

## USE OF AERIAL PHOTOGRAPHS IN THE CONSTRUCTION OF MILITARY TERRAIN MODELS

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**T**ERRAIN models are valuable military intelligence aids because the three-dimensional presentation of topography portrays enemy territory in a manner understandable to all echelons. The vertical scale of the model can be exaggerated in order to accent the physiography of the region; in at least large scale models, planimetric and hydrographic information can be shown in a naturalistic manner rather than symbolically; and vegetative types can be portrayed in three-dimensions. Models, therefore, are more nearly true replicas of the earth's surface than are flat maps and, consequently, combat troops absorb unit tactics more readily when briefed with models. However, as with other forms of military intelligence, models to be of value must show the latest available information on the area in question. Aerial photographs, being the most reliable source material on areas inaccessible to actual ground observation, are used in preparing or revising base map manuscripts for practically every type of terrain model.

During the past war, terrain models were prepared for almost all major offensive operations, some being made in limited quantities in very forward areas; others being produced in quantity in this country and flown to awaiting task or combat forces poised for the assault.

### CHARACTERISTICS OF MODELS

The extent to which aerial photographs are used in producing terrain models is dependent upon the type of model requested. The types requested, in turn, are dictated by and large by the intended use of the model, the time allowed and the facilities at hand for their production. Based on intended use, seven model types are generally recognized as follows:

1. *Strategic Planning*: (See Figure 1). This type includes horizontal scales from 1:100,000 to 1:1,000,000 with smaller and vertical scales exaggerated from 4:1 to 10:1 over the horizontal. Only major streams, roads, railroads and cities are shown. Maps and miscellaneous terrain studies constitute basic source material with aerial photographs employed only for planimetric and topographic revision of critical areas. They are produced in limited quantities for high echelon planning of major military operations embracing continents or countries, and are generally made in rear echelon locations. If strategic map coverage exists, models of this type can be prepared months or years in advance of operational need.

2. *Tactical Planning*: (See Figure 2). Models in this category cover horizontal scales from 1:25,000 to 1:100,000; vertical scales are exaggerated from 2:1 to 4:1. Cultural and planimetric patterns are more detailed than on strategic scale models. Aerial photographs are used commonly for planimetric revisions of the base maps. Sufficient copies are produced in theater headquarters, as well as in the rear echelons, for Corps and Divisional use; limited production is possible in forward areas. It is not always possible to anticipate model requirements at these scales, so production prior to operational need is seldom realized.

3. *Assault Landing*: (See Figure 3). This is more commonly termed the amphibious assault model and includes horizontal scales from 1:5,000 to 1:25,000 with greater production at the larger scale. Vertical exaggeration varies from none to 2:1. Detailed topography, planimetry and hydrography are delineated to simulate nature and aerial photographs are extensively used for compiling up-to-date information on enemy defenses, communications, off-shore hazards and vegetative patterns. Effort is made to produce sufficient copies for all echelons, with particular emphasis for combat personnel. This type is produced in forward as well as in rear echelon locations. It is not possible to prepare assault models far in advance of operational needs, since targets may be changed quickly depending on the course of month to month or day to day combat.

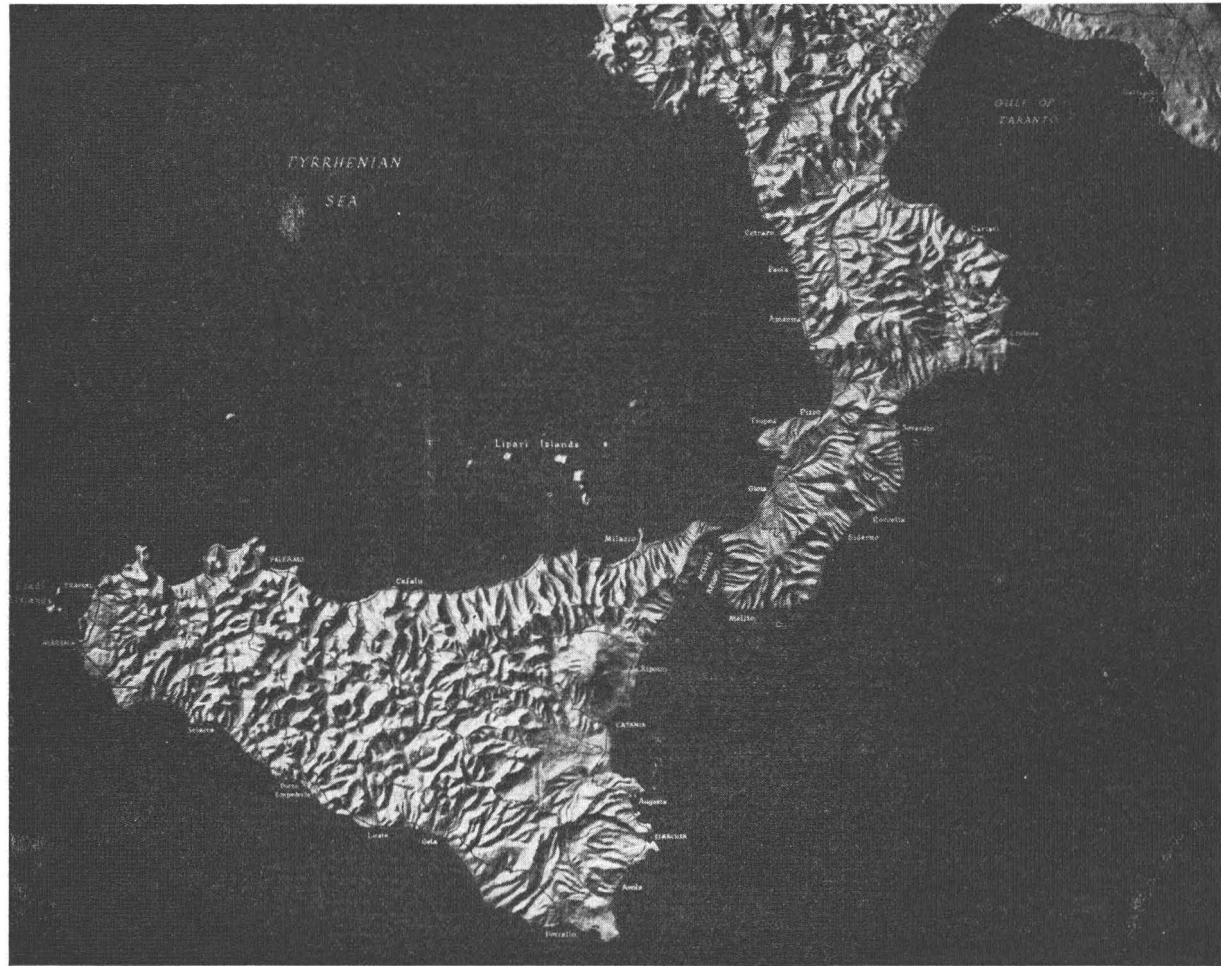


FIG. 1. Example of a strategic type model, scale 1:1,000,000, as produced by the Office of Strategic Services during the war. Cultural has been minimized in order to accent the physiography of the region.

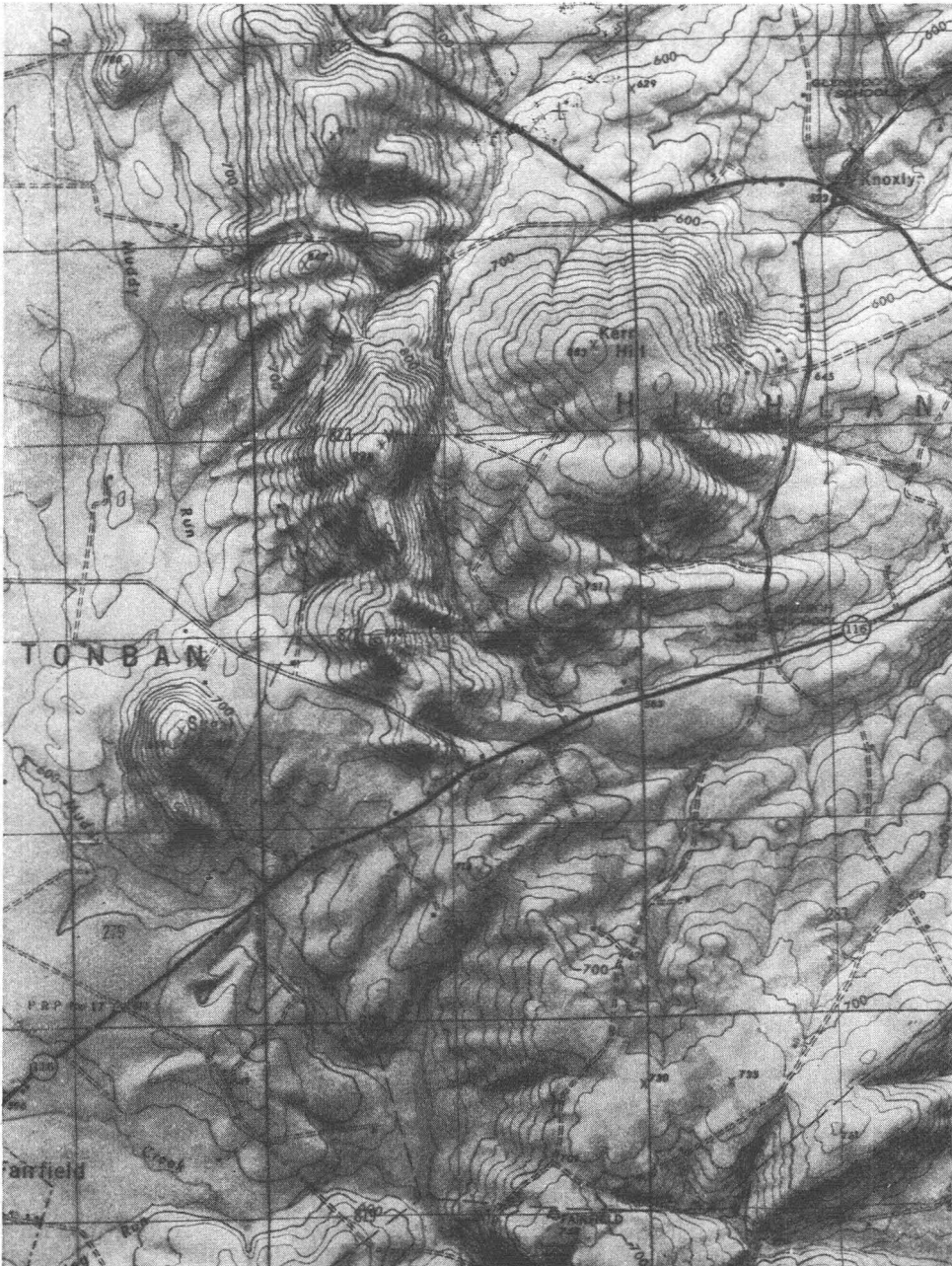


FIG. 2. Example of a tactical type model as produced by the Army Map Service. This is a portion of the 1:25,000 plastic embossed model of Fairfield, Pennsylvania and portrays identical information as shown on the flat map issue of the area.



FIG. 3. Example of an assault landing type model as prepared by the U. S. Navy. This is a partial view of the model of Iwo Jima, scale 1:5,000. Note detail of enemy defenses along beach.

4. *Assault:* (See Figure 4). Models in this class are large scale, i.e., from 1:500 to 1:5,000 with no exaggeration of the vertical. These models usually emphasize some specific target such as a radar unit, airfield, rocket launching platform, etc., and are painstakingly made to simulate nature to the extent possible, with accurate and detailed location of trees, brush, culverts, buildings, etc. Aerial photographs are used extensively in their construction. Limited copies are produced for briefing of assault of commando forces. These assault models are generally made under stringent production deadlines and, consequently, are produced in forward locations only.



FIG. 4. This photograph illustrates the assault type model prepared for specific targets. It is a view of the 1:2,000 reproducible sponge rubber model of the Army Map Service as prepared by that Agency.

5. *Airborne Landings*: This type embraces models from 1:1,000 to 1:15,000 with vertical exaggerations from none to 2:1. Effort is expended to portray the area as seen from the air rather than from the ground. Aerial photographs are carefully analyzed to determine unusual vegetative patterns, rock outcroppings, road patterns, or stream junctions which would provide quick orientation for pilots carrying airborne troops. They are produced in limited quantities at theater headquarters or more forward locations, for briefing of airborne personnel as to drop zones.

6. *Aerial Target*: Models of this type are produced for tactical and assault bombing purposes and usually range from 1:2,500 to 1:5,000, with exaggeration of the vertical from none to 2:1. Aerial photographs are used extensively to portray the target in a naturalistic fashion and to show salient terrain features surrounding the target, as well as enemy defenses. They are produced in limited quantities in forward areas as well as in theater headquarters for briefing purposes.

7. *Hasty Construction*: (See Figure 5). Models in this class vary from 1:100, to 1:5,000 in horizontal scale with vertical exaggerations from none to 2:1. They may be produced from sundry materials on hand in a forward location such as twigs, sand, leaves, shells, etc., in which case the master model is non-reproducible, or limited production of plaster of Paris models may be possible, if the master is reproducible. As with other large scale models, aerial photographs are used extensively as source material. The primary purpose of the hasty construction type of model is to provide some resemblance of the terrain within an elapsed time far shorter than that required for other model types.

The time allowed for the production of models is an important factor in determining the type and quality of the end product. The rapidity with which military operations can move frequently results in radical changes in plans and permits only 2 to 3 weeks for model construction. In such cases, work may have to be done in shifts and highly generalized models may result. If, on the other hand, 2 to 4 months can be allotted for preparing the models, detailed products can usually be produced in reasonable quantities.

Facilities at hand for model production are another factor affecting the type of models available. A fully equipped model plant has facilities for making sponge-rubber models, metal models, vacuum drawn or embossed plastic relief maps, plastic photo-surface models, phenolic resin models, or plaster of Paris models. Major items of equipment include hydraulic presses, curing ovens, jig saws, mechanical pantographs, reflecting or orthographic projectors, stereo-plotting devices, vacuum pumps, air compressors, wood working equipment, mold injection presses, metal lathes, etc. In addition, the model producing group must maintain close liaison with topographic, photogrammetric and map reproduction facilities in order that the source material for model construction may be quickly and competently processed. In rear echelon locations, these services usually come from outside the model plant, but in forward areas of combat, the model organization must include map compilers and photogrammetrists within its complement.

### TOPOGRAPHIC COMPILATIONS

Although aerial photographs are not commonly used for strategic and tactical scale models, they are extensively employed as current source material for large scale assault types. The first data to be extracted from aerial photographs are usually the topography. If available base maps are in error, the photographs are used to revise the topography, but if no maps are available, the relief map technician must then resort to photogrammetric techniques for compiling the topography from the vertical or oblique aerial prints as furnished by supporting air groups.

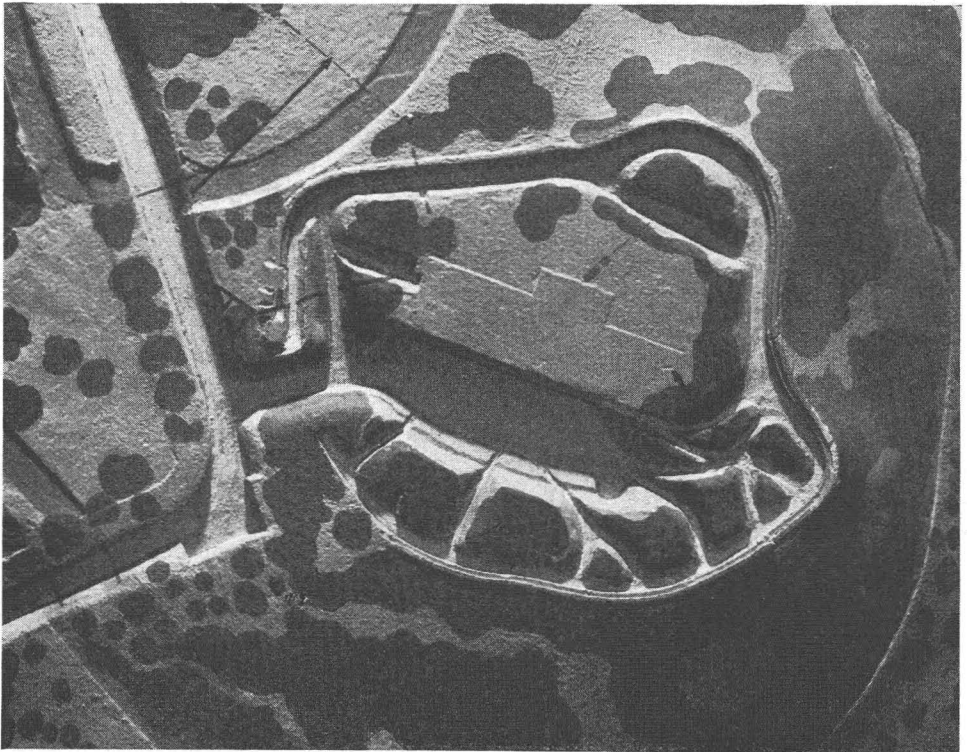


FIG. 5. A view of a portion of the 1:1,000 scale model of the Metz fortifications. Example of hasty construction produced by Army Engineer Model Makers Detachment Unit for our armored forces for their drive across Germany.

Technicians operating in forward areas usually function without benefit of refined stereoplotting equipment such as multiplex projectors or stereoplanigraphs. Instead, they must employ simpler aids such as stereocomparagraphs,<sup>1</sup> vertical and oblique sketchmasters,<sup>2</sup> parallax bars or ladders or to mere form lining under stereoscopes.<sup>3</sup>

High or low oblique aerial photographs are sometimes the only source material on hand. In such instances, planimetric maps may be compiled by oblique photogrammetric procedures such as the Canadian Perspective Grid System,<sup>4</sup> or by employing hastily built pin-hole rectifiers for oblique photographs.

### STEREO-MODELING

Upon completion of the base map, it is enlarged or reduced photographically to the scale of the model, and cutting of the model terrain base begins. In forward areas, jig-saws or cutawl machines are usually used to cut cardboard laminates, the thickness of one cardboard coinciding with the desired vertical scale of the model. In rear locations, more accurate terrain base construction is possible by use of three-dimensional pantographs. After the stepped terrain base is assembled, modeling clay or plaster compounds are carefully applied over the stepped contour terrain base, filling in the inter-contour spaces, thus establishing a modeled or developed surface. Contour lines on a flat map depict a uniform slope existing between one contour line and the next. When modeling to the contours of the terrain base, the same assumption rules, namely, that a uniform slope exists from one stepped contour to the next. Actually, the relief between two contours can vary any number of feet less than the stated contour interval of the base map. The introduction of the third dimension in the model enables the model technician to portray to scale, the complete relief if the needed source material is available. The second use of aerial photographs is therefore, stereo-modeling, or the examination of aerial photographs to facilitate the location and modeling of complete relief features not shown by contours on conventional maps. Examples of these formations are rock outcroppings, minor depressions, erosion gullies, stream banks, detail of borrow pits, road shoulders, cuts, fills, crestlines of ridges and rocky coast lines. Stereo-modeling is particularly important in the large scale assault type models where every effort is made to depict minute detail.

### PLANIMETRIC COMPILATION

In so far as the maps used in preparing the base map for model construction are usually of a smaller scale than that desired for the assault type of model, and since cultural features may change daily by enemy activity, planimetry shown on the base map must be supplemented by careful analysis of current aerial sorties. Therefore, the third use of aerial photographs is for compiling and transferring detailed planimetry to the model.

The first such study is that of the vegetation characterizing the model area. Based upon the stereoscopic analysis of the aerial photographs, vegetation types are determined and their outlines traced onto the photographs for later transfer to the model by reflecting or orthographic projectors. Vegetative classifications

<sup>1</sup> Nowicki, Albert L., "Practical Applications of the Stereocomparagraph," *MANUAL OF PHOTOGRAMMETRY*, Pitman Publishing Corp., New York, 1944, pp. 464-500.

<sup>2</sup> "Reconnaissance Mapping with Trimetrogon Photography," U. S. Army Air Forces, *MANUAL OF PHOTOGRAMMETRY*, Pitman Publishing Corp., New York, 1944, pp. 700-710.

<sup>3</sup> Sanders, Revere G., "Elementary Elevation Determination from Aerial Photographs," *MANUAL OF PHOTOGRAMMETRY*, Pitman Publishing Corp., New York, 1944, pp. 450-463.

<sup>4</sup> Eardley, A. J., "Aerial Photographs: Their Use and Interpretation," Chapter VIII, Harper and Brothers Publishers, New York, 1942, pp. 181-194.

are established more largely upon the concealment or protective value they offer to military forces than upon the species of plants forming a particular plant association. Vegetative breakdowns in the temperate zones might therefore, include such types as dense woods, tall and medium heights, scattered woods, dense brush, scattered brush, orchards, hedgerows, cultivated fields, pastures and isolated trees. In the tropics however, classes such as upland rain forest, swamp rain forest, short grass, tall grass, coconut plantations and mangroves would probably be delineated.

After the outlines of the vegetative classes have been projected onto the model, technicians working with stereo-pairs of aerial photographs endeavor to represent the vegetation in a naturalistic manner and to approximate vertical scale by applying cork or ground rubber chosen to represent each vegetative type.

Hydrographic information is frequently supplemented by study of the aerial prints. This is particularly true for the amphibious assault model where immediate offshore hydrography is important. Various techniques for determining underwater depths are employed<sup>5</sup> in order to determine beach gradients, high and low tide conditions. Offshore obstacles such as reefs, rocks and coral lagoons are plotted as accurately as possible.

Roads, railroads, houses, airfields, cities and defenses are important cultural features that are compiled carefully from aerial photographs for transfer to the model. If the models are produced in rear echelon locations, only the major defenses are shown. Forward intelligence groups receiving the models supplement the defenses shown from current aerial coverage of the area.

Radial line plots are compiled, when necessary, as a means of adjusting the planimetric and cultural information to the base map of the model. In some types of hastily constructed models, uncontrolled or semi-controlled mosaics are assembled of the aerial prints and glued over the terrain base. This procedure affords a rapid means of orienting detailed planimetry onto the model.<sup>6</sup>

### COLOR COMPILATIONS

Upon completion of the master model, molds are prepared and copies are produced. If the media of reproduction include plaster of Paris, sponge-rubber, phenolic resins or electro-deposited or sprayed metal, the resulting models must be hand painted. If the model is large scale, naturalistic finishing or painting is required. In this case, the tone and texture of black and white aerial photographs provide some clue as to colors of the area. On the aerial print, coniferous trees are usually clearly distinguished from deciduous by their darker tone; borrow pits, road cuts and fills are usually light in tone; and cultivated fields generally appear as varying shades of gray. By supplementing the aerial photographs with soil surveys, miscellaneous ground reports, and colored aerial views, it is possible to approach a naturalistic treatment of the model which is more easily understood by all echelons than if all features were portrayed symbolically.

### SPECIAL USES OF AERIAL PHOTOGRAPHS

Large scale models, as constructed and reproduced during the war required many hours of tedious hand work. Practically all finishing or painting of model reproductions was accomplished by hand. As a consequence, it was frequently

<sup>5</sup> Williams, W. W., "The Determination of Gradients on Enemy Held Beaches," *Royal Geographic Society, London*, July 1947, vol. CIX, Nos. 1-3.

<sup>6</sup> "Engineer Model Makers Detachment," *Manual published by Corps of Engineers, Department of the Army*, July 1945.



impossible to produce the required number of models for major military operations. Realizing this weakness, relief map cartographers have been concentrating on perfecting more rapid and accurate construction procedures and quantity reproduction methods. Some of these refinements utilize aerial photographs as the only source material. Experiments recently conducted at the Army Map Service indicate that it is very feasible to carve the topography out of plaster or wax directly under multiplex projectors. This procedure increases the accuracy of the model and eliminates the man hours required to cut and assemble a stepped contour terrain base to serve as a modeling guide. Whereas it is not always possible to incorporate the desired amount of vertical exaggeration in relation to the horizontal scale, the technique has its merits from an accuracy standpoint. An example of the utilization of aerial photographs as a means of finishing terrain models is to be found in the photo-surfaced model. From negative vacuum molds<sup>7</sup> or positive and negative dies prepared from the master model, it is possible to prepare plastic pre-forms of the topography. By sensitizing these plastic pre-forms with a photographic emulsion, exposing them under an orthographic projection system and developing the exposed pre-forms similarly to photographic prints, it is possible to produce a terrain model finished identically to the aerial photo.

These, and other techniques under study, will enable quantity production of accurate terrain models far exceeding that experienced in the last war; and aerial photographs, being a superior source material, will figure predominantly in their construction.

<sup>7</sup> Stanley, Albert, A., "Plastic Relief Models," *Military Engineer*, July 1947, pp. 287-290.

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