Topographic Maps of Missouri

by

THOMAS R. BEVERIDGE, FRANK C. WHALEY, and
LAWRENCE E. LAMBELET

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THOMAS R. BEVERIDGE, *State Geologist*

Rolla, Missouri

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INTRODUCTION

Topographic map distribution by the Missouri Geological Survey increased from 5,778 copies in the 1946-1948 biennium to 19,676 copies in the 1954-1956 biennium. Part of this increase resulted from expanding activities in construction, real estate, utilities, and mineral exploration, and part of it is attributable to a constantly increasing proportion of topographic map users such as hunters, fishermen, Scouts, and other out-of-door enthusiasts, some of whom are using the maps for the first time.

This report is intended to answer only the more common questions of the layman who is not familiar with the uses, interpretation, and limitations of topographic maps, thus, the reader is cautioned that even a careful study of the contained material will not make him an accomplished map reader, for map reading is a skill acquired by practice as well as by study.

Topographic maps are, in nontechnical language, maps designed to show the "lay of the land". They differ from most other maps by showing the surface of the ground in a third dimension of relief. This difference makes the hills, ridges, valleys, flatlands, streams, and other natural features readily recognizable, and on contoured topographic maps the elevations of these features are portrayed as accurately as is practicable with the scale used.

Some topographic maps show land forms by variation in color, some by shading which may be combined with color, some by a special variation of shading called hachures, and some by a more exact system of contour lines. The topographic maps described in this report show elevations and land forms by contour lines and encompass standard sized rectangular geographic areas or quadrangles. These maps are commonly referred to as "contour maps" or "quadrangles".

ACKNOWLEDGMENTS

The writers are indebted to Mr. Dan Saults, former editor of the *Missouri Conservationist* and present Assistant Director of the Missouri Conservation Commission, for permission to use parts of two of the senior author's articles on topographic maps published in the *Missouri Conservationist* in May and June of 1956. Figures 2, 3, and 4 have also been taken from these two articles.

Mr. James P. Rydeen, Mr. Charles T. Galloway, Mr. A. C. McCutchen, and Mr. Daniel Kennedy of the Topographic Division of the United States Geological Survey at Rolla made a number of helpful suggestions. Mr. John W. Koenig of the Missouri Geological Survey drafted figures 2 and 4 and edited the typescript prepared by Mrs. Virginia Jackson who also contributed many useful comments.

USES OF TOPOGRAPHIC MAPS

Topographic maps were originally devised to meet military demands for maps which would accurately portray the terrain. Civil engineers, in the planning of highway and railroad locations, were early users of these maps. Geologists have also found them to be necessary in mapping the distribution of rock formations and mineral resources and in searching for new mineral deposits. Engineering uses have expanded to include planning for hydroelectric, flood-control, pipeline, telephone, powerline, water main, drainage, sewerage, and major construction projects. Planning for the locations of airports, munition plants, and housing projects is greatly simplified with these maps. The schoolboy's geography atlas, the tourist's highway maps, and the aviator's aeronautical charts are largely based on topographic map data. State and Federal agencies find topographic maps a necessary aid in forestry, reclamation, and fish and game projects. Bankers, lawyers, and real estate men use these maps to locate and assist in evaluating land holdings.

This discussion would not be complete without mentioning the outdoorsman who finds the maps invaluable for hiking, fishing, or hunting. The fisherman can use these maps to preview a float trip on an unfamiliar stream. A study of the road and trail system, bluffs and valley flats, and fords and bridges will aid in determining a point of origin ("put-in") and termination ("take-out"). Camp sites can be predetermined to some extent because important springs are generally shown, and terraces above average high waters and sheltering cliffs are distinguishable after a little practice in map reading. The travel rate of a several-day float can be more satisfactorily established en route if the voyager checks his progress on a map. Also the pickup point may be shown on an extra map entrusted to the one who is to make a rendezvous at journey's end.

Because his plans are, or should be, influenced by topography and land ownership, the hunter can find a friend and coat-pocket guide in topographic maps. They show the boundaries of restricted areas such as game refuges and military reservations. A map devotee can generally recognize property fence lines after he has become familiar with fractional sections, townships and ranges. Most land owners know the legal descriptions of their property and are very cooperative in explaining their property lines to a stranger who observes the courtesy of requesting permission to hunt or fish on his land. One need not consult an engineer or geologist to learn the uses of legal land descriptions as portrayed on topographic maps, for many bankers, lawyers, and almost all real-estate or title and abstract specialists are familiar with these maps.

The hunter, properly equipped with topographic maps—and the ability to read them—can minimize the hazards of getting lost or of firing toward nearby homes or highways. With a graphic portrayal of the valleys, ridges, and uplands within pocket range, he can eliminate some of the guess but none of the sport from hunting. Many, but not all of these maps, have the wooded areas at the time of publication coded in green, a feature which aids in finding one's location as well as in selecting likely hunting and camping areas.

QUADRANGLES

Topographic maps, because of their rectangular shape, are customarily referred to as *quadrangles* and are named for contained, prominent geographic features. For example, the Jefferson City Quadrangle contains that city and its surrounding area. Two quadrangles, Sedalia East and Sedalia West, cover the area of the city of Sedalia.

In several cases, two quadrangles have the same name but differ in having different scales and sizes of included areas. The Rolla 7½-minute quadrangle contains one quarter of the area of the Rolla 15-minute quadrangle but is on a scale approximately two and a half times as great (or as detailed) as the 15-minute quadrangle. Other examples are the Jefferson City, Columbia, Smithville, Leavenworth, Dearborn, Gower, West Plains, Altenburg, Hale, and Moberly Quadrangles. In addition to the 7½- and 15-minute Moberly and Jefferson City Quadrangles, there are also 30-minute quadrangles with the same names which contain four times the area of the 15-minute quadrangles or 16 times the area of the 7½-minute maps. These two 30-minute quadrangles were mapped in the 1880's and are obsolete by modern standards.

The designations "7½-minute" or "15-minute" mean that the respective maps include the area spanned by 7½ or 15 minutes of latitude and longitude. Latitude lines circle the earth in an east-west direction parallel to the equator; longitude lines in a north-south direction, converging at the poles. A minute of latitude is approximately a nautical mile (6,080 feet). A minute of longitude is less than a nautical mile outside of the equatorial latitudes.

A 7½-minute quadrangle is 8.62 miles long by 7.00 miles wide in extreme southern Missouri and contains an area of approximately 60 square miles. Because of the convergence of longitude lines toward the poles, the same number of minutes of longitude spans a shorter east-west distance in northern Missouri than in the southern part of the state. As a result, a 7½-minute quadrangle in extreme northern Missouri is 8.62 miles long by 6.58 miles wide and includes an area of approximately 56 square miles. Fifteen-minute quadrangles in corresponding latitudes span twice the length and twice the width and contain four times the area of 7½-minute quadrangles. Thus a 15-minute quadrangle contains approximately 241 square miles in extreme southeastern Missouri and 227 square miles in extreme northern Missouri.

MAP READING

Ideally, one should be introduced to topographic maps with a map of his home or familiar surroundings. With this as a starting point, the map reader should first study the material in the legend because it reflects the limitations and degree of accuracy of the map. He should also note the date of publication. This is important because of the higher standards of accuracy achieved in recent years. If the map is quite old, the location of roads and houses may no longer be reliable because of road abandonment or relocations and population shifts. Modern highways are indicated by red-line overprints on relatively recent reprints of some old maps, but no attempt has been made to bring all of the roads up to date. The topography shown on maps made prior to the late 1920's is also much less accurate than that of recent maps. The scale and contour interval, both of which will be explained later, are likewise important in evaluating the degree of accuracy in both distances and elevations.

Map orientation.—A general rule applicable to all types of maps is that the top of the map is north, the bottom south, the right east, and the left west, unless otherwise indicated. Any departure from this rule is, or should be, indicated by a north-pointing arrow or suitable symbol. All topographic maps are published with the top of the map pointing north, and the beginner should attempt to "orient" or hold the map in the field so that this proper directional relationship is maintained.

Because the magnetic pole is not at the geographic north pole, a compass needle will not point to true north in Missouri, also it may be deflected by a local influence such as a high tension line or some types of nearby metal. In southeastern Missouri, the compass needle points about 5 degrees east of true north, and in the extreme northwestern part of the state, it points to between 8 and 9 degrees east of true north. Every topographic map contains in the legend two arrows showing the directions of true north and magnetic north respectively. The angular difference in degrees between these two directions is the declination. The amount of declination changes slightly with time but generally not enough to be considered when using an ordinary compass. Figure 1 shows by isogonic lines (lines of equal declination) the amount of declination in various parts of Missouri.

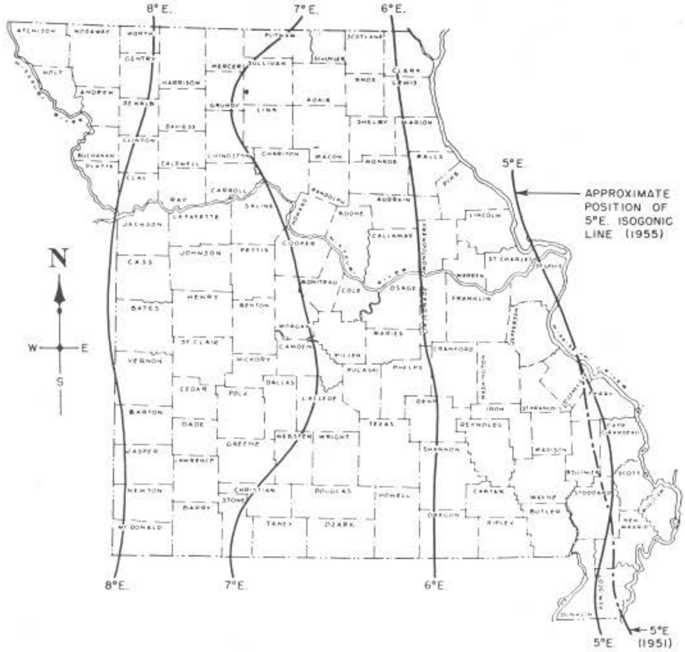

Fig. 1. Isogonic chart of Missouri. The lines of equal magnetic declination (isogonic lines) in 1955 are given for every degree within the state. The dashed line indicates the position of the 5°E isogonic line in 1951.

Map scales.—Map scales are commonly expressed by a fraction with the numerator-denominator ratio expressing the corresponding ratio between a unit of distance on the map and the same unit on the ground. For example, the scale 1/24,000 means that one unit of measurement on the map is equal to 24,000 units on the ground. One inch of distance on the map equals 24,000 inches on the ground; one foot on the map equals 24,000 feet on the ground.

For simplicity in measurement, scales are generally expressed in terms of miles or feet on the ground represented by inches on the map as shown in Table 1. Scales are also expressed by bar scales on the map, a feature which facilitates scaling of distances with a marked strip of cardboard or a pair of dividers.

The relationships of fractional scales to one another are often confusing to the novice. Because the numerator is a constant of 1, the scale increases as the denominator decreases. Thus, a 1/24,000 scale is both larger and more detailed than a 1/62,500 scale. The original topographic maps in Missouri were commonly at a scale of 1/125,000. Later maps were 15-minute quadrangles at a scale of 1/62,500, and relatively recent maps are commonly 7½-minute quadrangles at a scale of 1/24,000. Because of the trend to larger scaled quadrangles in 7½-minute size, joining quadrangles may not be of matching sizes or scales. Table 1 shows the values of some common United States Geological Survey topographic map scales used in Missouri.

TABLE 1

Feet and miles on earth's surface represented by inches on map

Scale of map	*Inches on map*	*Feet on earth's surface*	*Miles on earth's surface*	*Map size in minutes*
1/24,000	1 2.64	2,000 5,280	0.3788 1	7½
1/31,680	1 2	2,640 5,280	0.5000 1	Old 7½ and 15 maps
1/48,000	1 1.32	4,000 5,280	0.7576 1	
1/62,500	1 1 approx.	5,208.3 5,280	0.9864 1	15
1/125,000	1 ½ approx.	10,416.7 5,280	1.9729 1	30*
1/500,000	1 ⅛ approx.	41,666.7 5,280	7.8914 1	State topographic map

*Obsolete in Missouri

The scale of 1/24,000 means that 1 inch on the map represents 24,000 inches or 2,000 feet on the earth's surface (24,000÷12=2,000 feet). One mile contains 5,280 feet, therefore, 1 inch on the map represents 2,000÷5,280 or 0.3788 of a mile on the earth's surface. Since 1 inch on the map represents 0.3788 of a mile or 2,000 feet on the earth's surface, a complete mile on the map would be represented by 1÷0.3788 or by 5,280÷2,000=2.64 inches.

For convenient reference, maps of different scales are spoken of in terms of the approximate number of miles per inch. For instance, 1 inch on a map of the scale of 1/62,500 is approximately equal to 1 mile (actual measurement is 0.9864 of a mile). On a map of the scale 1/125,000, 1 inch equals approximately 2 miles (1.9729 miles), and at a scale of 1/500,000, 1 inch equals approximately 8 miles (7.8914 miles).

Contour lines and intervals.—The most important symbols on a topographic map, the contour lines, are for the novice the most difficult to comprehend. A contour line is an imaginary line connecting points of equal elevation (Figs. 2 and 3). The vertical distance between adjacent contour lines is called the contour interval. The amount of this interval is normally given in the legend of all topographic maps. On recent 7½-minute Missouri quadrangle maps, the contour interval is generally 10 feet, and on the smaller scale, 15-minute maps, it is 20 feet. If the land is exceptionally flat, as in the lowlands of southeastern Missouri, a contour interval of 5 feet is used.

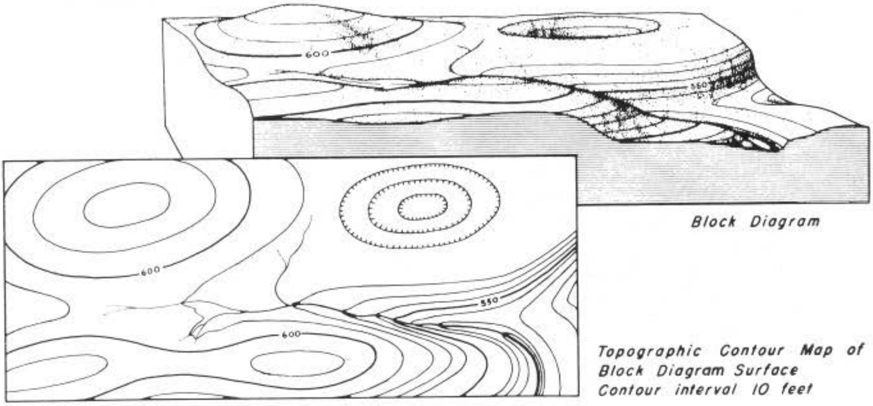

Fig. 2. Land forms. This figure depicts the manner in which relief is shown on a topographic map. The upper part of the figure shows a perspective view of a hill, a depression, and a river valley. The contour lines in this perspective view indicate the position of points of equal elevation and correspond with the contour lines in the topographic map in the lower part of the figure. The contour interval used here is 10 feet, which means that the vertical distance between one contour and the next is 10 feet.

Every fifth contour line is heavier than the intervening lines and can be traced to a point where the elevation in feet above sea level is given at a gap in the line. If a heavy contour line is marked as 550 and the contour interval is 10 feet, the lighter line immediately downslop from this line will have an elevation of 540 feet above sea level, and the first light line upslope will connect points lying at an elevation of 560 feet.

A conical hill would be represented by concentric contour lines with the innermost circle of the smallest diameter representing an elevation near the peak. A ridge is portrayed by roughly parallel contour lines which form an elongated U pattern if the ridge terminates in a nose. Contour lines that are relatively crowded indicate a steep slope such as a cliff or bluff, and those which are relatively wide apart indicate a relatively flat surface such as a flood plain or prairie (Fig. 3).

Contour lines always V upstream. This characteristic is demonstrated by the shore line of a dammed stream. Such a shore line represents a line of equal elevation above sea level and, thus, has a pattern identical to that of a contour line. Every contour line is like a string joined at both ends because it never comes to an end or splits. It ultimately forms a closed pattern, although it may be necessary to join several quadrangles to see this characteristic.

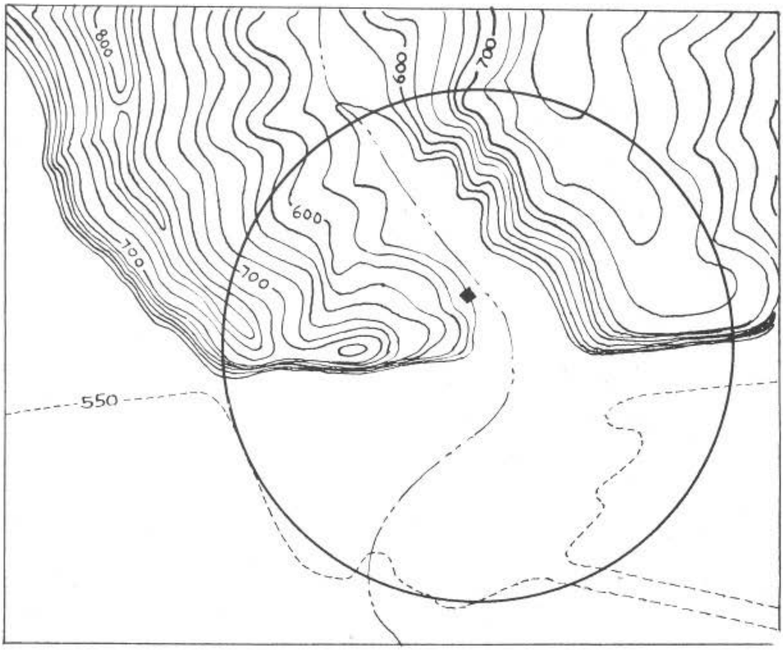

Fig. 3. Contour spacing. The crowding and spreading of the contour lines in the topographic map show respectively the bluffs and flood plain pictured in the photograph. The photograph was taken from a position on the flood plain looking north towards the bluffs and valley. The black square on the map represents the dwellings seen in the photograph, and the circle represents the approximate coverage of the photograph. The contour interval for the map is 20 feet. Photograph by courtesy of the Missouri Conservation Commission.

The novice often has difficulty in finding "which way is up" when encountering a maze of contour lines. Two good guides help the beginner to determine the directions of slopes: (1) the drainage lines (printed in blue) which mark the areas of relatively lower elevations and (2) the numerical values of elevations inserted on every fifth line which is heavier than the intermediate lines. On some quadrangles, selected contour lines are numbered between the heavy lines to facilitate reading elevations. Closed depressions are depicted by "depression contours". These contour lines have small barbs along the side facing the depression. If ordinary contour lines form a closed pattern, the highest point is in the area lying within the innermost closed line, conversely, the lowest point within a depression occupies a similar position within closed depression contours.

Additional benchmark or spot elevations are indicated respectively by a triangle or an X. The majority of such elevations are indicated by black numbers. If there is no triangle or X associated with the black numbers, the elevation referred to is generally at a road corner or at a road and section line intersection. Elevations are often given for section or quarter section corners.

An excellent Missouri map for the study of contour lines is the relief map of the Ironton Quadrangle in which the topographic features are accentuated by shading.

Colors and symbols.—Five colors are used to show major features on topographic maps: Black is used to indicate the works of man, such as houses, roads, transmission lines, and railroads; red is used to show surfaced roads or highways and on recent maps to show township boundaries, section lines, and township and section numbers; blue represents drainage and water features such as streams, ponds, lakes, and springs; brown is reserved for features of relief such as contour lines; and green represents timbered or orchard areas.

Variations in this color scheme will be found in some of the older Missouri maps. For example, section lines were shown in black until fairly recently, also the use of green to show timbered tracts or orchards is a relatively recent innovation.

A folder titled *Topographic Map Symbols,* published by the United States Geological Survey, may be obtained free of charge from that organization at Washington 25, D. C., or from the Missouri Geological Survey, Box 250, Rolla, Missouri. This folder, in addition to showing all of the various map symbols, contains a contour map and sketch of the same area showing the corresponding land forms. An excellent discussion of material similar to that presented herein is also given. United States Geological Survey Circular 368 titled *Features Shown on Topographic Maps,* may also be ordered from the Geological Survey in Washington at no charge. This publication discusses the various scales and symbols and also contains contour maps of selected topographic features.

Government land divisions.—Figure 4 shows the sizes and relationships of idealized townships, ranges, sections, and fractional sections. Government townships are designated by their positions relative to north-south lines of longitude called principal meridians and east-west latitude lines called base lines. For example, the abbreviation T. 1 S., R. 3 E., refers to a township lying in the first tier of townships south of a certain base line and in the third township east of a principal meridian.

The fractional section system of locations shown in Figure 4 is very convenient for designating locations in written and oral communications, but care must be taken that the proper township and range are read from the map. The abbreviated location of Area

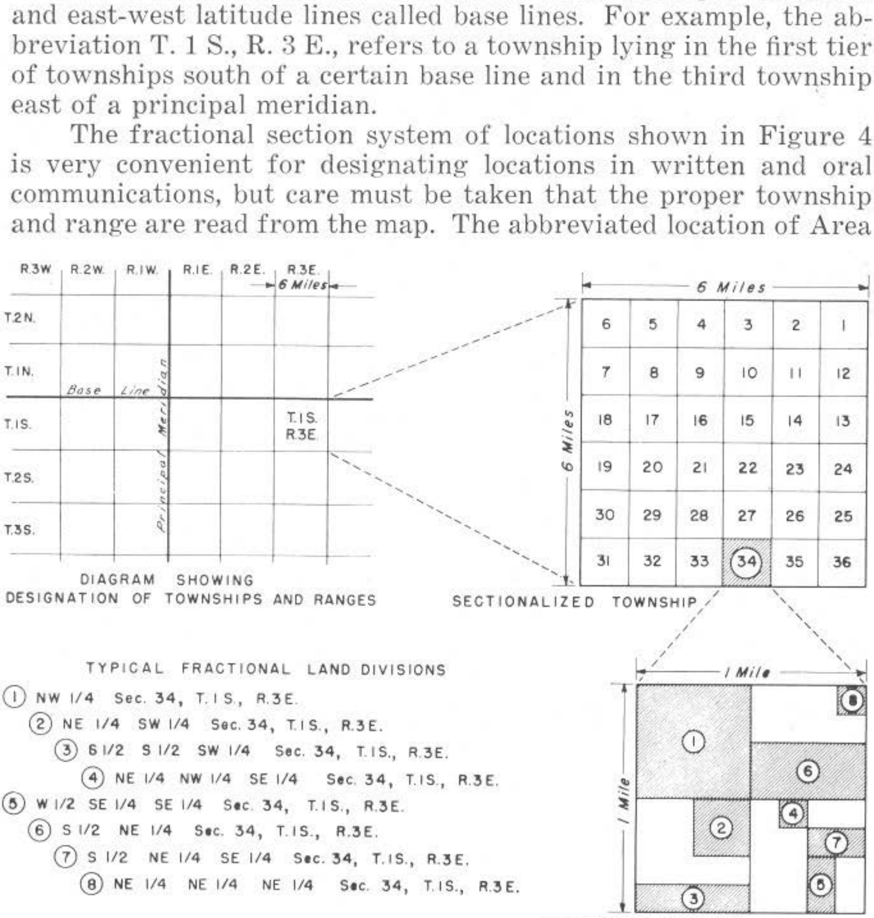

Fig. 4. Idealized government land divisions. This diagram illustrates the relationship of fractional land divisions in quartered sections to townships and ranges. The numbered location descriptions to the left of the quartered section correspond with the numbered and shaded areas in the section which in turn corresponds with the shaded area in the township above it.

7 in Figure 4 is designated as the S½ NE¼ SE¼ sec. 34, T. 1 S., R. 3 E. The expanded version of this abbreviation reads as follows: the south half of the northeast quarter of the southeast quarter of Section 34, Township 1 South, Range 3 East. Townships are coded along the east and west margins of the map; ranges along the north

and south margins. In general, boundaries of topographic maps do not follow township and range boundaries.

As shown in Figure 5, all Missouri townships extend northward from a parallel of latitude passing through central Arkansas and thus have a "north" designation. The Fifth Principal Meridian enters Missouri in southwestern Ripley County and leaves the state in eastern Pike County, therefore, all Missouri ranges are designated as "east" or "west" depending upon their relative position to this meridian.

An ideal government township is 6 miles long by 6 miles wide and contains 36 sections, each of which encompasses an area of 1 square mile or 640 acres (Table 2). It should be emphasized that a government township does not necessarily have the same area and boundaries as a political township. Political townships can be of various sizes and are given proper names such as *Liberty Township* rather than numerical designations.

Table 2

Common units of land measurement

Distance

1 Link=7.92 inches.
1 Rod=25 links=16½ feet=¼ chain.
1 Chain=100 links=66 feet=4 rods.
1 Furlong=660 feet=40 rods.
1 Square acre=208¾ feet on each side.
1 Statute mile=5,280 feet=1.609 kilometers=320 rods=80 chains=8 furlongs.
1 Meter=100 centimeters=39.37 inches=3.2808 feet.
1 Nautical mile=6,080 feet.
1 Kilometer=1,000 meters=0.6214 (approximately ⅝) mile.
1 Vara (Spanish land grants)=33⅓ inches; 36 varas=100 feet.
1 Arpent (French land grants)=linear distance along one side of a square arpent (about 11.5 rods).

Area

1 Acre=43,560 square feet=160 square rods=10 square chains.
1 Arpent (French land grants)=0.85 acre.
1 Section (ideal)=1 square mile=640 acres.
¼ section (ideal)=160 acres.
¼ ¼ section (ideal)=40 acres.
¼ ¼ ¼ section (ideal)= 10 acres.
1 Township (ideal)=36 square miles=36 sections=23,040 acres.

The surveyor's work of laying out square patterns is complicated by the fact that the earth is not flat. As a result, some townships and sections do not conform to the ideal shapes and areas. Further distortions of sizes and shapes have resulted from errors in original surveys. Generally, compensations for distortion are made in the western and northern tiers of sections in a township. Thus, sections 1 through 6 in the northern tier and sections 6, 7, 18, 19, 30, and 31 in the western tier may depart radically from the idealized square mile containing 640 acres.

Extreme distortions are exemplified in north-central Taney County where sections 1 through 6 in T. 24 N., R. 20 W., are more than 4 miles long. In T. 24 N., R. 19 W., immediately to the east, sections 4, 9, 16, 21, 28, and 33 are approximately a third of a mile wide and are the most westerly sections in that township and the one adjoining to the south.

As can be seen in Figure 5, many of the townships adjacent to the Fifth Principal Meridian in Missouri are approximate paral-

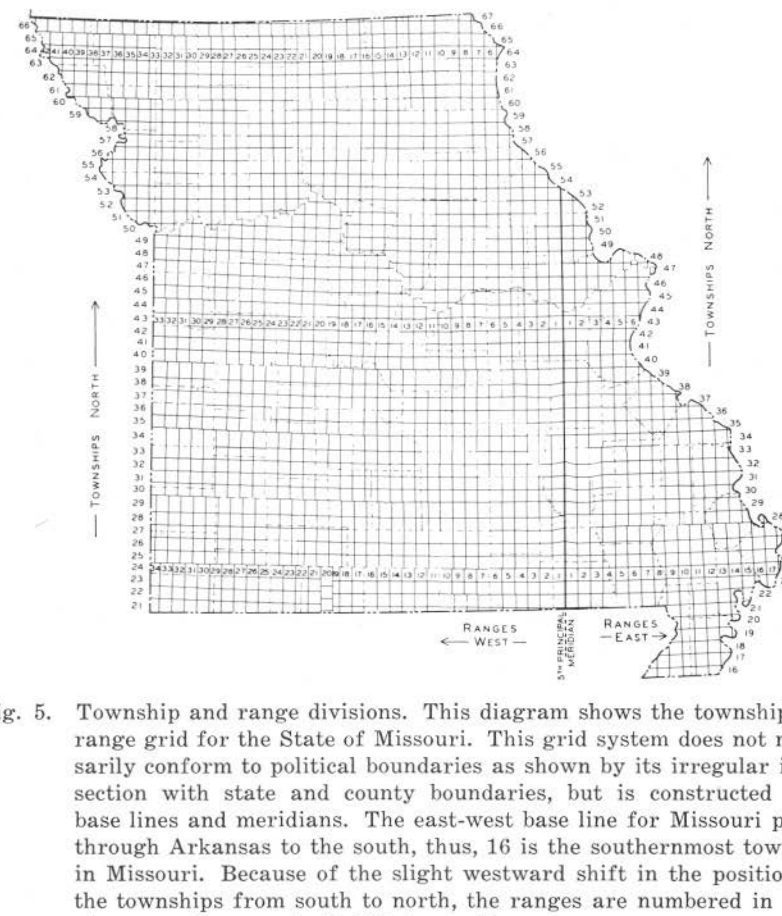

Fig. 5. Township and range divisions. This diagram shows the township and range grid for the State of Missouri. This grid system does not necessarily conform to political boundaries as shown by its irregular intersection with state and county boundaries, but is constructed upon base lines and meridians. The east-west base line for Missouri passes through Arkansas to the south, thus, 16 is the southernmost township in Missouri. Because of the slight westward shift in the positions of the townships from south to north, the ranges are numbered in three places on the map to facilitate reading.

lelograms. The sections within these townships contain similar distortions in shape. Because of the variation in sizes of sections, it is common practice to add the phrase "more or less" in giving acreages in deeds.

Land grants.—Parts of Missouri are not sectionalized. These areas contain irregular parcels of land which are usually rectangular or polygonal and are designated by survey numbers such as Survey 2938. Such plots are land grants made to settlers by the Spanish or French governments before Missouri was surveyed into sections and townships.

Because the distribution of land grants conforms to very early settlement patterns, they are most common along the Mississippi and lower Missouri Rivers and are located in the earliest mining areas farther inland, as in Washington, Iron, and Madison Counties. Subsequently established sections terminate at the boundaries of these irregular tracts of land as shown on the base map of a part of Ste. Genevieve County (Fig. 6).

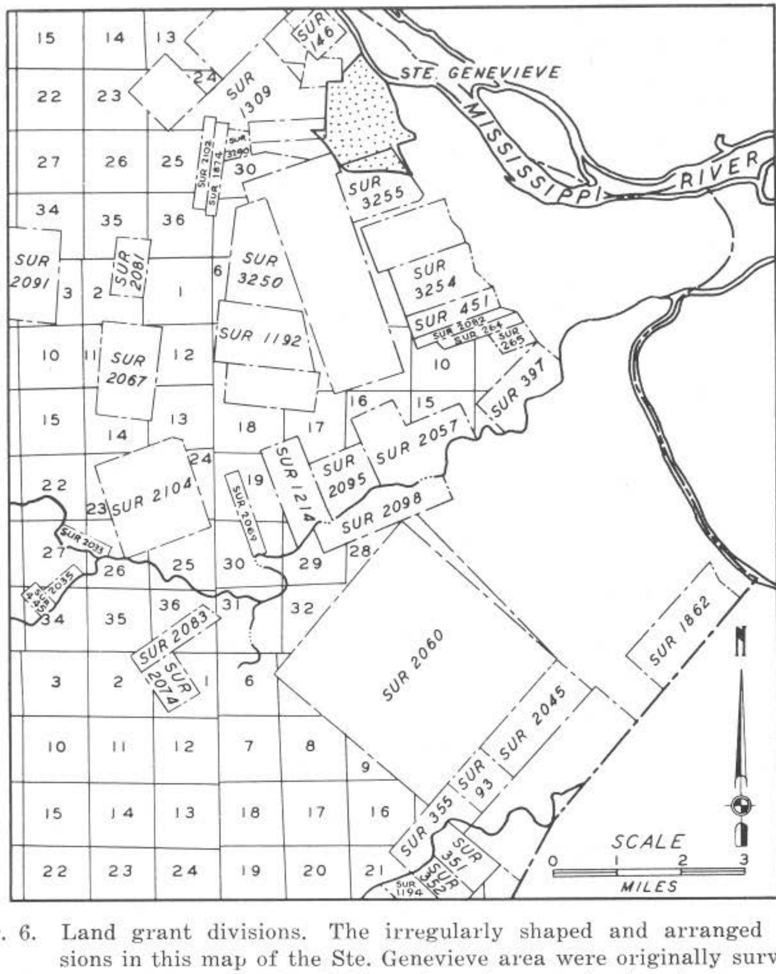

Fig. 6. Land grant divisions. The irregularly shaped and arranged divisions in this map of the Ste. Genevieve area were originally surveyed for land grants. The divisions have been retained and are marked in most instances by survey numbers such as SUR 2060. The more recent township and range divisions terminate at the boundaries of the older land grants.

Special topographic maps.—Topographic maps of the entire State of Missouri have been published on a scale of 1/500,000 or approximately 8 miles to the inch with a 200-foot contour interval. County topographic maps are available for Caldwell, Lawrence, Livingston, Perry, and Ste. Genevieve Counties. These county maps were all prepared prior to 1929, and most of the road and dwelling locations are out-of-date. Additional information on these maps, as well as other special topographic maps, may be obtained from the Missouri Geological Survey at Rolla.

MODERN MAP MAKING

The Topographic Division of the United States Geological Survey is the principal map making agency for the Federal Government. Under a cooperative agreement, Missouri topographic maps are prepared by this Federal agency with financial assistance from Missouri through the State Highway Commission and the Geological Survey. Some topographic mapping is done by the United States Army Corps of Engineers and the Mississippi River Commission in areas of special interest to those agencies such as in the boot-heel region of Missouri on the Mississippi River flood plain.

With the development of aerial photography, the aerial photograph has become one of the important sources from which the modern topographic map is constructed. Consequently, the technical procedures involved in map making have been profoundly altered in recent years.

An aerial photograph does not constitute a map. Because of variations in ground elevations, tilting of the camera and other phenomena related to the attitude of the aircraft in flight, and variable characteristics of the camera lens, an aerial photograph gives a perspective picture of the terrain. Also, a single aerial photograph affords no means of measuring variations in ground elevations. Therefore, before an aerial photograph can be of any value in map making, it must be processed so that the photographic image can be transformed into a projection from which measurements in three dimensions can be accurately taken. This processing utilizes the principle of the old parlor stereoscope, and all instruments which plot map detail from aerial photographs work on this principle.

If vertical aerial photographs are to be used for mapping, they must be taken in lines of flight so that each successive photograph will overlap the adjacent photograph by approximately 58 percent, and each line of flight must overlap adjacent flight lines by approximately 25 percent. The area on each photograph that is overlapped by an adjacent photograph can then be used to produce a stereoscopic image from which three dimensional measurements can be made.

The technical requirements for aerial photography are rigid. They specify the plane's altitude above mean ground level, the spacing between successive exposures, the focal length of the camera, film specifications, maximum tilt and tip variations, and other necessary factors.

When a particular area has been chosen for mapping, certain basic specifications are established from a reconnaissance report of the area. These include the publication scale, the contour interval, and the method of compilation. The contour interval has the greatest effect on the cost of mapping and on the time necessary to complete the work. The cost of photography will also depend on the method of production. If the area is relatively flat, only the planimetric features, such as roads and streams, are drawn from the photographs, and the contours are drawn in the field from field surveys. In such a case, considerable latitude is allowed in the choice of type and quality of photographs. If, however, the contouring is to be done with stero-plotting instruments, the photography must conform to more rigid specifications.

The value of any map depends upon its accuracy. Thus, the basic control which is established by surveying in the field is most important because the entire compilation of the map is dependent upon it. There are two types of basic control needed to produce maps: (1) the triangulation stations and traverse lines with monuments marking horizontal positions, and (2) the level lines which establish elevations. It is necessary that the distribution of this basic control be such that horizontal positions occur at the beginning and end of every other flight of photographs in order to tie the position of the photography to true ground position. In addition to this basic control a number of other control points are selected to furnish elevations. These points are located in each corner of the stereoscopic image formed by each pair of overlapping aerial photographs. This point selection is called supplemental control and the points selected on the stereoscopic image are all objects which can be easily located on the ground by a field engineer. The accuracy required for these supplemental control points varies with the contour interval of the area being mapped, and the elevation of a point should be constantly accurate to within one tenth of the contour interval. Thus, if the contour interval is 10 feet, the supplemental control point should be correct within one foot. However, the accuracy requirements for basic control remain constant for all maps, because it not only controls the accuracy of the mapping on any one quadrangle, but it also ascertains the accuracy of one map to another. Therefore, the accuracy of this basic control network must be such that a standard of mapping accuracy is maintained across the nation.

Most maps are compiled by stereo-plotting instruments after the supplemental control work has been completed. Several types of stereo-plotting instruments are used by the United States Geological Survey and other mapping agencies. These instruments are: the multiplex projector (Fig. 7), the Zeiss stereoplanigraph (Fig. 8), the Wild autograph, the Kelsh plotter, the ER-55 projector, and the Twinplex. Each type of instrument has its own special advantages or features.

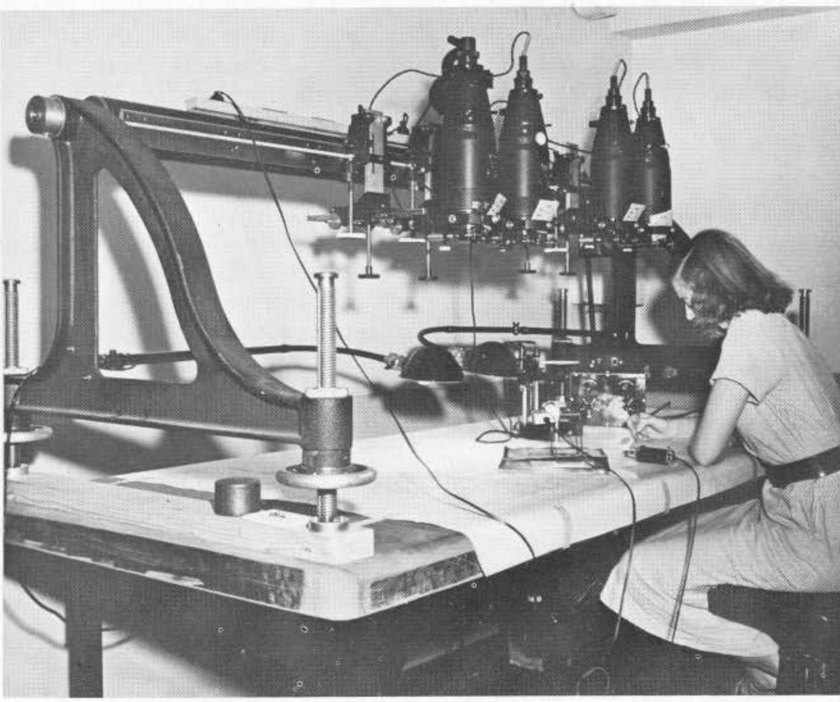

Fig. 7. Multiplex projection unit. A complete multiplex mapping unit with projectors mounted on a supporting frame. Auxiliary equipment and a part of the map being compiled are on the table.

Instruments using the ER-55 projectors are recent developments which are unique from the others mentioned in that they utilize oblique photographs rather than vertical aerial photographs. An oblique photograph is obtained by using a pair of aerial cameras which are coupled rigidly together so that their respective optical axes form an angle of 20 degrees with a vertical line and an angle of 40 degrees with each other. It is necessary that the shutters be synchronized so that simultaneous exposures are made with both cameras of the coupled pair. The camera couple may be oriented along the flight line or at right angles to it. When oriented along the flight line, convergent oblique photographs are obtained. For a series of exposure stations, the exposure in the forward looking camera at one station will be convergent with the exposure of the backward looking camera at the next exposure station. This convergent pair of exposures forms a stereoscopic image; the overlap being 100 percent in the direction of flight. The oblique angle from which the pictures are taken increases the angle at the intersection of the conjugate image rays, thereby, allowing for vertical measurements of greater accuracy.

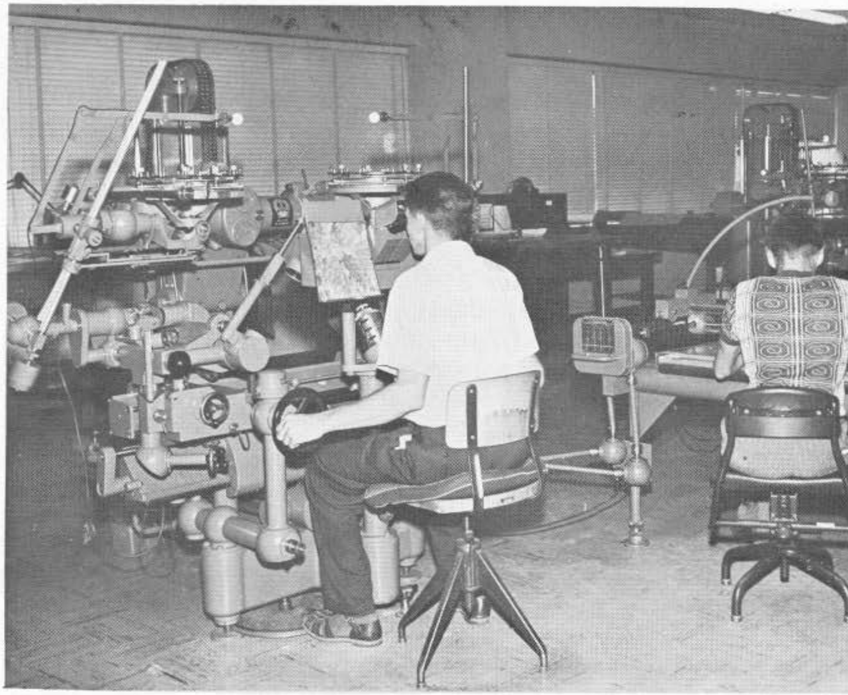

Fig. 8. Stereoplanigraph. This instrument which is manufactured by Zeiss Aerotopograph, Jena, Germany, is a highly complex and costly instrument. It is capable of performing very accurate aerial triangulation and map compilation and is classified as a double-projection type of instrument in which the projection of conjugate images is viewed through a complex optical system rather than directly as in the multiplex or Kelsh plotter. The optical system is connected through an interchangeable gear system to a plotting mechanism on the drawing table (shown on the right of the photograph) which may be selected so that the scale ratio may be changed over a wide range.

When the camera couple is oriented at right angles to the line of flight, photographic coverage is increased greatly but is only suitable for reconnaissance mapping and is not used for the production of standard topographic maps.

The height at which the photographs are taken depends upon the proposed contour interval and the instrument to be used for compilation. For example, if a multiplex instrument is to be used and a map with a 20-foot contour interval is desired, vertical photographs are usually taken from an altitude of about 12,000 feet above the average ground surface. If a map with a contour interval of 10 feet is desired, the photographs are usually taken at an altitude of 8,500 feet.

The deciding factor which affects the choice of instrument to be used in compilation and the type of photography is nearly always economy. The instrument selected for compilation should possess features that are most practical and economical for the mapping of a particular type of terrain. This is necessary even though all the instruments utilize the same principle of projecting an image of two overlapping aerial photographs through a stereoscopic arrangement.

When an individual aerial photograph is projected onto a flat surface, the image has many distortions. Straight roads which go over hills appear to have curves, the relative positions of points in the image are not proportionately related to the positions of the same points on the ground, and many other errors can be found. These distortions result from several causes, two of which are the tilt of the airplane from a horizontal flight position and the relief or varied elevations on the ground.

The only method found so far for correcting this distortion is to form a so-called *model* or stereoscopic image by projecting overlapping images of two aerial photographs through the projectors of a stereo-plotting instrument onto a flat surface below the instrument (Fig. 9). This stereoscopic image is commonly produced by projecting the image of one photograph with a red filtered light, the other with a green filtered light. The two images are then viewed through glasses which contain a red lens in one eyepiece and a green lens in the other eyepiece. The operator thus sees a stereoscopic image or model. This stereoscopic model is an exact three dimensional image of the ground surface and is reduced in size to fit the mapping scale. The exact scale of the model is achieved by first plotting the true geographic position of the basic control points on the map sheet and then by varying the size of the model to fit the position of these points. In order to read true elevations from this stereoscopic model, the projectors of the stereo-plotting instrument are tilted and adjusted in relation to the mapping surface so that their positions simulate the positions of the camera at the two exposure stations when the photographs were taken. This adjustment is checked by reading the elevations of the supplemental control points until they all read relatively true to each other within the same model.

The projectors are placed far enough above the mapping surface to allow room for a small moveable tracing table (Fig. 10) which has a 3-inch diameter, circular platform upon which the stereoscopic image is projected. In the center of this circular plat-

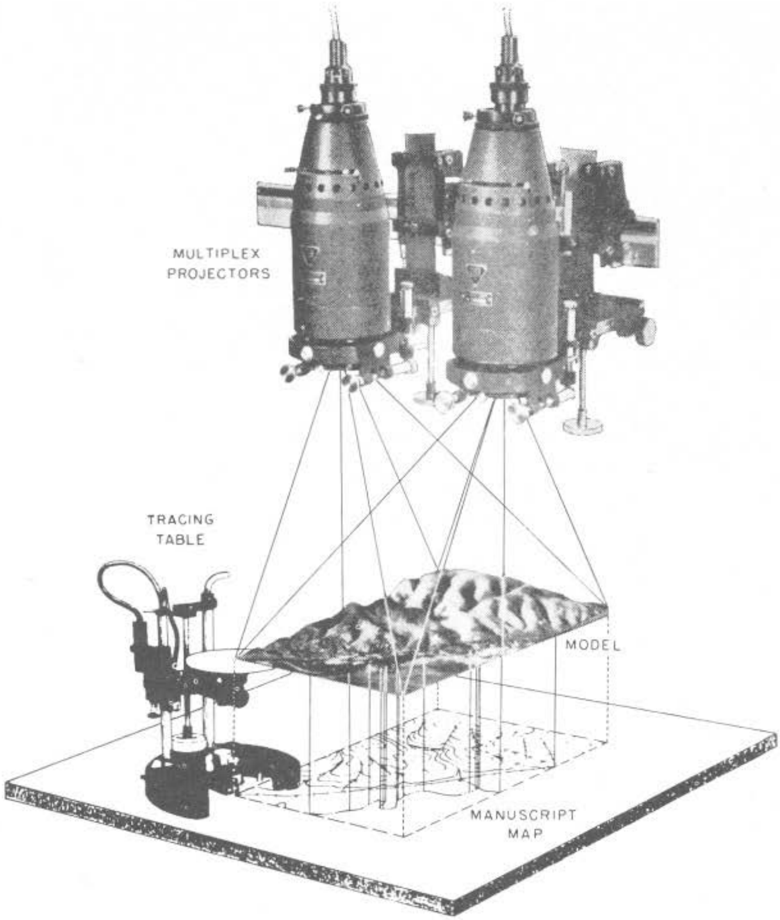

Fig. 9. Principle of the multiplex. This diagram graphically illustrates the principle of the multiplex projection of two overlapping aerial photographs—each of the two projectors produces an image of one of the two photographs—so that a three dimensional image or model which is graphically portrayed in the diagram can be seen by the operator on the adjustable platform of the tracing table. With the aid of the tracing table, the operator can then project points on the three dimensional image onto the two dimensional mapping surface beneath the image.

form, there is a small point or dot of light which lies directly above a pencil point at the base of the table. Thus, any point on the stereoscopic image or model can be selected or pinpointed by the dot of light and then projected to the mapping surface by dropping the pencil point to the map sheet below. At the present time, a pantograph is generally attached to the tracing table to enlarge or re-

Fig. 10. Multiplex tracing table. A Bausch and Lomb multiplex tracing table showing how detail from the stereoscopic image is projected onto the mapping surface. The entire table is mounted on roller bearings and can be moved to any desired position on the map by the operator.

duce a drawing of the image to the scale desired. To find an elevation on the stereoscopic image, the platform on the tracing table is raised or lowered so that the light dot in the center will touch the apparent ground surface in the model. A vernier scale attached to the tracing table registers the amount of vertical motion of the platform, and readings on this scale can be interpolated to read true ground elevations. A contour line can be traced at any desired elevation by locking the vertical position of the platform at the proper reading for that elevation, by lowering the pencil point of the tracing table to the map sheet, and by moving the table so that the light dot is in constant contact with the apparent ground surface. Contours and planimetric detail are traced in this manner on a Mylar plastic sheet, and as soon as the map copy is approved, it is scribed or engraved by cutting the pencil lines with engraving tools designed for this purpose. This Mylar sheet has a soft, yellow opaque coating which takes a pencil line without scratching. The engraving tool or scriber cuts through this opaque coating without disturbing the plastic base, and a neat, even, transparent line results. The cut line is thus similar to a transparent line on a photographic negative, and positive prints can be made directly from the scribed Mylar sheets in the same manner as prints are made from photographic negatives.

When the scribing of the map is completed, the scribed Mylar sheet is sent to the photographic unit, and a positive blue line contact print is made. This blue line print is then sent to the field engineers who inspect the map for accuracy and completeness. Missing contours are added, and necessary corrections are made on the spot. If the corrections are extensive, the copy is returned to the stereo-plotting unit with detailed instructions on how the corrections should be made. Also, boundaries of towns, civil township lines, counties, reservations, parks, section lines, land grants, and land corners are located and named. All names for towns, roads, railroads, streams, lakes, reservoirs, civil townships, and counties, are added. Swamps, types of drainage, and other features are classified. When the completion survey is finished the blue line copy is forwarded to the cartographic unit.

In the cartographic unit, the corrections on the blue line field copy are transferred to the original map scribed on the Mylar sheet. After all the corrections have been made, the photographic unit makes the necessary number of blue line copies for color separation plates; one plate for each color. Normally, five of these plates are required. They are then sent to the scribing unit for processing. On one of these plates, only those lines that are to appear in brown on the map will be scribed; on another only those lines that will appear in blue; on another the black, and so on until all the plates have been processed. The scribing of these plates must be very carefully done, otherwise, the lines will not be uniform in weight, and any variation from copy will result in poor registration when the final map is printed. When this operation is completed, a composite of the scribed plates is made by printing a copy of each plate on the same sheet of paper. This composite usually is in one color.

The composite and the scribed plates now go to the checking unit where careful inspection is made of the copy. Line inaccuracies are marked for correction, omitted parts called for, interference or poor registration noted, and any other omissions or errors are checked. The plates are then returned to the drafting unit for correction. When these are made and again checked and approved, another composite is made. This composite is then sent to the editing unit.

This unit adds the lettering and names to the map. All lettering in black is stuck up on a transparent overlay which is placed over a blue line composite of the culture and drainage sheets so that the lettering can be arranged where it will not interfere with other lines. Contour and section numbers are inlayed on the scribed copy of their respective plates, with the contour numbers on the brown plate and the section numbers on the red plate. This stickup type is specially prepared and comes in various sizes as ordered. It is printed on a transparent plastic film with a sticky backing that will adhere to any smooth surface when firmly pressed against it. To avoid delay, the editing unit anticipates the arrival of a map in their unit and has the necessary type in their file when it is needed. Final inspection is made for quality and completeness of the work, and further discrepancies are noted for correction. After the inspection and lettering are completed, the plates are returned to the photographic unit for a composite of the completed plates. This composite, except for color, will resemble the finished map when it is published.

Next comes the final review before going to the press. In this review, the map is given a cursory inspection to assure conformance to policy requirements and other map standards. The scribed plates and all needed material are then sent to the reproduction unit at Washington, D. C., for printing by photolithography.

MAP ACCURACY

In 1941, national map accuracy specifications were adopted, and all standard topographic maps of the Federal Government meet them. The specifications provide that not less than 90 percent of the elevations interpolated from contours shall be correct within half of a contour interval, and not less than 90 percent of all horizontal positions that are well defined shall be correct within 1/50 inch at publication scale. This tolerance would be equal in horizontal distance on the ground to 40 feet for 1/24,000 scale mapping and, by agreement, 85 feet for 1/62,500 scale mapping. Therefore, modern topographic maps meet the needs of advance studies for most engineering projects and should be sufficiently accurate for first cost estimates of construction.

ORDERING TOPOGRAPHIC MAPS

Topographic quadrangle maps may be ordered from the Missouri Geological Survey and Water Resources, Box 250, Rolla, Missouri, for 30 cents each, postpaid. Designation of the quadrangle desired may be made in several ways: (1) A topographic index map showing available topographic quadrangle maps in Missouri may be obtained from the Missouri Geological Survey at no charge. (2) The area for which coverage is desired may be expressed in fractional section, township, and range—these data are available from tax receipts or deeds if one desires coverage for a given parcel of property. (3) Requests for maps covering certain streams or parts of streams may be fulfilled by designating the part of the stream desired; for example, "Current River from Round Spring to Van Buren". (4) In the absence of any of the above information, give as accurate a description as possible of the area desired by referring to towns, streams, and highways in the immediate vicinity. If an index map is at hand, the size and scale of the map desired should be specified in cases where the same area is included in quadrangle of identical name but of different scales (e.g. Jefferson City, 7½- and 15-minute quadrangles). Those who wish to have maps with a green overlay showing timbered areas should specify this desire with the realization that this type of information is not available for all the quadrangles in the state.

SELECTED REFERENCES

The following publications are listed for those readers who may wish to have additional information on the subject of topographic maps:

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