

Oct. 17, 1972

M. J. KELLY

3,698,906

PHOTOGRAPHIC MULTI-TONE SEPARATION PROCESS

Filed June 26, 1970

9 Sheets-Sheet 1

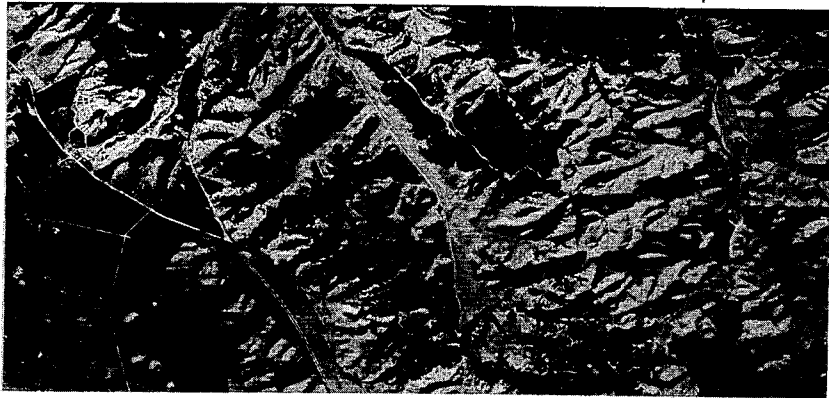


FIG. 1a

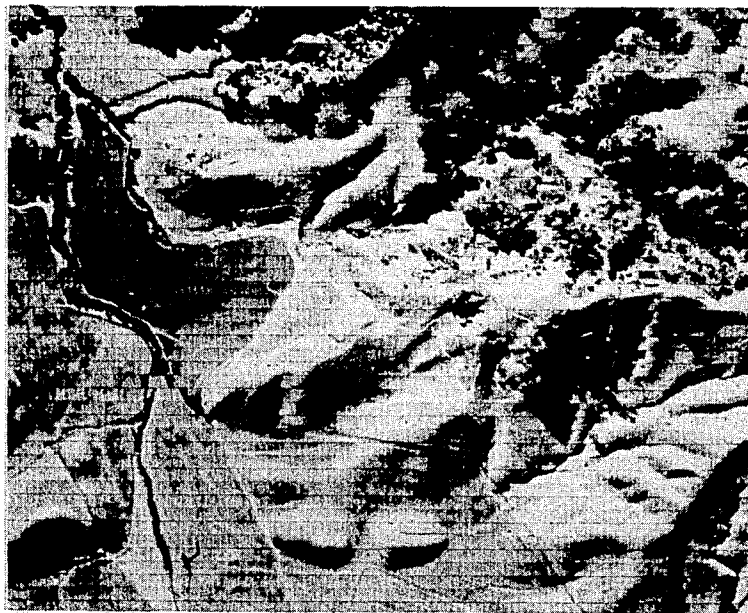


FIG. 1b

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9 Sheets-Sheet 2

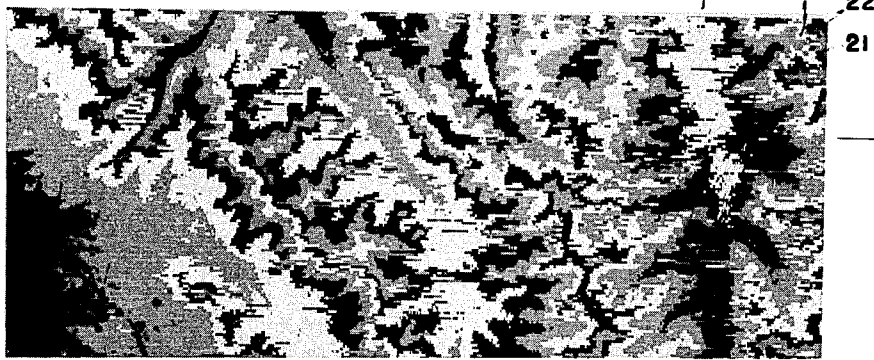


FIG. 2a

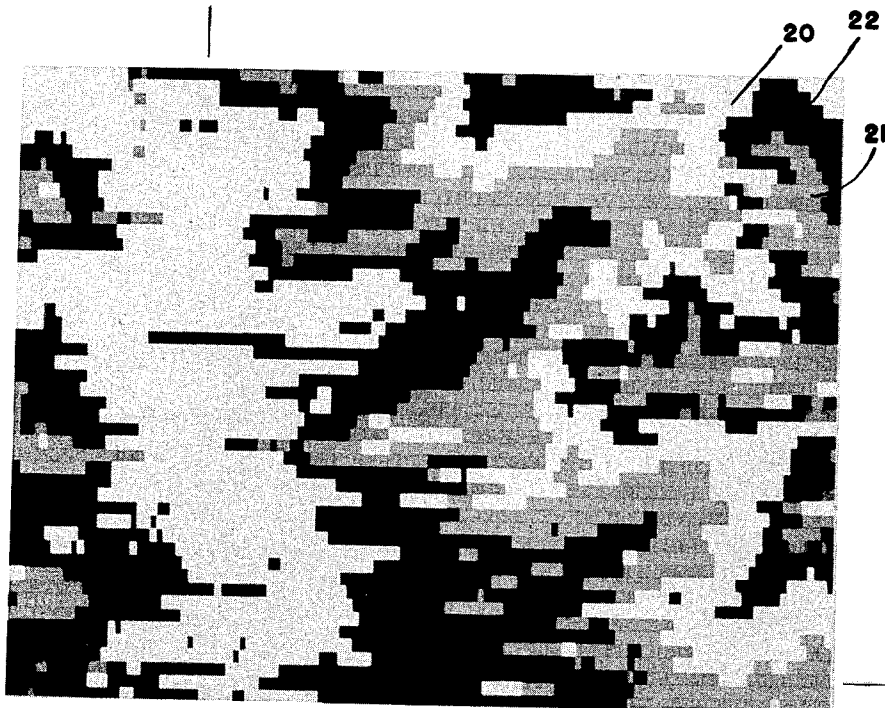


FIG. 2b

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9 Sheets-Sheet 3

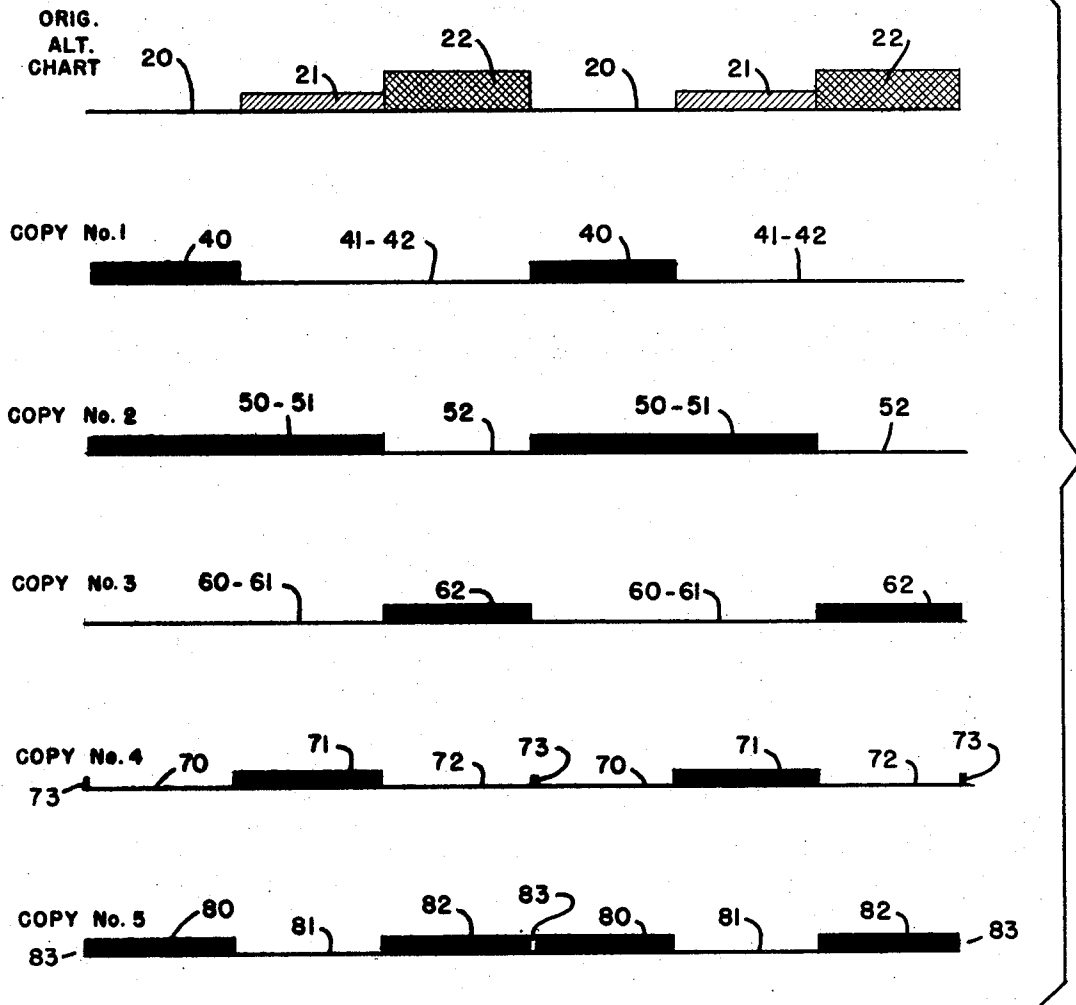


FIG. 3

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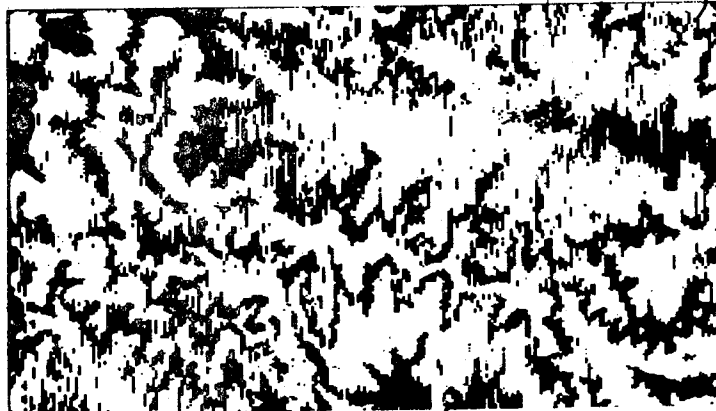
PHOTOGRAPHIC MULTI-TONE SEPARATION PROCESS

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9 Sheets-Sheet 4

FIG. 4a

COPY No. 1



COPY No. 1

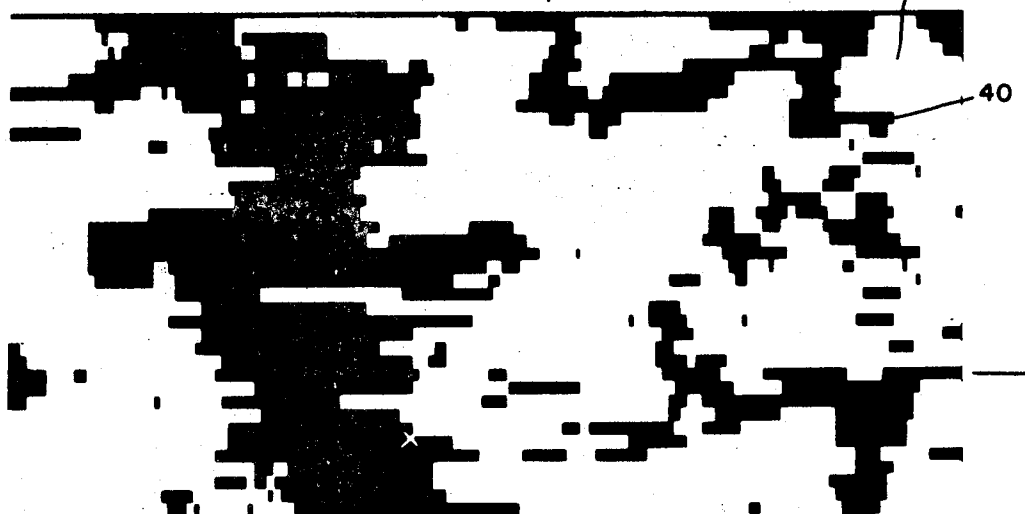


FIG. 4b

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PHOTOGRAPHIC MULTI-TONE SEPARATION PROCESS

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9 Sheets-Sheet 5

FIG. 5a

COPY No. 2



COPY No. 2

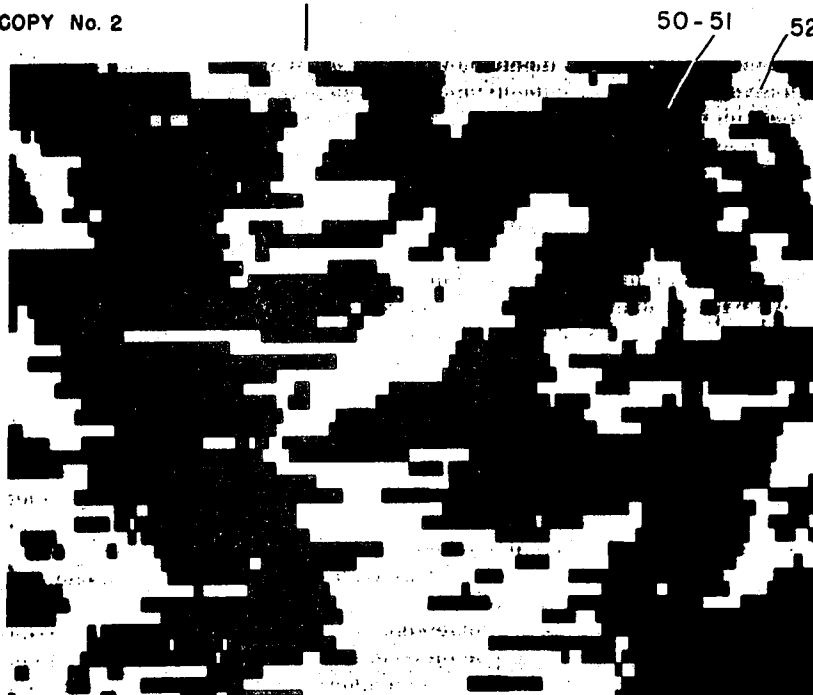


FIG. 5b

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PHOTOGRAPHIC MULTI-TONE SEPARATION PROCESS

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9 Sheets-Sheet 6

FIG. 6a

COPY No. 3



COPY No. 3

FIG. 6b

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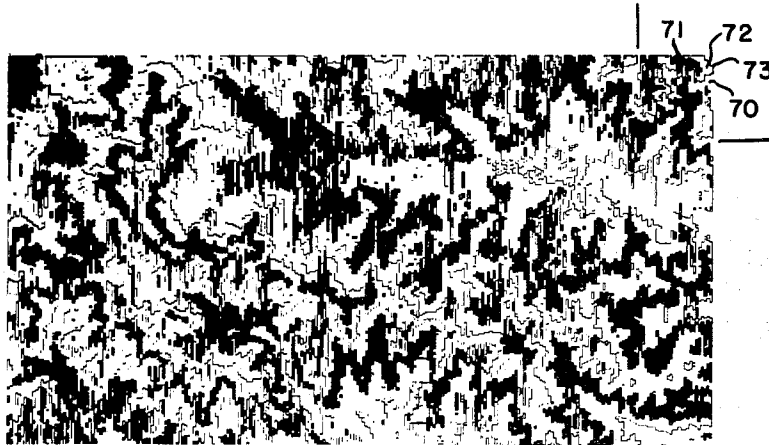
PHOTOGRAPHIC MULTI-TONE SEPARATION PROCESS

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9 Sheets-Sheet 7

FIG. 7a

COPY No. 4



COPY No. 4

FIG. 7b

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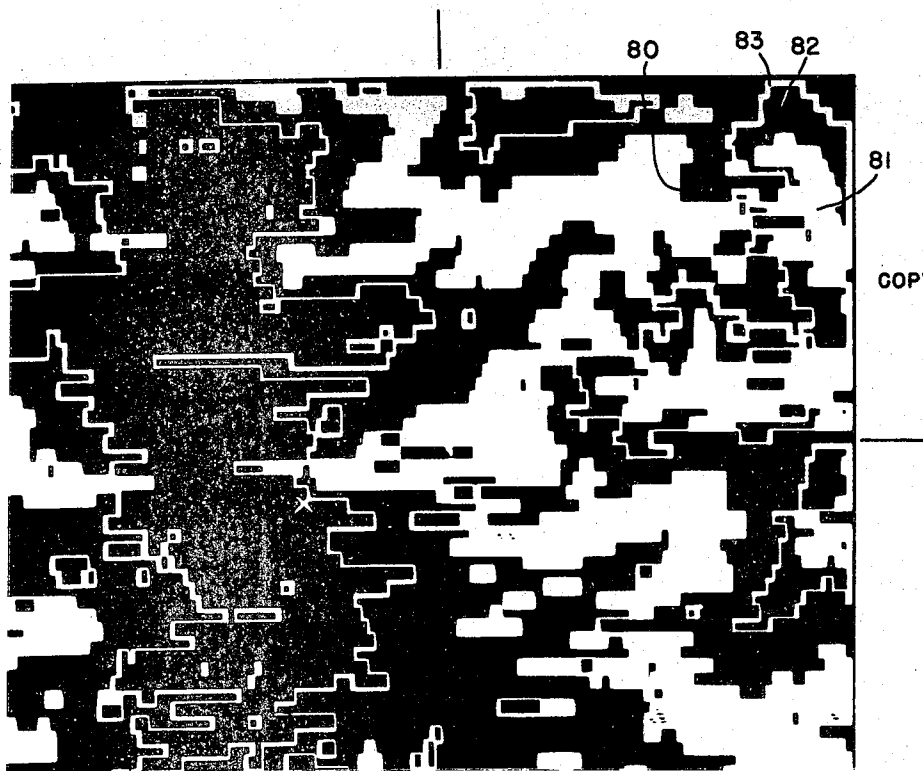
PHOTOGRAPHIC MULTI-TONE SEPARATION PROCESS

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FIG. 8a

COPY No. 5



COPY No. 5

FIG. 8b

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PHOTOGRAPHIC MULTI-TONE SEPARATION PROCESS

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FIG. 9a

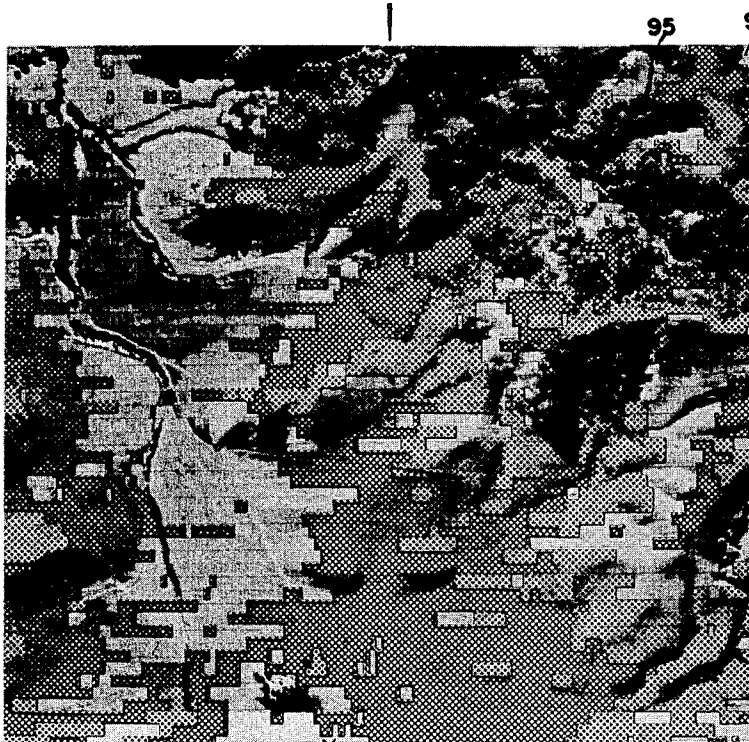
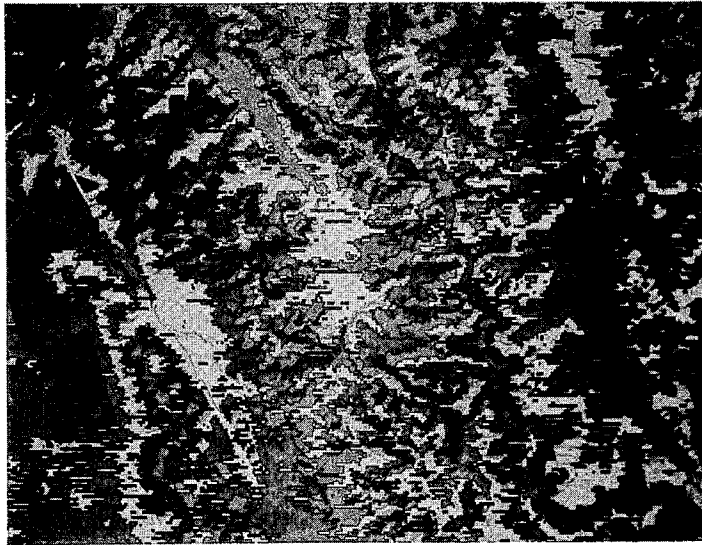


FIG. 9b

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PHOTOGRAPHIC MULTI-TONE SEPARATION PROCESS

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Int. Cl. G03c 5/06

U.S. Cl. 96-44

40 Claims

ABSTRACT OF THE DISCLOSURE

A process for the separation of tonal bands from an original transparency having multiple tonal bands. The process includes a phase which makes a series of masks of the original tonal bands by controlled exposure through the original transparency and a phase in which a new photosensitive material is exposed through the masks and screens, or, alternatively, using the masks with light-sensitive color dyes. A final product is obtained in which the areas corresponding to the original tonal bands have a changed pictorial representation and these areas are represented by screen patterns, or, alternatively, colored bands. A specific example of the process starts with altitude charts having three tonal bands produced by the Universal Automatic Map Compilation Equipment (UNAMACE). By means of controlled exposure of the original altitude chart, a series of masks of the altitude bands are produced and the masks are then used in making a final product in which the areas corresponding to the original tonal bands are represented as screen patterns or, alternatively, as colored bands.

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty thereon.

BACKGROUND OF THE INVENTION

(1) Field of the invention

The field of art to which this invention pertains is processes of performing photographic operations upon a light sensitive medium in which an original transparency having a plurality of distinct tonal bands is used as the source to produce a mask which is then utilized in operations in which means for changing pictorial representation are used to produce a final product with areas corresponding to the tonal bands in the original transparency having a changed mode of pictorial representation.

(2) Description of the prior art

The present invention results from special problems in the prior art. The prior art includes the photographic output of the Universal Automatic Map Compilation Equipment (acronym: UNAMACE). The UNAMACE is described in Army Digest, 22:24 (November 1967) and in Photogrammetric Engineering, 29:675 (July 1963) and 31:244 (March 1965), wherein the UNAMACE machine and its two photographic outputs are described. The two photographic outputs are called the "orthophoto" and the "altitude chart," respectively. FIG. 1a is an example of an orthophoto and FIG. 2a is an example of an altitude chart of the same terrain. The orthophoto, FIG. 1a, is a corrected right angle projection of an aerial photo. The altitude chart, FIG. 2a, is a photograph having three distinct tonal bands depicting relative change in the altitude of the terrain in a rotary sequence.

The three distinct tonal bands of the altitude chart FIG. 2a are bands of differing density. The tonal bands result from the variable intensity of a light scanner which exposes the altitude chart film inside the UNAMACE.

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The scanner operates in one of three modes: "off," "medium," or "bright." The photographic results of these three scanner modes may be seen in the light band 20, medium band 21, and dark band 22 of altitude chart, FIG. 2a.

In a prior art map-making process, an orthophoto mosaic is overlaid in register with an altitude chart mosaic. The mosaic will usually be the size of a map sheet. A piece of tracing paper is placed on top of the orthophoto-altitude chart mosaic sandwich. Then a map compiler views the sandwich and a stereoprint of the same terrain through a stereoscope. The compiler sees a three dimensional spatial model and by following the tonal bands of the altitude chart within the sandwich with a pencil, he traces in the contour lines on the tracing paper adding topographic expression.

The deficiencies in the prior art become manifest at this point. The first problem is variation in density between the individual altitude charts put together to make the mosaic. There may be great differences in density between the corresponding tonal bands in adjacent pieces of film in a mosaic. For instance, the dark band in one altitude chart may be of approximately the same density as the medium band of the adjacent altitude chart. This lack of uniformity between adjacent altitude charts makes it difficult for the compiler to follow the altitude bands when tracing in the contour lines.

The second problem with the prior art altitude charts produced by the UNAMACE is that the compiler has difficulty tracing along the altitude chart bands in dark forest areas and in terrain which is in shadows, as in a mountain range when the photograph was taken with the sun low in the sky. When the altitude chart is viewed through the orthophoto, the medium and dark altitude bands become lost in the dark areas.

Because of these problems in the prior art, the map compilers have great need for an easier and more effective method for delineating the altitude bands and the present invention solves these problems.

SUMMARY OF THE INVENTION

A photographic method comprising providing an original transparency having a plurality of distinct tonal bands, exposing a first photosensitive material employing a predetermined controlled exposure through the original transparency to obtain density in the area corresponding to a first tonal band in the original transparency, developing the first photosensitive material to produce a mask of the first tonal band in the original transparency, exposing a second photosensitive material through the mask employing means interposed between the light source and the second photosensitive material for changing the mode in which an area corresponding to a second tonal band in the original transparency is pictorially represented in a final photographic product, and developing the second photosensitive material to produce a final product having changed pictorial representation in the area corresponding to the second tonal band in the original transparency. The means interposed between the light source and the second photosensitive material for changing the mode in which an area corresponding to a second tonal band in the original transparency is pictorially represented in a final photographic product, may be a screen or a light-sensitive color dye.

In an alternative embodiment, the invention is a photographic method comprising providing an original transparency having a plurality of distinct tonal bands, exposing a first photosensitive material employing a predetermined exposure through the original transparency to obtain density in the area corresponding to a first tonal band in the original transparency, developing the first photosensitive material to produce a first mask of the

first tonal band in the original transparency, exposing the first mask to a second photosensitive material, developing the second photosensitive material to produce an open-window mask having an open window in the area corresponding to the first tonal band in the original transparency, exposing a third photosensitive material through the open-window mask employing means interposed between the light source and the third photosensitive material for changing the mode in which the area corresponding to the first tonal band in the original transparency is pictorially represented in a final photographic product, and developing the third photosensitive material to produce a final product having changed pictorial representation in the area corresponding to the first tonal band in the original transparency.

The above summary describes the simplest form of the present invention, i.e., separation of two tonal bands. The separation of three tonal bands is described herein-after in the specification.

Accordingly, it is an object of this invention to provide a process for improving the definition between areas in a final photographic product which correspond to multiple tonal bands in an original transparency.

A further object of this invention is to provide a process for photographically separating a multiplicity of tones in an original transparency.

A further object of this invention is to provide a process which solves the prior art problems involved in UNAMACE altitude charts.

Other objects and purposes of this invention will be apparent from the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a is a photographic print of an orthophoto produced by the Universal Automated Map Compilation Equipment (UNAMACE).

FIG. 1b is a five times enlargement of the upper right-hand corner of FIG. 1a.

FIG. 2a is a photographic print of an altitude chart produced by the Universal Automated Map Compilation Equipment (UNAMACE). This figure is a photographic print of the altitude chart made by the UNAMACE from the aerial photographs of the terrain seen in FIG. 1a.

FIG. 2b is a five times enlargement of the upper right-hand corner of FIG. 2a.

FIG. 3 is a schematic diagram representing a series of masks, called Copies #1-#5, produced in one embodiment of Phase II of the present process.

FIG. 4a is a photographic print of Copy #1 produced in Phase II of the present process.

FIG. 4b is a five times enlarged reverse positive print of the upper right-hand corner of FIG. 4a.

FIG. 5a is a photographic print of Copy #2 produced in one embodiment of the present process.

FIG. 5b is a five times enlarged reverse positive print of the upper right-hand corner of FIG. 5a.

FIG. 6a is a photographic print of Copy #3 produced in one embodiment of Phase II of the present process.

FIG. 6b is a five times enlarged reverse positive print of the upper right-hand corner of FIG. 6a.

FIG. 7a is a photographic print of Copy #4 produced in one embodiment of Phase II of the present process.

FIG. 7b is a five times enlarged reverse positive print of the upper right-hand corner of FIG. 7a.

FIG. 8a is a photographic print of Copy #5 produced in one embodiment of Phase II of the present process.

FIG. 8b is a five times enlarged reverse positive print of the upper right-hand corner of FIG. 8a.

FIG. 9a is a composite final product of one embodiment of the present process wherein the screen dot altitude bands appear superimposed on the orthophoto.

FIG. 9b is a five times enlargement of the upper right-hand corner of FIG. 9a.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is a process comprising two or three phases. The process has particular application to the prior art problems present in UNAMACE altitude charts. The process also has practical application to any original transparency having a plurality of distinct tonal bands where one desires to change the mode of pictorial representation of the areas corresponding to the tonal bands in the original transparency.

The first phase (Phase I) of the process is providing a suitable original transparency having a plurality of distinct tonal bands. In the context of the UNAMACE altitude charts, this phase solves the problem of lack of uniformity between the individual altitude charts by tone-controlled positive duplicating of the original altitude charts. In other practical applications, Phase I is simply providing an original transparency having a plurality of distinct tonal bands. This original transparency may be any transparent planar object having three or more distinct tonal bands. If the individual transparencies are uniform in density, or if only a single transparency is involved, no further work needs to be done before going to Phase II of the process.

The second phase (Phase II) of the process produces a series of masks of the areas corresponding to the tonal bands in the original transparency.

The third phase (Phase III) of the process involves using the masks with some means for changing the mode of pictorial representation. A final product with areas corresponding to the tonal bands in the original transparency having a changed mode of pictorial representation is produced by the overall process. In the context of the UNAMACE altitude charts, the process produces a final product in which the altitude bands are represented in a more useful form and in a form which solves the problem of indistinguishability between the medium and dark bands.

A detailed explanation will now be given of how to use the present process in the context of the UNAMACE altitude charts. This explanation also has direct application to any original transparency having a plurality of distinct tonal bands where one desires to change the mode of pictorial representation of the areas corresponding to the tonal bands in the original transparency.

PHASE I

The starting point for this working example of the process is the original altitude chart, of which FIG. 2a is a photographic print, which is one of the two photographic outputs of the UNAMACE. The original altitude chart may be either the developed photographic negative transparency from the UNAMACE or it may be a positive transparency made from the negative. In either case, the original altitude chart, of which FIG. 2a is a photographic print, is a transparency and not a print thereof. This is important since light is transmitted through the original altitude chart at several points in the process and therefore it must be a transparency. For reference purposes, FIGS. 2a-b will be called the original altitude chart, but it will be understood that FIGS. 2a-b are actually photographic prints of the original altitude chart. Likewise, FIGS. 4a-8a will be referred to as Copies #1-#5, respectively, but FIGS. 4a-8a are actually photographic prints of the transparencies called Copies #1-#5, respectively.

The original altitude chart FIG. 2a, produced by the UNAMACE, is produced on continuous tone film, which is photographic film with a low gamma emulsion. Duplicate positives are usually made using lithographic film, which is photographic film having a high gamma emulsion. In either case, if the several altitude charts which are to be paneled together in a mosaic exhibit lack of uniform density, this phase wherein tone-controlled duplicate positives are produced is necessary.

In order to obtain uniformity of density among the individual altitude charts which will be paneled to make a map-size mosaic, the following procedure is employed. First, the individual altitude charts are measured on a densitometer and separated into groups having a density difference of less than or equal to 0.5 in the medium tone. Each of the altitude charts in the lightest of the groups is then exposed in contact with new sheets of lithographic film. Du Pont Ortho S lithographic film has been found satisfactory. Continuous tone film may also be substituted for the lithographic film at this point and an exposure guide made up for the continuous tone film to give the desired results. What is preferred at this point is a film with a gamma of approximately 5.0. In order to achieve this result, the standard lithographic film can be developed in a continuous tone developer such as Kodak DK-50. The usual gamma of lithographic film developed in lithographic developer is approximately 15. The usual gamma of continuous tone film developed in continuous tone developer is less than 2. Hence, a gamma of 5.0 is a hybrid between standard lithographic film and standard continuous tone film. Du Pont Ortho S film developed in DK-50 for 2 minutes at 68° F. gives the desired gamma of approximately 5.0. The exposure is done with a collimated light source to retain details. An exposure time of 12 seconds with the light intensity adjusted to give an average density of $1.2 \pm .30$ in the medium band when processed in continuous tone developer for 2 minutes has been found useful.

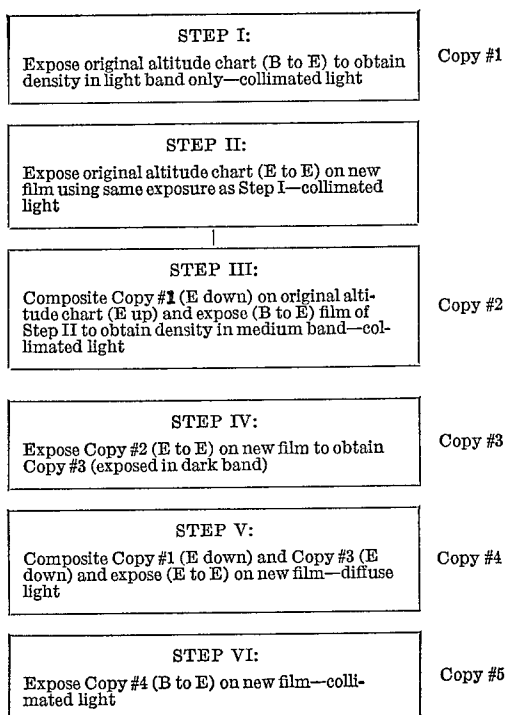
Next, the other groups of altitude charts are successively exposed on new lithographic film to maintain a uniform density in the medium tone of $1.2 \pm .30$ when developed in continuous tone developer.

It has been found that a minimum density difference of .70 between the tonal bands is desirable to adequately perform the further steps of this process.

PHASE II

This phase of the process produces a series of masks which separate the tonal bands of an altitude chart or any original transparency having multiple tonal bands. The steps of Phase II are summarized in the following flow diagram:

PHASE II



The original altitude chart and the masks made in this phase of the process, referred to as Copies #1–#5, respectively, may be seen schematically in FIG. 3, which is an aid in visualizing the steps of Phase II. In FIG. 3, two of the rotary sequences of tonal bands from the original altitude chart are shown schematically as light band 20, intermediate or medium band 21, and dark band 22. The corresponding areas in Copies #1–#5, respectively, are shown directly below the schematic representation of the original altitude chart. The black areas in Copies #1–#5 represent, as will be explained, dark (exposed) portions in the respective photographic transparency. The reader may find it helpful to refer to FIG. 3 throughout the remaining explanation.

A more complete and detailed explanation of the steps of Phase II follows:

Step I.—Contact and expose the original altitude chart FIG. 2a on a new sheet of lithographic film (Ortho S) with the base side of the altitude chart to the emulsion side of the new film. A collimated light source is used to retain sharpness of detail. The developed film which results from this step is seen in FIG. 4a at normal scale and in FIG. 4b which is a 5 times enlargement of the upper right-hand corner in FIG. 4a. FIG. 4b is a reverse positive of FIG. 4a so the details in the enlargement are reversed. This developed film is called Copy #1 for reference. As may be seen in FIG. 4a and FIG. 4b, Copy #1 has density in dark area 40 which corresponds to light band 20 of original altitude chart FIGS. 2a–b. No development occurs in Copy #1 in light area 41–42 corresponding to medium band 21 and dark band 22 of original altitude chart FIGS. 2a–b. The results seen in Copy #1 are achieved by controlling the exposure through original altitude chart FIG. 2a onto the new sheet of lithographic film. The exposure can be controlled by controlling either the light intensity or the time the light is activated. Given an original altitude chart with a density difference of .70 between bands, a person of ordinary skill in the art can readily make an exposure table giving the amount of exposure needed to yield the density desired in dark area 40 of Copy #1. A density (D-Max.) of 1.75^+ for dark area 40 has been found satisfactory. Hence, a person of ordinary skill in the photographic art, given an altitude chart can easily determine the amount of exposure needed to give a density of 1.75^+ in dark area 40 of Copy #1 when exposed through the measurable density of the light band 20 of the altitude chart. Once the proper exposure has been determined to give density in the dark area 40 of Copy #1 corresponding to the light band 20 of FIG. 2 a typical development time in standard lithographic developer (D-85) would be $2\frac{1}{2}$ –3 minutes at 68° F. As may be seen from Copy #1, the original altitude chart FIG. 2a has served like a mask in this step by virtue of the controlled exposure to yield development only in dark area 40 of Copy #1 which corresponds to light band 20 of original altitude chart FIGS. 2a–b.

Step II.—Contact and expose the original altitude chart FIG. 2a on a new sheet of lithographic film (Ortho S) with the emulsion side of the altitude chart to the emulsion side of the new film. The light intensity and time of exposure of the new sheet of lithographic film should be the same as used in Step I, above. This will expose the new film only in the area corresponding to the light band 20 of the original altitude chart FIG. 2a as done in Step I. However, no further work occurs in this step. No processing or development occurs because this same sheet of film must be re-exposed in the next step (Step III).

Step III.—Using the same sheet of lithographic film exposed in Step II, above, place Copy #1 with its emulsion side down on top of the emulsion side of original altitude chart FIG. 2a. Copy #1 here serves as a mask to prevent overexposure of the film from Step II in the area corresponding to light band 20 of original altitude chart FIG. 2a. Copy #1 and the original altitude chart are placed on top of the film from Step II with the base of the original

altitude chart to the emulsion of the film. This sandwich is exposed using a collimated light source. The developed film which results from this step is seen in FIG. 5a at normal scale and in FIG. 5b which is a 5 times enlargement of the upper right-hand corner in FIG. 5a. FIG. 5b is a reverse positive of FIG. 5a. The developed film is called Copy #2 for reference. As may be seen in FIG. 5a and FIG. 5b, Copy #2 has density in the dark area 50-51 which corresponds to light band 20 and medium band 21 of original altitude chart FIG. 2a. No development occurs in Copy #2 in light area 52 corresponding to dark band 22 of original altitude chart FIGS. 2a-b. The results seen in Copy #2 are achieved by controlling the exposure through Copy #1 and original altitude chart FIGS. 2a-b. As discussed above in Step I, a person of ordinary skill in the art can readily make an exposure table giving the amount of exposure needed to yield the desired density of 1.75+ in dark area 50-51 of Copy #2. Such an exposure table will be made for this step based on the measurable density of medium band 21 of original altitude chart FIGS. 2a-b. With the proper exposure, a typical development time in standard lithographic developer (D-85) would again be 2½-3 minutes at 68° F. to yield a D-Max. of 1.75+. As may be seen from Copy #2, the original altitude chart FIG. 2a has served as a mask in this step by virtue of the controlled exposure to yield development only in dark area 50-51 of Copy #2 which corresponds to light band 20 and medium band 21 of original altitude chart FIGS. 2a-b.

Step IV.—Contact and expose Copy #2 on a new sheet of lithographic film (Ortho S). The emulsion side of Copy #2 will be facing the emulsion side of the new film. A collimated or uncollimated light source may be used. The film may be developed in standard lithographic developer (D-85) for 2½-3 minutes at 68° F. to give a D-Max. of 1.75+. The developed film which results from this step is seen in FIG. 6a at normal scale and in FIG. 6b which is a 5 times enlargement of the upper right-hand corner of FIG. 6a. FIG. 6b is a reverse positive of FIG. 6a. This developed film is called Copy #3 for reference. As may be seen in FIGS. 6a-b, Copy #3 has density in dark area 62 which corresponds to light area 52 of Copy #2 which in turn corresponds to dark band 22 in original altitude chart FIGS. 2a-b. No development occurs in Copy #3 in light area 60-61 corresponding to dark area 50-51 of Copy #2 which in turn corresponds to light band 20 and medium band 21 in original altitude chart FIGS. 2a-b.

Step V.—Composite Copy #1 and Copy #3 with the emulsion side of each facing down. Contact and expose the composite on a new sheet of lithographic film (Ortho S) with the emulsion side of the new film facing up. This exposure is performed using a diffuse light source such as four lights in a circle where the lights are at a 45° angle to the plane of the film. This diffuse type of light source is also called a vignette light source. The film may be developed in standard lithographic developer (D-85) for 2½-3 minutes at 68° F. to give a D-Max. of 1.75+. The developed film which results from this step is seen in FIG. 7a at normal scale and FIG. 7b which is a 5 times enlargement of the upper right-hand corner in FIG. 7a. FIG. 7b is a reverse positive of FIG. 7a. This developed film is called Copy #4 for reference. As may be seen in FIGS. 7a-b, Copy #4 has density in dark area 71 which corresponds to medium band 21 in original altitude chart FIGS. 2a-b. No development occurs in Copy #4 in light area 70 which corresponds to light band 20 in original altitude chart FIGS. 2a-b and no development occurs in Copy #4 in light area 72 which corresponds to dark band 22 in original altitude chart FIGS. 2a-b. Copy #4 has a black line 73 which outlines the boundary between light area 70 (which corresponds to light band 20 in original altitude chart FIGS. 2a-b) and light area 72 (which corresponds to dark band 22 in original altitude chart FIGS. 2a-b). Black line 73 results from the diffuse light shining in between the dark areas of Copy #1 and Copy #3 since the

base of Copy #1 acts as a spacer which permits a fine line of light to pass through. This phenomenon is well known in the art, as it is described in U.S. Pat. No. 2,455,849, issued Dec. 7, 1948 to J. Yule. The black line effect is sometimes referred to as ap icto-line by those in the art.

Step VI.—Contact and expose Copy #4 on a new sheet of lithographic film (Ortho S). The base side of Copy #4 is to the emulsion side of the new film. A collimated light source is used to retain detail. The film may be developed in standard lithographic developer (D-85) for 2½-3 minutes at 68° F. to give a D-Max. of 1.75+. The developed film which results from this step is seen in FIG. 8a at normal scale and in FIG. 8b which is a 5 times enlargement of the upper right-hand corner in FIG. 8a. FIG. 8b is a reverse positive of FIG. 8a. This developed film is called Copy #5 for reference. As may be seen in FIGS. 6a-b, Copy #5 has density in dark area 80 which corresponds to light band 20 in original altitude chart FIGS. 2a-b and density in dark area 82 which corresponds to dark band 22 in original altitude chart FIGS. 2a-b. No development occurs in Copy #5 in light area 81 corresponding to medium band 21 in original altitude chart FIGS. 2a-b. Copy #5 has a clear line 83 which outlines the boundary between dark area 82 and dark area 80.

With the production of Copy #5, Phase II of this example is complete.

Several alternate embodiments of Phase II exist. The embodiment described above is the preferred embodiment since it produces Copy #5 which will ultimately produce a black line effect in the final composite product in Phase III. However, an alternate final composite product without the black line effect may nevertheless be useful to a map compiler. To produce such an alternate composite final product, one would produce Copy #1 by the controlled exposure step described above. Then Copy #1 is contacted with the original altitude chart and by controlling the exposure, a mask of the area corresponding to medium band 21 in original altitude chart FIGS. 2a-b is produced. This mask may be called Copy #2' for reference (not shown in the drawings). Then Copy #1 and Copy #2' are contacted and a new piece of film is exposed to produce a mask of the area corresponding to the dark band 22 in original altitude chart FIGS. 2a-b. This mask may be called Copy #3 and it is identical to Copy #3 in FIG. 3 and FIGS. 6a-b. Thus, this alternate embodiment of Phase II produces only three masks, each being a mask of the area corresponding to a single tonal band in the original altitude chart.

These three masks (Copy #1, Copy #2' and Copy #3) may be used directly in Phase III as it will be described. Alternatively, these three masks (Copy #1, Copy #2' and Copy #3) may be contacted and exposed to new film to produce three new masks which may be called Copy #1', Copy #2'' and Copy #3' (not shown in drawings). These new masks (Copy #1', Copy #2'' and Copy #3') are, of course, just the negatives of Copy #1, Copy #2' and Copy #3. The new masks (Copy #1', Copy #2'' and Copy #3') are called open-window masks since they have an open window for each of the areas corresponding to the tonal bands in the original altitude chart.

Either set of the above masks (Copy #1, Copy #2' and Copy #3 or Copy #1', Copy #2'' and Copy #3') may be used in Phase III as will be obvious after describing Phase III.

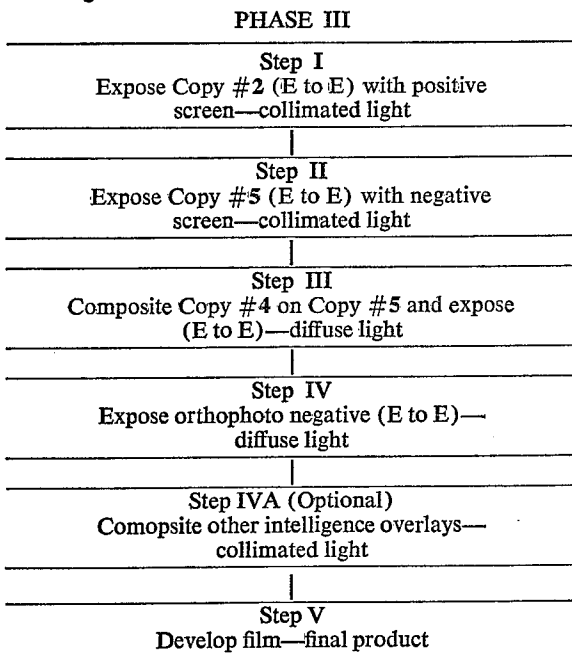
PHASE III

This phase of the process uses the masks, Copies #1-#5, respectively, produced in Phase II to produce a final composite product. One embodiment of the present invention produces the final composite product seen in FIG. 9a at normal scale and in FIG. 9b which is a 5 times enlargement of the upper right-hand corner in FIG. 9a. The final product seen in FIGS. 9a-b is used by a map compiler.

Before explaining the steps of Phase III, it is helpful to examine FIG. 9b wherein the altitude chart bands are

superimposed on the orthophoto. The superimposed bands produced by the present invention are easily discernible even in areas of rapidly changing elevation and in shadow areas. In FIG. 9b, light area 90 corresponds to light band 20 in original altitude chart FIGS. 2a-b, screen area 91 which appears to be black dots corresponds to medium band 21 in original altitude chart FIGS. 2a-b and screen area 92 which appears to be cross-hatching or white dots, depending on how it is viewed, corresponds to dark band 22 in original altitude chart FIGS. 2a-b.

The steps of Phase III are summarized in the following flow diagram:



The final product of the present process, which is the final product of Phase III, may be either in the nature of a photographic transparency or in the nature of an opaque photographic print, depending on the artisan's choice of photographic materials which will probably be dictated by the end use of the final product.

The steps in Phase III, as summarized above, will now be explained in more detail. One of the many photographic films which may be used for this phase is Keuffel and Esser Photact which is a continuous tone emulsion placed on an opaque plastic base (also called scribe coat), and which therefore yields a developed final product which is opaque, in the nature of a photographic print rather than a transparency. This phase may also be carried out using standard continuous tone film to yield a developed final composite product which is a transparency.

Step I.—Using a collimated light source, expose Copy #2 from Phase II on the new film with the emulsion side of Copy #2 to the emulsion side of the film. Place a positive screen under Copy #2 prior to exposure. A positive screen is a screen which consists of regularly spaced black dots. A screen with 133 lines per inch has been found satisfactory. The film is not developed until the last step of this phase since it must be re-exposed several times. The isolated effect produced by Step I may be seen in the final product after development in cross-hatched area 92 in FIG. 9b. Cross-hatched area 92 corresponds to dark band 22 in original altitude chart FIGS. 2a-b.

Step II.—Using the same sheet of film from Step I of this phase, expose Copy #5 of Phase II to the film with the emulsion side of Copy #5 to the emulsion side of the film. Place a negative screen under Copy #5 prior to exposure. A negative screen is a screen which consists of black cross-hatching, or white dots, depending on how it is viewed. A screen with 133 lines per inch has been

found satisfactory. The film is not developed in this step. The isolated effect produced in this Step II may be seen in the final product after development in black dot area 91 in FIG. 9b and in black line 93 which separates light area 90 and cross-hatched area 92. Black dot area 91 corresponds to medium band 21 in original altitude chart FIGS. 2a-b.

Step III.—Using the same sheet of film from Step II of this phase, composite Copy #4 with emulsion side down on top of copy #5 with emulsion side down to the emulsion side of the film. Expose this sandwich using a diffuse light source. The film is not developed in this step. The isolated effect produced in this Step II may be seen in the final product after development in FIG. 9b in black line 94 which separates cross-hatched area 92 and black dot area 91 and in black line 95 which separates light area 90 and black dot area 91.

Step IV.—Using the same sheet of film from Step III of this phase, contact and expose the orthophoto to the film. A diffuse or vignette light source has been found suitable for this purpose. Best results have been obtained using an exposure and processing combination which yields a density difference between the D-Max. and D-Min. of the orthophoto of .75 or less, with a D-Max. of 1.0 or below. This tone control is to prevent blacking out of the superimposed altitude bands on the final product.

Step V (optional).—Using the same sheet of film from Step IV of this phase, composite intelligence overlays and expose to the film using a collimated light source. This step transfers to the final product intelligence details which are useful to the map compiler.

Step VI.—The film from Step V is developed. For example, Keuffel and Esser Photact film may be developed in standard continuous tone developer (2:1 D-72) at 68° F. for 1½ to 2 minutes. The film is fixed, washed and air dried. The result is the final product seen in FIG. 9a and FIG. 9b.

The final product is used by a map compiler with a stereoscope to scribe the contour lines adding topographic expression on the final composite product. This product is then used as a guide for making the finished contour scribe. The finished contour scribe is then used to make a printing plate. The advance over the prior art demonstrated by the final product is best seen in FIG. 9b. The altitude bands are sharply delineated and are unambiguous, even in the shadow areas. In FIG. 9b, light area 90 corresponds to light band 20 in original altitude chart FIGS. 2a-b, black dot area 91 corresponds to medium band 21 in original altitude chart FIGS. 2a-b and cross-hatch area 92 corresponds to dark band 22 in original altitude chart FIGS. 2a-b.

The foregoing description explains how to make the final composite product seen in FIGS. 9a-b. As mentioned previously, an alternate final composite product which does not have the black line effect may be made using Copy #1, Copy #2' and Copy #3, or the open-window type of mask, Copy #1', Copy #2'' and Copy #3'. The aforesaid alternate masks are composited with the screens in the manner already described to produce an alternate composite final product which lacks the black line effect, but which in other respects is identical to FIGS. 9a-b.

Another modification of Phase III is to composite Copy #4 and Copy #5 and expose a new photosensitive material through the composite employing a diffuse light source. This produces in the final product just the black line effect seen in FIGS. 9a-b without any screen pattern.

It is obvious that the exact sequence of the screens used in Phase III is not critical in this invention. For example, the cross-hatched area may be made a light area or a black dot area; the light area may be a cross-hatched area or a black dot area; etc. The screens may be used in any sequence without departing from the invention process. Furthermore, the screens used in Phase III may have "dots" of any geometrical shape. The "dots" need not be

circles—they may be squares, triangles, or any other shape.

The use of screens illustrates just one embodiment of Phase III of the process. An alternate embodiment of Phase III makes colored bands instead of screen patterns. One well known method of selectively producing colors is by the use of rub-on diazo dyes. Such dyes are photosensitive and are chemically changed when exposed to light. Such dyes are applied and then exposed through the masks from Phase II. When the dyes are developed and fixed, as part of Phase III, the preselected color bands may, for example, appear in place of the cross-hatched area 92 and the black dot area 91. The exact colors and dyes and the sequence of colors used by the artisan are a matter of individual choice and further explanation of this obvious alternate embodiment is unnecessary to one of ordinary skill in the art. If desired, a screen and a dye may be used in combination to give a colored screen pattern.

I claim:

1. A photographic process comprising:
 - (a) providing an original transparency having a plurality of distinct tonal bands;
 - (b) exposing a first photosensitive material employing a predetermined controlled exposure through said original transparency to obtain density in the area corresponding to a first tonal band in said original transparency;
 - (c) developing said first photosensitive material to produce a mask of said first tonal band in said original transparency;
 - (d) exposing a second photosensitive material through said mask employing means interposed between the light source and said second photosensitive material for changing the mode in which an area corresponding to a second tonal band in said original transparency is pictorially represented in a final photographic product; and
 - (e) developing said second photosensitive material to produce said final product having changed pictorial representation in said area corresponding to said second tonal band in said original transparency.
2. The process as defined in claim 1 wherein said means interposed between the light source and said second photosensitive material for changing the mode in which an area corresponding to a second tonal band in said original transparency is pictorially represented in a final photographic product, comprises a screen.
3. The process as defined in claim 1 wherein said means interposed between the light source and said second photosensitive material for changing the mode in which an area corresponding to a second tonal band in said original transparency is pictorially represented in a final photographic product, comprises a light-sensitive color dye.
4. The process as defined in claim 1 wherein said original transparency having a plurality of distinct tonal bands is an altitude chart produced by the UNAMACE.
5. A photographic process comprising:
 - (a) providing an original transparency having a plurality of distinct tonal bands;
 - (b) exposing a first photosensitive material employing a predetermined controlled exposure through said original transparency to obtain density in the area corresponding to a first tonal band in said original transparency;
 - (c) developing said first photosensitive material to produce a first mask of said first tonal band in said original transparency;
 - (d) exposing a second photosensitive material through said first mask;
 - (e) developing said second photosensitive material to produce a first open-window mask having an open window in said area corresponding to said first tonal band in said original transparency;
 - (f) exposing a third photosensitive material through

said first open-window mask employing means interposed between the light source and said third photosensitive material for changing the mode in which said area corresponding to said first tonal band in said original transparency is pictorially represented in a final photographic product; and

- (g) developing said third photosensitive material to produce said final product having changed pictorial representation in said area corresponding to said first tonal band in said original transparency.

6. The process as defined in claim 5 wherein said means interposed between the light source and said third photosensitive material for changing the mode in which said area corresponding to said first tonal band in said original transparency is pictorially represented in a final photographic product, comprises a screen.

7. The process as defined in claim 5 wherein said means interposed between the light source and said third photosensitive material for changing the mode in which said area corresponding to said first tonal band in said original transparency is pictorially represented in a final photographic product, comprises a light-sensitive color dye.

8. The process as defined in claim 5 wherein said original transparency having a plurality of distinct tonal bands is an altitude chart produced by the UNAMACE.

9. A photographic multi-tone separation process comprising:

- (a) providing an original transparency having a plurality of distinct tonal bands;
- (b) exposing a first photosensitive material employing a predetermined controlled exposure through said original transparency to obtain density in the area corresponding to the lightest tonal band in said original transparency and developing said first photosensitive material to produce a first mask;
- (c) exposing a second photosensitive material employing a predetermined controlled exposure through said original transparency and said first mask to obtain density in the area corresponding to an intermediate tonal band and developing said second photosensitive material to produce a second mask; and
- (d) exposing a third photosensitive material through said first mask and said second mask to obtain density in the area corresponding to a third tonal band in said original transparency and developing said third photosensitive material to produce a third mask.

10. The process as defined in claim 9 wherein the step of providing an original transparency having a plurality of distinct tonal bands comprises producing a tone-controlled duplicate having a predetermined density differential between tonal bands and a predetermined density range within said tonal bands.

11. The process as defined in claim 9 wherein the process further comprises the steps of:

- (a) exposing a fourth photosensitive material through a preselected pair of said masks to permit exposure of a first area in said fourth photosensitive material corresponding to a first tonal band in said original transparency and employing means interposed between the light source and said fourth photosensitive material for changing the mode in which said first area corresponding to said first tonal band in said original transparency is pictorially represented in a final photographic product;
- (b) exposing said fourth photosensitive material through a pair other than said preselected pair of said masks to permit exposure of a second area in said fourth photosensitive material corresponding to a second tonal band in said original transparency and employing means interposed between the light source and said fourth photosensitive material for changing the mode in which said second area corresponding to said second tonal band in said original transparency is pictorially represented in a final photographic product; and

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(c) developing said fourth photosensitive material to produce said final photographic product having changed pictorial representation in said first area corresponding to said first tonal band in said original transparency, and in said second area corresponding to said second tonal band in said original transparency.

12. The process as defined in claim 11 wherein said means interposed between the light source and said fourth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises a screen.

13. The process as defined in claim 11 wherein said means interposed between the light source and said fourth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises a light-sensitive color dye.

14. The process as defined in claim 11 wherein said means interposed between the light source and said fourth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises selectively employing a screen and a light-sensitive color dye.

15. The process as defined in claim 11 wherein said original transparency having a plurality of distinct tonal bands is an altitude chart produced by the UNAMACE.

16. A photographic multi-tone separation process comprising:

- (a) providing an original transparency having a plurality of distinct tonal bands;
- (b) exposing a first photosensitive material employing a predetermined controlled exposure through said original transparency to obtain density in the area corresponding to the lightest tonal band in said original transparency and developing said first photosensitive material whereby a first mask is produced;
- (c) exposing said first mask to a second photosensitive material and developing said second photosensitive material whereby a first open-window mask having an open window in said area corresponding to said lightest tonal band in said original transparency is produced;
- (d) exposing a third photosensitive material employing a predetermined exposure through said original transparency and said first mask to obtain density in the area corresponding to an intermediate tonal band in said original transparency and developing said third photosensitive material whereby a second mask is produced; and
- (e) exposing said second mask to a fourth photosensitive material and developing said fourth photosensitive material to produce a second open-window mask having an open window in said area corresponding to said intermediate tonal band in said original transparency.

17. The process as defined in claim 16 wherein the process further comprises the preparation of a third open-window mask by the additional steps of:

- (a) exposing a new photosensitive material through said first mask and said second mask to obtain density in a third area corresponding to a third tonal band in said original transparency and developing said new photosensitive material whereby a third mask is produced; and
- (b) exposing said third mask to a second new photosensitive material and developing said second new photosensitive material to produce a third open-window mask, having an open window in said third area corresponding to said third tonal band in said original transparency.

18. The process as defined in claim 16 wherein the step of providing an original transparency having a plurality

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of distinct tonal bands comprises producing a tone-controlled duplicate having a predetermined density differential between tonal bands and a predetermined density range within said tonal bands.

19. The process as defined in claim 16 wherein the process further comprises the steps of:

- (a) exposing a fifth photosensitive material through a first of said open-window masks to permit exposure of a first area corresponding to a first tonal band in said original transparency and employing means interposed between the light source and said fifth photosensitive material for changing the mode in which said first area corresponding to said first tonal band in said original transparency is pictorially represented in a final photographic product;
- (b) exposing said fifth photosensitive material through a second of said open-window masks to permit exposure of a second area corresponding to a second tonal band in said original transparency and employing means interposed between the light source and said fifth photosensitive material for changing the mode in which said second area corresponding to said second tonal band in said original transparency is pictorially represented in a final photographic product; and
- (c) developing said fifth photosensitive material to produce said final photographic product having changed pictorial representation in said first area corresponding to said first tonal band in said original transparency and in said second area corresponding to said second tonal band in said original transparency.

20. The process as defined in claim 19 wherein said means interposed between the light source and said fifth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises a screen.

21. The process as defined in claim 19 wherein said means interposed between the light source and said fifth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises a light-sensitive color dye.

22. The process as defined in claim 19 wherein said means interposed between the light source and said fifth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises selectively employing a screen and a light-sensitive color dye.

23. The process as defined in claim 19 wherein said original transparency having a plurality of distinct tonal bands is an altitude chart produced by the UNAMACE.

24. A photographic multi-tone separation process comprising:

- (a) providing an original transparency having a plurality of distinct tonal bands;
- (b) exposing a first photosensitive material employing a predetermined controlled exposure through said original transparency to obtain density in the area corresponding to the lightest tonal band in said original transparency and developing said first photosensitive material whereby a first mask is produced;
- (c) exposing a second photosensitive material employing the same predetermined controlled exposure used in step (b) to obtain density in said area corresponding to said lightest tonal band in said original transparency;
- (d) exposing said second photosensitive material employing a predetermined controlled exposure through said original transparency and said first mask to obtain density in the area corresponding to an intermediate tonal band in said original transparency and developing said second photosensitive material to produce a second mask, having density in said area

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corresponding to said lightest tonal band in said original transparency and in said area corresponding to said intermediate tonal band in said original transparency;

(e) exposing a third photosensitive material through said second mask to obtain density in the area corresponding to a third tonal band in said original transparency and developing said third photosensitive material whereby a third mask is produced;

(f) exposing a fourth photosensitive material through said first mask and said third mask employing a diffuse light source to obtain density in the area corresponding to said intermediate tonal band in said original transparency and to obtain a black line effect between the areas corresponding to said lightest tonal band in said original transparency and to said third tonal band in said original transparency and developing said fourth photosensitive material whereby a fourth mask is produced; and

(g) exposing a fifth photosensitive material through said fourth mask to obtain density in the areas corresponding to said lightest tonal band in said original transparency and to said third tonal band in said original transparency and to obtain a clear line effect between the areas corresponding to said lightest tonal band in said original transparency and to said third tonal band in said original transparency and developing said fifth photosensitive material whereby a fifth mask is produced.

25 The process as defined in claim 24 wherein the step of providing an original transparency having a plurality of distinct tonal bands comprises producing a tone-controlled duplicate having a predetermined density differential between tonal bands and a predetermined density range within said tonal bands.

26. The process as defined in claim 24 wherein the process further comprises the steps of:

(a) exposing a sixth photosensitive material through said second mask to permit exposure of said area corresponding to said third tonal band in said original transparency and employing means interposed between the light source and said sixth photosensitive material for changing the mode in which said area corresponding to said third tonal band in said original transparency is pictorially represented in a final photographic product;

(b) exposing said sixth photosensitive material through said fifth mask to permit exposure of the area corresponding to said intermediate tonal band in said original transparency and to obtain a black line effect between said areas corresponding to said lightest tonal band in said original transparency and said third tonal band in said original transparency and employing means interposed between the light source and said sixth photosensitive material for changing the mode in which said area corresponding to said intermediate tonal band in said original transparency is pictorially represented in a final photographic product;

(c) exposing said sixth photosensitive material through said fourth and fifth masks employing a diffuse light source to obtain a black line effect between said areas corresponding to said lightest tonal band, said intermediate tonal band, and said third tonal band in said original transparency; and

(d) developing said sixth photosensitive material to produce said final photographic product, having changed pictorial representation in said area corresponding to said intermediate tonal band in said original transparency and in said area corresponding to said third tonal band in said original transparency and having a black line effect between said areas corresponding to said lightest tonal band, said intermediate tonal band, and said third tonal band in said original transparency.

27. The process as defined in claim 26 wherein said

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means interposed between the light source and said sixth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises a screen.

28. The process as defined in claim 26 wherein said means interposed between the light source and said sixth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises a light-sensitive color dye.

29. The process as defined in claim 26 wherein said means interposed between the light source and said sixth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises selectively employing a screen and a light-sensitive color dye.

30. The process as defined in claim 26 wherein said original transparency having a plurality of distinct tonal bands is an altitude chart produced by the UNAMACE.

31. A photographic multi-tone separation process comprising:

(a) providing an original transparency having a plurality of distinct tonal bands;

(b) exposing a first photosensitive material employing a predetermined controlled exposure with a collimated light source through said original transparency with the base side of said original transparency to the emulsion side of said first photosensitive material to obtain density in the area corresponding to the lightest tonal band in said original transparency and developing said first photosensitive material whereby a first mask is produced;

(c) exposing a second photosensitive material as in step (b) to obtain density in the area corresponding to the lightest tonal band in said original transparency;

(d) exposing said second photosensitive material employing a predetermined controlled exposure with a collimated light source through said original transparency and said first mask with the base side of said original transparency to the emulsion side of said second photosensitive material to obtain density in the area corresponding to an intermediate tonal band in said original transparency and developing said second photosensitive material to produce a second mask, having density in said area corresponding to said lightest tonal band in said original transparency and in said area corresponding to said intermediate tonal band in said original transparency;

(e) exposing a third photosensitive material employing a collimated light source through said second mask to obtain density in the area corresponding to a third tonal band in said original transparency and developing said third photosensitive material whereby a third mask is produced;

(f) exposing a fourth photosensitive material through said first mask and said third mask with the emulsion sides of said masks toward the emulsion side of said fourth photosensitive material employing a diffuse light source to obtain density in the area corresponding to said intermediate tonal band in said original transparency and to obtain a black line effect between the areas corresponding to said lightest tonal band in said original transparency and to said third tonal band in said original transparency and developing said fourth photosensitive material whereby a fourth mask is produced; and

(g) exposing a fifth photosensitive material employing a collimated light source through said fourth mask with the base side of said fourth mask to the emulsion side of said fifth photosensitive material to obtain density in the areas corresponding to said lightest tonal band in said original transparency and to said

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third tonal band in said original transparency and to obtain a clear line effect between the areas corresponding to said lightest tonal band in said original transparency and to said third tonal band in said original transparency and developing said fifth photosensitive material whereby a fifth mask is produced.

32. The process as defined in claim 31 wherein the step of providing an original transparency having a plurality of distinct tonal bands comprises producing a tone-controlled duplicate having a predetermined density differential between tonal bands and a predetermined density range within said tonal bands.

33. The process as defined in claim 31 wherein the process further comprises the steps of:

(a) exposing a sixth photosensitive material employing a diffuse light source through said fourth mask and said fifth mask with the emulsion sides of said masks toward the emulsion side of said sixth photosensitive material; and

(b) developing said sixth photosensitive material to produce a final photographic product having a black line effect between the areas corresponding to said lightest tonal band, said intermediate tonal band and said third tonal band in said original transparency.

34. The process as defined in claim 31 wherein the process further comprises the steps of:

(a) exposing a sixth photosensitive material employing a collimated light source through said second mask with the emulsion side of said second mask to the emulsion side of said sixth photosensitive material to permit exposure of said area corresponding to said third tonal band in said original transparency and employing means interposed between the light source and said sixth photosensitive material for changing the mode in which said area corresponding to said third tonal band in said original transparency is pictorially represented in a final photographic product;

(b) exposing said sixth photosensitive material employing a collimated light source through said fifth mask with the emulsion side of said fifth mask to the emulsion side of said sixth photosensitive material to permit exposure of said area corresponding to said intermediate tonal band in said original transparency and to obtain a black line effect between said areas corresponding to said lightest tonal band in said original transparency and said third tonal band in said original transparency and employing means interposed between the light source and said sixth photosensitive material for changing the mode in which said area corresponding to said intermediate tonal band in said original transparency is pictorially represented in a final photographic product;

(c) exposing said sixth photosensitive material employing a diffuse light source through said fourth and fifth masks with the emulsion sides of said masks facing

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the emulsion side of said sixth photosensitive material to obtain a black line effect between said areas corresponding to said lightest tonal band, said intermediate tonal band, and said third tonal band in said original transparency;

(d) exposing any other desired image onto said sixth photosensitive material; and

(e) developing said sixth photosensitive material to produce said final photographic product having changed pictorial representation in said area corresponding to said intermediate tonal band in said original transparency and in said area corresponding to said third tonal band in said original transparency and having a black line effect between the areas corresponding to said lightest tonal band, said intermediate tonal band, and said third tonal band in said original transparency.

35. The process as defined in claim 34 wherein said means interposed between the light source and said sixth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises a screen.

36. The process as defined in claim 34 wherein said means interposed between the light source and said sixth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises a light-sensitive color dye.

37. The process as defined in claim 34 wherein said means interposed between the light source and said sixth photosensitive material for changing the mode in which an area corresponding to a tonal band in said original transparency is pictorially represented in a final photographic product, comprises selectively employing a screen and a light-sensitive color dye.

38. The process as defined in claim 34 wherein said original transparency having a plurality of distinct tonal bands is an altitude chart produced by the UNAMACE.

39. The product produced by the process recited in claim 26.

40. The product produced by the process recited in claim 33.

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