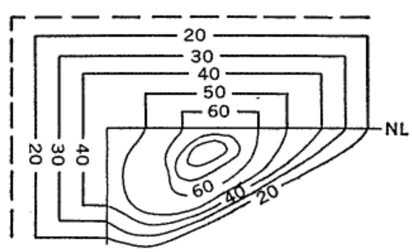
b. It is deemed more expedient, however, to cut laminae at the limit of the false topo areas and clay model to the limit of the flowline plotted on the model base. See figure 42.



① Normal flowline adding false topography.



② Developed flowline transferring detail from adjoining map.



③ Normal flowline showing alternate treatment of false topography.

Figure 41. Flowline treatment.

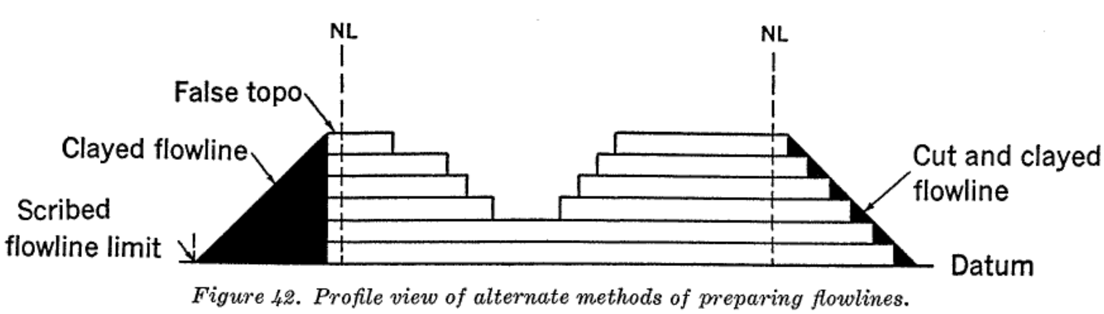


Figure 42. Profile view of alternate methods of preparing flowlines.

APPENDIX IV

ALLOWABLE TOLERANCES

	Model construction	
Vertical Tolerance	± 10%	Commercial tolerance for thickness of laminae.
Horizontal Tolerance	± 0.015″	Vinyl acetate and plaster expansion.
	Plastic Map	
	± 0.015″	Plastic sheet expansion in printing.

APPENDIX V
COMMON POWER TOOLS

1. The K–10 cutawl is a precision-built machine with ball bearings used extensively throughout. Many parts are permanently lubricated. It is powered by a $\frac{1}{6}$-horsepower motor, which may be used on a current of 115 volts, AC or DC. The cutawl uses a chisel type cutting tool. It will cut soft materials to a maximum of $\frac{11}{16}$ inch. It is used primarily in cutting contour laminae.

2. The jigsaw is powered by a $\frac{1}{3}$-horsepower motor with a 4-speed pulley which provides speeds of 650, 1000, 1300, and 1750 RPM with a standard 1,725-RPM motor. The motor is of the sealed-bearing type which needs no lubrication. The guide on this machine is of a universal type, which makes it adaptable to blades of practically any size. The blower is designed so that enough air is furnished to blow sawdust away from around the lines marking the design on the work. The jigsaw is used primarily in cutting contour laminae.

3. The 14-inch bandsaw can be used for almost any sawing operation in model making. Its chief use is cutting curved edges. The size of the bandsaw is determined by the size of the bandsaw wheel. The blade must be kept sharp and accurately set to cut in a straight line. The width of the blade to use depends on the radius of the curves to be cut. A narrow blade is used to cut a small-radius curve; a wider blade to cut larger-radius curves.

4. Jointers are used primarily for surfacing and edging stock. They can also be used for other operations such as rabbeting, chamfering, and tapering. The work is done by a cutting head containing 3 knives which revolve at 3,600 RPM.

5. The disk sander is used primarily for smoothing and finishing any shaped edge, irregular, circular, or straight. A No. 2 sandpaper is used for most work; for fine work a very fine grit of paper is used.

6. The drill press is designed primarily for boring holes in any workable material, but it can also be used for many other jobs such as routing, polishing, and sanding.

7. The circular-table saw can perform a wide range of jobs, including ripping, cross-cutting, mitering, beveling, grooving, tenoning, dadoing, and cutting moldings.

8. The bench grinder is used primarily for tool grinding, but by replacing the grinding wheel with a cloth buff, it can also be used for buffing operations. A grinding wheel of aluminum oxide is used for general tool grinding.

9. The skill saw, electric or air operated, is used for cutting large panels and boards to the correct size.

10. The portable electric hand drills are normally $\frac{1}{4}$ to $\frac{1}{2}$ inch in size. They are used primarily when a job is too large or cumbersome to be handled by the bench drill. They are also very useful for drilling screw holes in assembly work, and drilling holes in terrain models for the placement of trees, line poles, and the like.

11. The Dremel moto-tool is a high-speed motor fitted with a collet chuck to take various types of rotary cutters. The moto-tool runs at 25,000 RPM when it is running free. It is used for light carving and shaping wood, plastic, metal, and other workable materials.

APPENDIX VI
GLOSSARY

Carving—The development of the model surface by carving away the steps of the plaster step cast.

Checking positive—A composite printing on glass of the contour and drainage drawings used on the shadow projector for checking horizontal accuracy of landforms.

Cutting positive—A printing on glass of the contour drawing used to make the etched zinc plate.

Etched zinc plate—An etched copy of the contour drawing of the base map, used as the guide in cutting the stepped terrain base.

Flowline—The slope extending from the heights along the neatline to the model datum, at an angle no greater than 45°, to preclude forming the plastic sheets at a 90° angle at the neatline.

Forming machine—The equipment for forming, by heat and vacuum, preprinted plastic maps over a mold representing the terrain of the area.

Library negative mold—A negative mold which has been extended to a size compatible with the printed plastic litho and forming equipment, and which is kept in file for subsequent castings.

Masking or screening—A means of controlling plastic expansion locally during forming to obtain more accurate register of preprinted line work to the landforms of the mold. By masking, differential heating is achieved.

Master or original model—The developed original terrain model which bears, in miniature, the same spatial relationships as the actual ground it represents.

Model datum—The level plane from which relative heights are determined. For relief maps or models the datum may or may not be sea level but is consistent within a relief map series.

Modeling—The development of the model surface by the application of modeling clay between the step edges of the step cast.

Model marriage—The rejoining of sections of a model, after the carving operation, to the original neatline limits.

Mold alterations—The slight modification of the landforms of the mold, often necessary in local areas in order to obtain proper register due to unequal stretch required to accommodate the landforms.

Negative forming—Forming into a negative mold.

Negative mold—The cast resulting from casting over a master model.

Plastic block or laminate—The block of bonded cellulose-acetate sheets, each sheet equal in thickness to the contour interval at the scale of the model, from which the terrain base is cut.

Plastic relief map—A topographic map preprinted on plastic material and formed by heat and vacuum over a reproduction positive mold.

Positive forming—Forming over a positive mold.

Positive mold—The cast pulled from a negative mold.

Register trials—The test runs necessary to obtain the proper combination of the degree of partial vacuum and the length of the heating cycle required for individual models.

Reproduction positive mold—The positive mold which has been drilled through with vacuum holes, and over which the plastic map is formed.

Shadow projector—The optical device developed for checking dimensional accuracy of the various casts.

Step cast—The negative or positive reproduction of the stepped terrain base.

Stepped terrain base—The acetate three-dimensional representation, in stepped form, of the contours appearing on the base map.

Two-dimensional pantograph—The machine permitting the cutting, at a predetermined scale, of the three-dimensional terrain base from the flat map contour drawing.

Vacuum box—The frame, containing its own vacuum unit, which encloses the mold for the forming operation.

Vertical exaggeration—The increase of the vertical scale over the horizontal scale of the model.

[AG 060 (24 Jan 56)]

By Order of *Wilber M. Brucker*, Secretary of the Army:

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Chief of Staff.

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5–56R, Hq, H & S Co, Engr Topo Bn, Army (3)
5–57R, Engr Map Repro and Distr Co, Army (1)
5–157R, Engr Fld Maint Co (3)
5–329R, Engr Port Cons Co (2)
5–346R, Hq & Hq Det, Engr Base Topo Bn (5)
5–347R, Engr Base Repor Co (1)
5–348R, Engr Base Surv Co (2)
5–500R (AA–AD), Engr Svc Org (5)

NG: State AG (6); units—same as Active Army except allowance is one copy per unit.

USAR: None.

For explanation of abbreviations used, see SR 320–50–1.

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