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THE USE OF SHORT WAVE ULTRA-VIOLET RAYS 
FOR THE SEGREGATION 
OF COMMINGLED SKELETAL REMAINS
Major General Andrew T. McNamara  
The Quartermaster General  
Washington 25, D. C.

Dear General McNamara:

This report, "The Use of Short Wave Ultra-Violet Rays for the Segregation of Commingled Skeletal Remains," discusses one of the problems often confronting the identification specialist: sorting individual skeletons from mixed burials.

The report describes the reactions of cadaver and archaeological skeletal material to ultra-violet irradiation and evaluates these reactions as a means for separating commingled skeletal remains. Although this method will not differentiate between individuals in all cases, the simplicity of the apparatus required and the speed of resolution make it a valuable adjunct to routine field operations. It represents another tool in the Quartermaster Corps effort to achieve better identification of the Army's war dead.

Sincerely yours,

C. G. Calloway  
Major General, USA  
Commanding
HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
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ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report
EP-96

THE USE OF SHORT WAVE ULTRA-VIOLET RAYS
FOR THE SEGREGATION OF COMMINGED SKELETAL REMAINS

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Anthropology Branch

Project Reference:
AE War Dead Identification

August 1958
Foreword

The identification specialist is often confronted with human skeletal remains that comprise two or more individuals. By using a combination of standard techniques, such as articulation, bilateral and serial symmetry, osteometry, and reconstruction, he may achieve accurate segregation after long and careful analysis. As a part of the Quartermaster Corps research program to improve present identification techniques, as well as to devise new methodology for the identification of American war dead, the present study describes and evaluates a fast and simple test for sorting individual remains from mixed burials.

Based on the reaction of bone to ultra-violet irradiation, this report suggests that individual color differences may be used to segregate commingled skeletal remains, either as a primary technique or as a supplement to present methods.

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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>iv</td>
</tr>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. Materials and methods</td>
<td>1</td>
</tr>
<tr>
<td>3. Range of color</td>
<td>2</td>
</tr>
<tr>
<td>a. Cadaver material</td>
<td></td>
</tr>
<tr>
<td>b. Archaeological material</td>
<td></td>
</tr>
<tr>
<td>4. Source of color</td>
<td>3</td>
</tr>
<tr>
<td>a. Fluorescence</td>
<td></td>
</tr>
<tr>
<td>b. Reflected light</td>
<td></td>
</tr>
<tr>
<td>5. Segregation of commingled remains</td>
<td>4</td>
</tr>
<tr>
<td>a. Virginia ossuary</td>
<td></td>
</tr>
<tr>
<td>b. Woodruff ossuary, Kansas</td>
<td></td>
</tr>
<tr>
<td>c. Illinois burials</td>
<td></td>
</tr>
<tr>
<td>d. Material from Pachacamac, Peru</td>
<td></td>
</tr>
<tr>
<td>e. Mixed cadaver material</td>
<td></td>
</tr>
<tr>
<td>6. Summary and conclusions</td>
<td>6</td>
</tr>
<tr>
<td>7. Acknowledgements</td>
<td>6</td>
</tr>
<tr>
<td>8. References</td>
<td>7</td>
</tr>
</tbody>
</table>
Abstract

When bone surfaces are exposed to short wave ultraviolet irradiation, most of them reflect a variety of colors. The wide range of color emission, as well as the fixed relationship of these colors to the substances that emit them, is justification for attempting to apply these qualities to the segregation of commingled skeletal remains.

After demonstrations of the results of ultra-violet exposure on a large sample of skeletal material, it is suggested that short wave ultra-violet lamps can be used in certain instances for the accurate sorting of commingled remains.
THE USE OF SHORT WAVE ULTRA-VIOLET RAYS FOR
THE SEGREGATION OF CONJINGLED SKELETAL REMAINS

1. Introduction

Ultra-violet rays have a useful property which depends on
the power possessed by certain substances to absorb them and
emit or re-emit radiations visible to the human eye within the
relatively narrow ultra-violet region. When this emission
phenomenon lasts only during the period of excitation, it is
known as fluorescence and usually results from the simplest
form of exposure.

Many substances, both inorganic and organic, fluoresce
under ultra-violet irradiation and may be identified by their
characteristic colors. For example, mineralogists and petrolo-
gists have long used ultra-violet sources to detect the presence
of various minerals. Calcites fluoresce red to violet, fluorites
show up as red specks, hydrocarbons are yellow, and uranium is
green (Radley and Grant, 1956). This same procedure has been
employed by medical diagnosticians who can identify certain
animal tissues by their colors. Fatty tissues generally fluo-
resce a strong bluish color, thyroid is reddish, and the pancreas
a brown-yellow (Dake, 1942). The more compact the tissue, the
stronger is its fluorescence, thus, tendons fluoresce more than
muscle, and bone has a still brighter fluorescence. Bone fluo-
rescence is usually whitish with an occasional yellowish cast.
However, bone altered by disease, burning, or decalcification
may show changes in fluorescence (Hoshijima, 1933).

Because of these known color changes in the fluorescence
of bone and the quality of fluorescing substances to emit charac-
teristic colors, the present investigation was made. This report
will describe and evaluate the use of ultra-violet irradiation
on cadaver and archaeological bone as a means for segregating
conjoined skeletal remains.

2. Materials and methods

To insure a complete coverage of ultra-violet activity,
the bone samples used for the present investigation had to
represent different geographical areas, racial groups, skeletal
age groups, chronological horizons, both sexes, and varying
stages of decomposition. Access to the extensive skeletal col-
lection housed in the U.S. National Museum was of great assist-
ance in meeting these criteria. Thus, the sample included speci-
mens from many parts of the world (eight areas of the United
States, Alaska, Peru, Patagonia, Japan, China, Philippines,
Russia, Iraq, Palestine, Egypt, Italy, Germany, Sweden, and
Ireland) and six racial groups (Caucasoid, Mongoloid, American
Indian, Ainu, Negroid, and Neanderthal*).

Most skeletal age groups were represented (from fetal to
adult specimens) and both male and female remains were used
when available. The bone samples were completely skeletonized
and included fairly recent cadaver remains (Huntington collect-
ion, see sect.5c), as well as archaeological material dating from
the middle 1st century A.D. back to approximately 40,000 years
B.C.

All skeletal material was exposed, under varying conditions,
to a portable ultra-violet light (2537 angstrom units).

3. Range of color

Under the ultra-violet lamp, the range of colors emanating
from most of the bone surfaces was surprisingly wide, including
varying shades of red, orange, yellow, green, blue, purple, and
brown.

a. Cadaver material

Most cadaver bone emitted a white, pale yellow, or light
green fluorescence, especially from the shafts of the long
bones and the flat surfaces of the other skeletal members. On
many of these bones, light blue, non-fluorescent spots appeared
on the areas of articulation. Paired cadaver humeri exhibited
equal color intensities as well as similar color patterning,
e.g., the patterns of light blue spots were approximately the
same for both right and left bones. There seemed to be no
distinguishable color or pattern differences between the sexes
or racial groups.

b. Archaeological material

The color range for archaeological material was much more
varied. For example, bones from Illinois were reddish-purple,
from Egypt, yellow-brown, and from Palestine, pink. For the
most part, bleached bones from Japan and Peru showed no fluo-
rescence or color reflectance. In some cases, slight shadings
of blue could be detected; this was probably where bleaching
was not complete.

The Neanderthal material consisted of long bone fragments
from Shanidar Cave, Iraq.
4. **Sources of color**

Before the problem of segregation is considered, it might be well to point out some of the known sources for the color seen under ultra-violet irradiation. Generally, these sources may be classified as fluorescence and reflected light.

**a. Fluorescence**

Fluorescence accounts for most of the color radiation seen in bone. The ultra-violet rays excite certain organic elements, (e.g., organic fat) which in turn fluoresce (Dake, 1942). Thus, the radiated color is directly related to the elements present on the bone surfaces. Blending with or sometimes completely overshadowing the fluorescence of organic constituents are inorganic impurities which may be introduced to the bone surfaces from the surrounding environment. For example, the burial of human remains usually starts a variety of chemical interactions between the bone and its burial environment which may add a number of inorganic substances to the bone surfaces, all emitting their own characteristic color patterns (see sect. 1).

Two simple experiments were performed to demonstrate the importance of surface contamination to color emission. First, a small portion of the surface area of a clavicle (archaeological), which radiated reddish-purple under the ultra-violet lamp, was scraped with a sharp knife. Placed under the ultra-violet lamp, this scraped area was a yellowish-white and showed no trace of reddish-purple. Second, small amounts of soil with a high calcium content were rubbed into the surfaces of fresh cadaver bone until—under daylight conditions—all visible soil traces had disappeared. Before this application, under ultra-violet exposure, the cadaver bone had demonstrated only a whitish fluorescence. After application, under ultra-violet exposure the rubbed areas were blue.

**b. Reflected light**

Although a majority of the ultra-violet rays are absorbed by the bone surface, a certain percentage which varies depending on the condition of the bone is reflected back. This reflected blue light (blue because of the blue filter used in the ultra-violet source) may be great enough to completely cloak low levels of organic or inorganic fluorescence, or it may merely blend with that of the fluorescing substances.

*Actually, this reaction is one of replacement (fossilization) in which organic elements are replaced by inorganic. Studies have shown that some of the organic constituents of bone are more slowly lost or replaced than others. For example, certain amino acids have been identified in bones of great archaeological age (Sara and Cook, 1957 and Abelson, 1957).*
To summarize: the visible radiation seen under ultra-violet exposure cannot be identified as solely bone fluorescence, but represents a combination of: 1) the fluorescence of organic substances, 2) the fluorescence of variable quantities of mineral substances introduced to the bone surfaces from the external environment, and 3) the reflected blue filter color of the ultra-violet source.

5. Segregation of conjoined remains

Samples of mixed skeletal remains were exposed to ultra-violet irradiation to test the suitability of this method for identification. The samples ranged from mixed ossuary material (from a number of archaeological sites) and single burials to cadaver bone in varying stages of decomposition. Each sample was exposed to short wave ultra-violet rays and sorting of individuals was attempted solely on the basis of color differences. The following examples illustrate the general range of results.

a. Virginia ossuary

The material from this ossuary was all from the same pit and represented three individuals. The bones were extremely friable and fragmented. Under the ultra-violet lamp, the bones became a dappled pink and slight shade differences between bones were apparent. However, positive segregation of individual skeletons based on these shading differences was not feasible.

b. Woodruff ossuary, Kansas

Three burials in which bone duplications were found were exposed to ultra-violet irradiation. Exposure produced red, purple and yellow combinations, and it was fairly easy to distinguish and segregate the extra bones from the three burials. However, mixed fetal remains from a single burial could not be differentiated by color alone.

c. Two Illinois burials from adjoining counties (Calhoun and Jersey)

Both burials were complete and came from approximately the same type of soil. Under ultra-violet exposure, all bone surfaces appeared reddish-blue but differences in color shading between burials made accurate segregation possible. It was found that shading differences are not immediately noticeable but are detectable after the bone has been exposed for approximately 30 seconds. This delay may be due to normal visual adaptation or may be connected in some way to the function of the exciting process of the rays.
1. Material from Pack暧昧e, Peru

This sample consisted of parts of three burials from the same archaeological site in Peru. Ultra-violet exposure produced distinct color differences (Figure 1) and the sorting of individual remains was successfully performed.

a. Mixed cadaver material

The cadaver material for this investigation was selected from the Huntington collection; this collection was started around 1905 and has been periodically enlarged. In most cases, segregation of individual bones was accomplished by observing the color differences as well as the depth and shade of color. Also, in cadaver bone, the color is usually spotty and forms complex patterns (see sect. 3a). Thus, in a mixture of paired humeri, the bones belonging to some individuals were differentiated on the basis of color similarity, while in cases where color differences could not be detected, sorting was done by matching similar patterns of color.

The above tests have shown instances where segregation by ultra-violet irradiation was easily accomplished, either through observed color differences or, as in some of the cadaver material, by means of color patterning. In other cases, differentiation was impossible. Color differences were either not present or not great enough to be relied upon for identification purposes.

It is difficult to evaluate these results in the quantitative terms usually applied to the introduction of new methodology. Because of the many variables influencing the radiant elements of a bone, at any given time, from any given place, it would be meaningless to tabulate the percentages of the successes and failures in the present investigation.

To summarize: the results indicate that ultra-violet irradiation can be used in some cases to aid in the sorting of mixed skeletal remains. This technique has two distinct advantages over the standard methods of segregation (articulation, bilateral and serial symmetry, osteometry, etc.). First, it is fast. The process of observation and segregation can be accomplished in a matter of seconds. Second, it is simple. The investigator can tell at the moment of exposure whether his efforts will be successful. He sees either distinct and dramatic color differences or undifferentiated uniformity.
6. **Summary and conclusions**

The present study was initiated for the purposes of describing the reactions of various stages of post-mortem bone to ultra-violet irradiation and to evaluate these reactions in terms of their use as a tool for the segregation of commingled skeletal remains.

A knowledge of the range of color produced by ultra-violet exposure was obtained from bone samples (both archaeological and cadaver) that represented various geographical areas, different racial and skeletal age groups, distinct chronological horizons, and both sexes. A wide range of color, which included most colors in the visible spectrum, was demonstrated.

Based on this wide color range of irradiated bone and on the evidence that most colors are consistent in characterizing the particular substances that emit them, tests were undertaken on commingled bone samples to demonstrate the possibility of segregating individuals by means of color differences. The results showed that in a majority of cases, the sorting of individual remains on the basis of differences in observed color was easily accomplished. This was true for both archaeological and cadaver remains. Moreover, for cadaver remains where color differences could not be detected, segregation was done by observing the similarities of color patterns.

Although it is not possible to render quantitative predictions or probability values from this ultra-violet analysis, the study has demonstrated that when other techniques for the segregation of commingled skeletal remains have failed, short wave ultra-violet irradiation is a possible supplement.

7. **Acknowledgements**

The author is indebted to Dr. T. D. Stewart and Dr. Clifford Evans of the U. S. National Museum for their assistance and cooperation during the collection of the data.

Special thanks are due Mr. Doron Linnaberry of the QM RAE Center for his expert help in photographing the irradiated bone samples.
Figure 1. The distal ends of three humeri from Pachacamac, Peru, showing color differences under ultra-violet exposure.
8. References


Dear Mr. Bush,


The above report currently carries a limitation code #2, which restricts its dissemination to government agencies and their contractors. After reviewing TR EP 98, I believe the restriction on distribution is long outdated, and recommend that the distribution code be changed to permit unlimited distribution.

Should you have any questions regarding this letter, or any of the Army’s past or present anthropology publications from Natick, please feel free to contact me directly at DSN 256-5429.

Sincerely Yours,

CLAIRE C. GORDON, Ph.D.
Senior Anthropologist
Science & Technology Directorate

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Completed 7 Jun 2000

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