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From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Atomic Bombs, Hiroshima and Nagasaki, Article 2 - Medical Effects, Supplementary Studies.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, covering a portion of Target X-28 of Fascicle X-1 of reference (a), is submitted herewith.

2. The report was prepared by Captain Shields Warren, MC (S), USNR.

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ATOMIC BOMBS, HIROSHIMA AND NAGASAKI

ARTICLE 2

MEDICAL EFFECTS, SUPPLEMENTARY STUDIES

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

FASCICLE X-1, TARGET X-28

MAY 1946

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

MISCELLANEOUS TARGETS

ATOMIC BOMBS, HIROSHIMA AND NAGASAKI - ARTICLE 2
MEDICAL EFFECTS, SUPPLEMENTARY STUDIES

There is no essential difference in the tissue changes produced by the bombs dropped at HIROSHIMA and NAGASAKI.

Atomic bomb injuries may be classified as follows:

1. Air blast injury.

    a. Primary, due to thrust or compression of sonic wave.
    b. Secondary, due to impact with wreckage.

2. Radiation blast injury.

    a. Thermal radiation blast injury.

        (1) Primary, flash burn due to radiant heat.
        (2) Secondary, due to burn from induced fire.

    b. Ionizing radiation blast injury.

        (1) Primary, due to gamma rays and neutrons.
        (2) Secondary, due to induced radiation.
        (3) Tertiary, due to residual radiation.

Changes clearly due to the effect of ionizing radiation blast include lymphoid atrophy, damage to hematopoietic tissue, production of leukopenia, injury to gonadal tissue and epilation.

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INTRODUCTION

Article 1 of this report* presented information as to the effects of atomic bombs dropped at HIROSHIMA and NAGASAKI on installations, buildings and personnel, as well as data of general biologic interest. An analysis of the number, nature and types of casualties also was presented, together with a description of the variations in casualties due to the factors of distance from the center of the bomb explosions, the passage of time since the explosion, and complications due to secondary factors.

Article 2 pertains to (a) histologic changes noted in the tissues of persons dying from the effects of the bomb blasts at HIROSHIMA and NAGASAKI and (b) residual radioactivity at NAGASAKI.

The material on histologic changes in the tissues of those who died is based on autopsies performed by the Japanese from which samples of tissue were obtained for histologic examination, and on those autopsies which U. S. personnel performed. The Joint U. S. Army-Imperial Japanese Government Atomic Bomb Commission co-operated in obtaining this material for study. The facts presented are based on approximately 240 autopsies.

The study was carried out largely at the Naval Medical Research Institute, Naval Medical Center, Bethesda, Maryland. Aid given by the Institute and by its Medical-Officer-in-Charge, Captain S. K. Hakansson, are gratefully acknowledged. The sections for histologic study were prepared in the Pathologic Laboratory of the New England Deaconess Hospital, Boston, Mass. in order to expedite the study, as rapid demobilization led to a shortage of personnel which otherwise would have precluded completing adequate study within a reasonable length of time. Aid has been received from the Army Institute of Pathology, Col. J. D. Ash, Commanding Officer.

The material on residual radioactivity is based on reports of two groups of Japanese physicists who were sent to NAGASAKI to make further measurements, in accordance with arrangements made jointly by representatives of NavTechJap and the U. S. Strategic Bombing Survey. One group was from the Kyushu Imperial University, FUKUOKA, and worked under the direction of K. SHINOHARA. The other group was from the Institute of Physical and Chemical Research, TOKYO, and worked under the direction of Dr. Y. NISHINA. The separate reports of these groups are summarized.

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*NavTechJap Report, "Atomic Bombs, HIROSHIMA and NAGASAKI, Article 1 - Medical Effects". Index No. X-28-1

THE REPORT

PART I
HISTOLOGIC FINDINGS IN THE VICTIMS OF THE ATOMIC-BOMBS AT HIROSHIMA AND NAGASAKI

A. FINDINGS IN HIROSHIMA VICTIMS

To permit orderly and logical presentation we will discuss the changes produced in the various tissues, organ by organ, in arbitrary order, and then discuss the changes in the body as a whole.

1. Heart and Vascular System: No changes of significance were noted in the heart and in the larger blood vessels. The small blood vessels supplying burned areas of the skin showed varying degrees of thickening of their walls and thrombosis according to the degree of damage that they and the adjacent tissues had received, chiefly from the thermal radiation of the bomb. No evidence of ionizing radiation effect was noted in the cardiovascular system.

In those cases where damage of the hemapoietic system had led to the impairment of the clotting power of the blood, there were frequently hemorrhages of greater or less extent in the epicardium, pericardium and sometimes in the myocardium.

2. Lungs: A number of cases in which early death occurred, showed varying degrees of pulmonary edema. In most of the cases in which this was a striking feature, there also were fairly extensive burns of the body's surface. The pulmonary edema in these cases was probably secondary to the burns rather than directly induced by ionizing radiation. Two important secondary effects were noted, (1) focal hemorrhages into the lungs secondary to the impaired clotting power of the blood; and (2) the formation of abscesses due to the radiation-induced leukopenia that many of the cases showed. These abscesses were first small, usually in contact with a terminal bronchus, and owing to the generally lowered resistance of the patients, extended more or less rapidly tc involve a considerable portion of the lobe. Bronchial pneumonia and rarely, lobar pneumonia occurred as a result of the general lowering of resistance to infection. No changes characteristic of ionizing radiation were noted. One case of incidental Paragonimus infection was encountered. There were some cases of rupture of the lung or hemorrhage into the lung due to trauma to the chest wall, usually due to secondary air blast injury.

3. Spleen: Rupture of the spleen occurred as a result of external trauma in a moderate number of cases of secondary air blast injury. Those cases subject to primary ionizing radiation, showed, in the early days, a rapid destruction of the lymphoid elements of the spleen with a concurrent marked congestion which prevented any appreciable decrease in size of the organ. After about two weeks, this congestion subsided and the spleen became shrunken and flabby with very little evidence of lymphoid tissue on microscopic examination. A large number of immature cells, probably lymphoblasts, were irregularly scattered through the splenic pulp. The reticulo-endothelial cells showed some degree of erythrophagocytosis. However, hemosiderosis was infrequent and inconspicuous. The destruction of the lymphoid elements was apparently accomplished largely through autolysis, there being very little evidence of phagocytosis of lymphoid cells or remnants of lymphoid nuclei. In those cases that survived beyond five or six weeks, a slight amount of hematopoiesis developed in the spleen, but not to a sufficient degree to alter the over all hemologic picture.

4. Pancreas: There was no evidence of injury to the pancreas. A few of the Japanese doctors mentioned that cases of acute pancreatitis, secondary to abdominal trauma, had occurred.

5. Gastro-Intestinal Tract:

a. The tongue and pharynx showed, in those cases dying with leukopenia in the latter part of August and early September, an extensive coagulative necrosis, often reaching one or more centimeters beneath the surface. There was virtually no reaction to this necrosis, although a small number of macrophages, lymphocytes and plasma cells collected at the viable margin.

In such instances, edema of interstitial tissue quite commonly occurred. The faucial ring and posterior tongue was often involved.

b. The esophagus presented no essential changes beyond superficial coagulative necrosis at its upper end in some of the leukopenic cases. Petechial hemorrhages occurred irregularly beneath mucosa in thrombocytopenic cases.

c. The stomach showed no changes due specifically to the effects of the bomb. Submucosal edema occurred in a fair number of the cases who developed low serum protein. Scattered petechial hemorrhages as a result of thrombocytopenia were quite frequent. Occasionally, acute focal ulceration developed, probably agonal, secondary to the lowered resistance to infection.

d. In the small intestine, no effects referrable to ionizing radiation were encountered. Edema of all coats was not infrequent in some cases, particularly those with extensive skin burns and low serum protein. Petechial hemorrhages were irregularly scattered in the thrombocytopenic cases. Owing to the lowered resistance to infection, a considerable number of cases showed, particularly in the lower ileum, a wide range of ulcerations, usually without appreciable cellular reaction except for the presence of macrophages, plasma cells, and lymphocytes. In some cases, this ulceration had progressed sufficiently far to permit the establishment of a peritonitis, and in such cases, there was a varying amount of fibrin deposition on the serosa with a slight cellular exudation poor in granulocytes. One of the frequent sites of fairly massive hemorrhage in the thrombocytopenic stage was the ileocecal valve. Sometimes the combined hemorrhage and edema in this region completely obliterated the lumen of the tract.

e. In the large intestine, a fairly striking feature, particularly in the later cases, was a shaggy ulceration, usually most marked in the rectum and less marked in the upper portion of the large intestine. This was associated with varying degrees of edema of muscularis and submucosa, and occasionally with more or less extensive hemorrhage. The microscopic study of such areas showed a sharply delineated coagulative necrosis of the mucosa, submucosa and sometimes the muscularis combined with autolysis of the tissue, producing a rather deep ulcer not unlike that due to amebic dysentery. As a matter of fact, in some cases, the initial diagnosis was amebic dysentery, which was later ruled out in most cases. Some of the cases in the leukopenic stage were complicated by bacillary dysentery, in which case the characteristic histologic appearance of this disease was presented with the exception that no polymorphonuclear leukocytes were present. In general, the ulcerations were worst in the rectum and in the region of the ileocecal valve. Elsewhere, less extensive lesions frequently occurred. In general, the changes in the large bowel resembled those of an acute ulcerative colitis without polymorphonuclear reaction.

6. Liver: No significant or constant changes in the liver were noted. As would be expected, focal necroses were present because of the prevalence of sepsis. In some cases, fibrosis about the central vein was fairly prominent, but the age of the fibrosis tissue was such as to suggest that its deposition antedated the time of the bomb explosion.

7. Gall Bladder and Bile Ducts: No significant changes were found.

8. Adrenals: Adrenal cortical changes were fairly striking in a considerable portion of the cases. The initial alteration was a re-absorption of lipoid from the cortical cells. Together with this shrinking of the cortical cells, actual focal necrosis occurred in some instances. Likewise, there was apparent atrophy of the cells of the zona glomerulosa with clumps of residual cells persisting. In the thrombocytopenic cases, peri-adrenal hemorrhages were occasionally encountered.

9. Kidneys: No changes characteristic of the effect of ionizing radiation were encountered. Scattered hemorrhages occurred in the thrombocytopenic cases.

Sometimes albuminous degeneration of tubular epithelium was encountered and occasionally the tubules contained hyaline and, rarely, brown granular casts. Petechial hemorrhages occurred not infrequently in the parenchyma and rather commonly in the pelvis in thrombocytopenic cases.

10. Ureters: The ureters rarely showed evidence of change except for scattered hemorrhages in the thrombocytopenic cases.

11. Bladder: The mucosa of the bladder in a number of instances showed coagulative necrosis without appreciable reaction. Chronic inflammation with infiltration by macrophages, plasma cells, and lymphocytes, with or without a fair degree of edema of submucosa and the muscularis, was found in a few cases.

12. Prostate and Seminal Vesicles: In these organs no significant changes were encountered.

13. Testes and Epididymes: In most cases, the epididymes were negative. Sometimes, their tubules contained spermatozoa, some of which was being phagocyted by macrophages. The testes in some of the cases nearer the center of explosion showed marked changes of an atrophic nature. In the more extremely damaged, only Sertoli cells persisted within the tubules. These Sertoli cells sometimes had proliferated to form syncytial masses almost occluding the lumen. The basement membrane ranged from normal to a rather marked degree of hyalin thickening. In a few cases, patches of spermatogonial cells persisted, but only rarely were mitoses seen in them. Spermatozoa were absent or infrequent in appearance. There were no significant changes in the interstitial tissue or interstitial cells. All these effects would be expected as a result of the ionizing radiation. In other cases, no change of any sort was apparent. Such cases were more than two kilometers from the center or were in such positions that the testes were shielded from the radiation blast.

14. Ovaries: In most instances, the ovaries were negative. In a few of the thrombocytopenic cases, focal hemorrhage had occurred into the stroma or in the brood ligament. In some of the cases which had been close to the center of the explosion, some evidence of nuclear degeneration was apparent in the ova. Very rarely no ova were seen. In one instance, a binucleate ovum was seen. The significance of this as related to radiant energy is not apparent.

15. Tubes: The tubes were essentially negative.

16. Uterus: A few cases of incidental uterine pathology such as leiomuomas and polypi were found. In a few instances, women of child-bearing age showed both strophic ovaries and atrophic endometrium suggesting a probable radiation effect.

17. Genitalia: The external genitalia were sometimes the site of extensive gangrene in leukipenic cases. Histologic examination in such instances showed a superfacial coagulative necrosis often with masses of bacteria present in it and little, if any, cellular reaction.

18. Lymphoid Tissue: The lymphoid tissue throughout, including the tnymus, showed striking alterations in cases where appreciable degrees of ionizing radiation had been received. In the earlier cases, atrophy of the lymphoid elements including the germinal centers was a prominent feature. Swelling of reticulo-endothelial cells was not infrequent. As in the case of the spleen, the lymphoid destruction apparently occurred by autolysis rather than by phagocytosis. In some of the hemorrhagic cases, red blood cells were present in the sinuses of the lymph nodes and some phagocytosis of them by reticulo-endothelial cells occurred. Partial regeneration of lymph nodes was apparent in many of the cases, particularly those dying after 1 September, and at times, abnormal lymphoblastic cells occurred.

19. Thyroid and Parathyroid: No significant changes were seen in these organs.

20. Larynx and Trachea: In the leukopenic cases, developing from soon after the bombing until mid-September, extensive coagulative necrosis occurring in the organs of the neck was not infrequent. The gross picture was that of a typical Ludwig's angina. This necrosis was frequently accompanied by the presence of bacterial masses and such reaction as occurred to it was usually made up of scattered macrophages, plasma cells, and rare lymphocytes. The viable tissue adjoining the necrotic portions was frequently edematous and some degree of fibrin precipitation occurred in it. Usually, the laryngeal cartilages remained viable even though extensive coagulative necrosis occurred both within and without. In some of the later cases, there was some submucosal fibrosis.

21. Skin: The pathologic changes in the skin varied materially with the character of injury, the time at which the patient died, and the extent of other organic changes, such as leukopenia and thrombocytopenia. In general, the burns presented a similar picture to that of any type of flash burn with the exception that practically no polymorphonuclear reaction occurred, and scattered macrophages, plasma cells, and lymphocytes were present in the edematous viable tissue adjacent to the base of the burn. In some cases, there was fair proliferation of fibroblasts adjacent tc the burns. In others, no effect of repair was apparent. In some cases, with healing, an appreciable degree of keloidal formation occurred. This was more apparent in the poorly nourished patients with low serum protein.

The only evidence of radiation effect on skin was seen in unburned areas where there had been sufficient exposure to cause partial or complete epilation. Here, only rare cases were available for study, so the early changes are not known. Atrophy of the hair follicle was a striking feature. Often the hair follicles had been completely destroyed and the erector pili muscles alone remain to show where they had been. In other instances, a broad strand of hylin connective tissue surrounded the few residual epithelial elements of the hair follicles. Sometimes, an attenuated hair shaft was presented within the follicle. At other times, only amorphous material existed there. The sebaceous glands are apparently more sensitive to radiation than the sweat glands, since disappearance of sebaceous glands was not an infrequent feature.

The sweat glands, on the other hand, rarely disappeared, although some showed thickening of their basement membrane, vacuolization of the cytoplasm of the secretory cells, and, rarely, squamous metaplasia of the duct cells.

22. Hematopoietic Tissues: In general, the bone marrow had a reddish cast, but somewhat more translucent than normal. In histologic examination, this was found to be due to the fact that frequently hyperemia occurred rather than erythropoietic tissue in the bone marrow. In later cases, there was a fair degree of regenerative effort which progressed, in some of the cases dying after the end of September, to such a degree that a picture resembling that of leukemia was presented, the marrow being crowded by great numbers of immature cells, chiefly of the granulopoietic series. In the early stages of regenerative activity, plasmalike cells, some being very large size and multinucleated, were not an infrequent occurrance. Practically every variation was seen, from marrows showing little but fat and reticulo-endothelial cells to those presenting a pseudoleukemic picture. Some degree of regeneration was attempted by the development of hematopoietic foci in the long bones, particularly the femurs and humeri.

23. Brain and Spinal Cord: No significant changes were encountered beyond meningeal hemorrhages, with or without focal petechial hemorrhages in the brain substance in some of the thrombocytopenic cases. No changes specific to ionizing radiation were encountered.

24. Bone: No significant changes in the structure of bone were found.

25. Eyes: Relatively few eyes were available for histologic examination, but in those which were available, hemorrhages showing varying degrees of organization and re-absorption occurred in the retina, chiefly radiating out from the margin of the disc.

B. FINDINGS IN NAGASAKI VICTIMS

The histologic findings of Nagasaki cases were essentially the same as those in the Hiroshima cases. The bone marrow showed in some instances stippling of erythropoietic cells, a finding which was not seen in Hiroshima. The significance of this has not been determined. In the Nishiyama group of cases, none of whom died, detailed hematology study has shown the existence of a macrosytosis of red blood cells which would be expected in view of the residual radiation of minor grade which they received.

C. CONCLUSIONS

There is no essential difference in the tissue changes produced by the Hiroshima and Nagasaki bombs. As would be expected, the effects of various types of blast injury are encountered. On the basis of the study presented in the basic report* and this supplement, we suggest the following classification for atomic bomb injury:

1. Air blast injury
   a. Primary, due to thrust or compression of sonic wave.
   b. Secondary, due to impact with wreckage.
2. Radiation blast injury
   a. Thermal radiation blast injury

(1) Primary, flash burn due to radiant heat.
(2) Secondary, due to burn from induced fire.

b. Ionizing radiation blast injury.

(1) Primary, due to gamma rays and neutrons.
(2) Secondary, due to induced radiation.
(3) Tertiary, due to residual radiation.

This classification encompasses practically all types of casualties encountered in the two cities. Frequently, of course, several types of injury are co-existent in the same individual. Thus, a person may have received a fractured femur from having a building collapse on him, been burned as a secondary fire spread through the area, and developed thrombocytopenia as a result of ionizing radiation blast.

The pattern of injuries in both cities followed a definite chronological order based on the character and extent and severity of the injury the victims received. Most crush injuries died quite early. Most of those receiving flash burns of first and second degree over one-third or less of the body, survived. Those receiving more severe burns died after varying lengths of time. Those receiving a lethal to sublethal dose of ionizing radiation presented a very definite course, whether injury from ionizing radiation was the only one received or whether co-existent with other types of injury. The first group were those killed as a result of widespread autolytic destruction of tissue. These cases began to die early, within a few hours, and most had died within the first four to five days. The second group of cases was made up of the leukopenic cases in which the destruction of white blood cells reduced the protection to infection. The majority of these cases died from four days to six weeks after the explosion. In those cases in which the megakaryocytes and blood platelets were damaged, the hemorrhagic manifestation became most apparent in the latter part of August and up to mid-September. Some hemorrhagic manifestations persisted even up until December. The group of cases slowest to show evidence of injury to hematopoietic tissue were those of injury to erythropoietic tissue. Here, the anemia developed slowly and became more apparent with the passage of time, as the new formation of red blood cells failed to keep pace with the normal rate of destruction of the already formed cells. The majority of anemic deaths occurred after mid-September and were relatively few in number. A considerable number of cases with severe anemia were still present when we left JAPAN and a few additional deaths may be expected even up to the present time.

In general, the changes clearly referrable to the effect of ionizing radiation blast include lymphoid atrophy, damage to hematopoietic tissue, production of leukopenia, injury to gonadal tissue and epilation. Ionizing radiation blast is a very real source of damage to those persons exposed to an explosion of an atomic bomb.

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*NavTechJap Report "Atomic Bomb, HIROSHIMA and NAGASAKI, Article 1 - Medical Effects", Index No. X-28-1.

D. TREATMENT

Therapy for atomic victims should consist of:

1. Prompt and adequate treatment of traumatic injuries (fractures, lacerations, ruptured viscera).

2. Prompt and adequate treatment of burns (pressure dressings, plasma, whole blood transfusions, high-caloric diet, high vitamin intake).

3. Prompt and adequate treatment of ionizing radiation blast injury to the hematopoietic system (whole blood tranfusions, penicillin to combat infection, high vitamin intake, high-caloric diet).

PART II
MEASUREMENT OF RESIDUAL RADIOACTIVITY AT NAGASAKI

A group of physicists from the Kyushu Imperial University, sent to Nagasaki to make further measurements of residual radioactivity, submitted a report which is preliminary in nature and consists chiefly of tables of actual measurements. These measurements were a continuation of observations made by the group on at least four previous occasions. The instruments used were two Lauritsen electroscopes, which had also been used previously. The tabular material in the report shows the relationship of activity recorded by the electroscope as a function of the thickness of lead filters placed between the instrument and the ground at various locations in the Nishiyama area. These data are valuable in characterizing the nature of the radiation but require further interpretation. A value for the activity at the explosion center on 23 - 25 December 1945 is given, and from this value and the previous data, an approximate half-life of the activity at the center is given as 150 days. The last previously determined half-life given by this group, as of 28 October 1945, is approximately 70 days. Such a lengthening of the apparent half-life is to be expected owing to the fact that, as each of the shorter half-life components disappears, the apparent half-life increases toward the value for the longest half-life component. On the basis of previous experience with this group, it is believed that the data are essentially sound.

A more complete study of residual radioactivity at Nagasaki was made by a group of physicists from the Institute of Physical and Chemical Research, TOKYO. The measurements made by this group were carried out using a Neher electrometer and hence the results are not directly comparable to those of the group from Kyushu Imperial University. Furthermore, the chief value of the latter measurements lies in describing the time relationships and nature of the residual activity, whereas the measurements made by the Tokyo group are valuable in reaffirming the geographical distribution of the activity.

The results of this study are best abstracted by reproduction of the five Figures incorporated in the report, which are largely self-explanatory. Figure 1 indicates the detailed location of the explosion center just south of the prison. Figure 2 indicates the location of the group areas measured along north and east radii for the construction of Figure 3, which is a plot of residual activity versus distance from the center. Figure 4 represents a neat contribution in that it indicates the residual as a function of the thickness of earth at the center, immediately below the point of bursting in the air. Unfortunately, only three points were obtained. However, these data are of considerable interest and serve to emphasize the effectiveness of earth as a barrier to neutrons and gamma radiation. Figure 5 shows the pattern of deposition of fission products from the cloud formed as a result of the explosion, and agrees well with previous observations of this phenomenon.

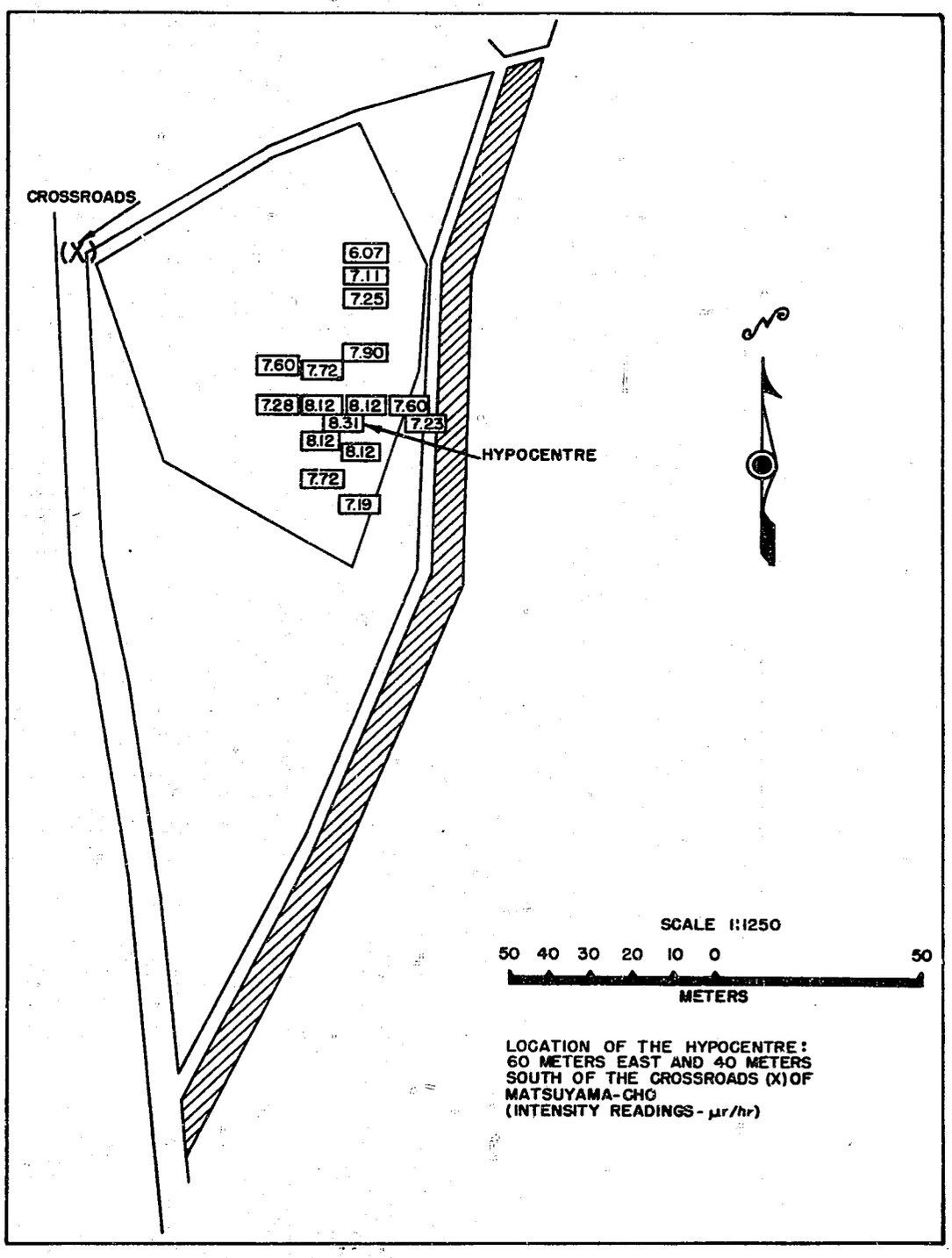


Figure 1

DETERMINATION OF HYPOCENTRE FROM INTENSITY DISTRIBUTION NAGASAKI 27 DECEMBER 1945

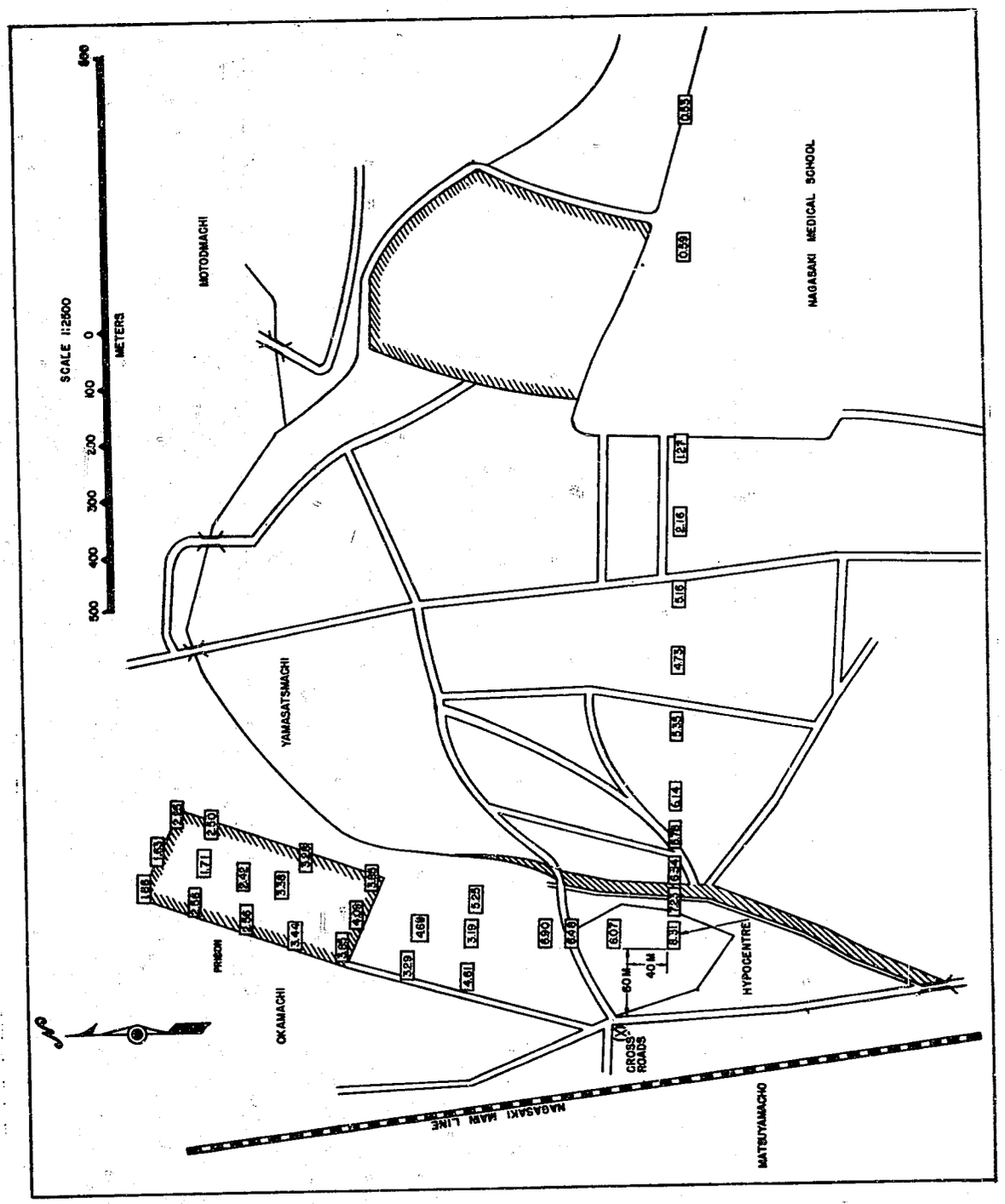


Figure 2
RESIDUAL RADIO-ACTIVITY AT NAGASAKI
(μr/hr) 26-29 DECEMBER 1946

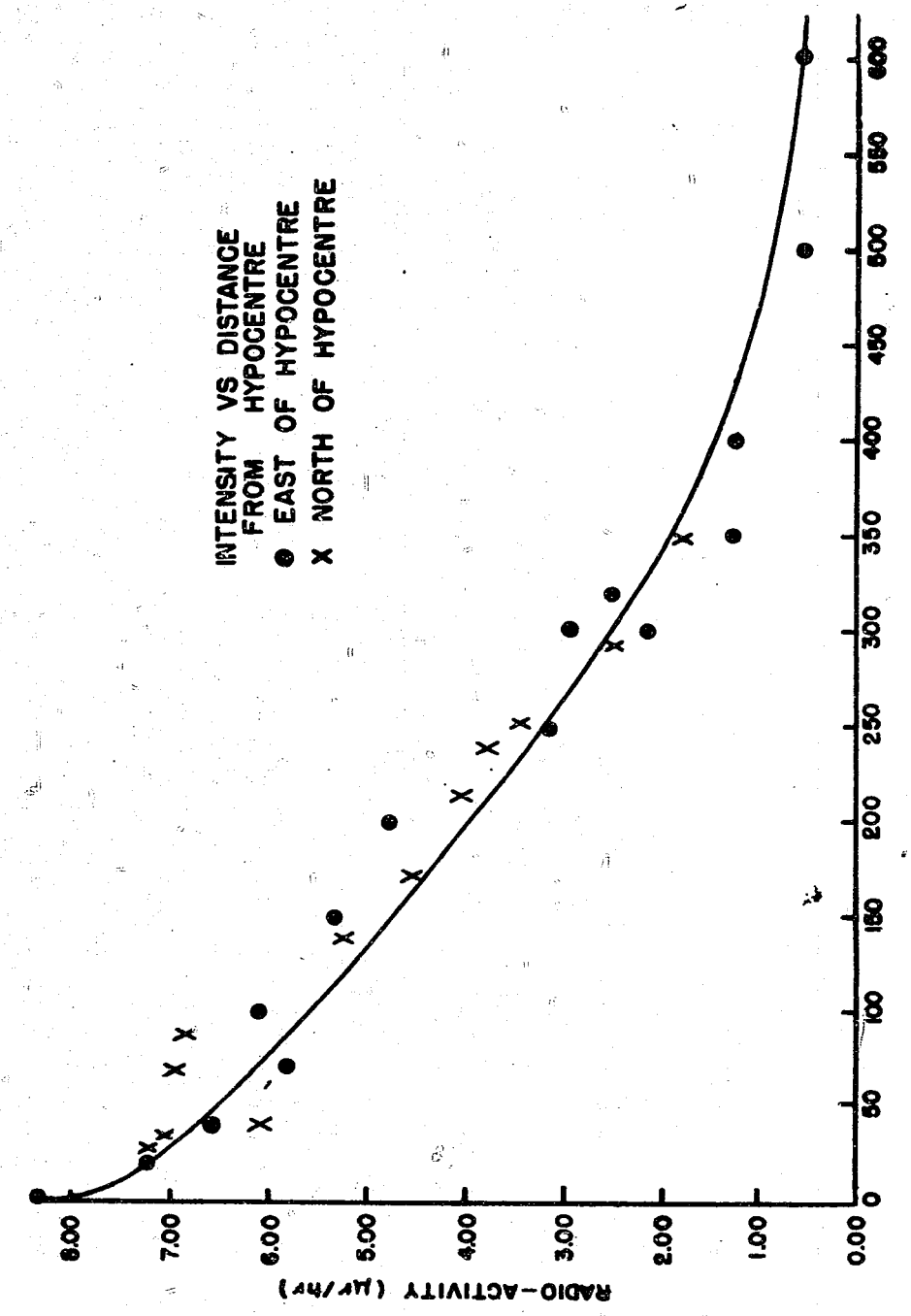
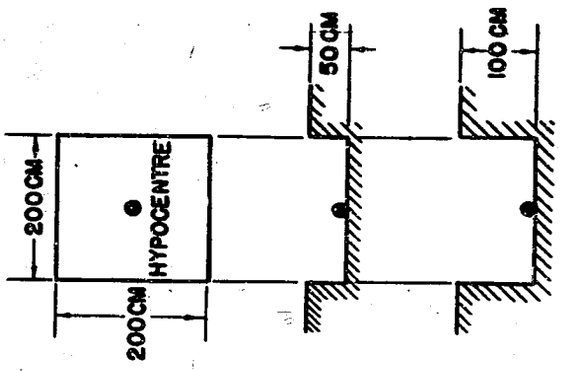


Figure 3
RESIDUAL RADIO-ACTIVITY AT NAGASAKI
26-29 DECEMBER 1946



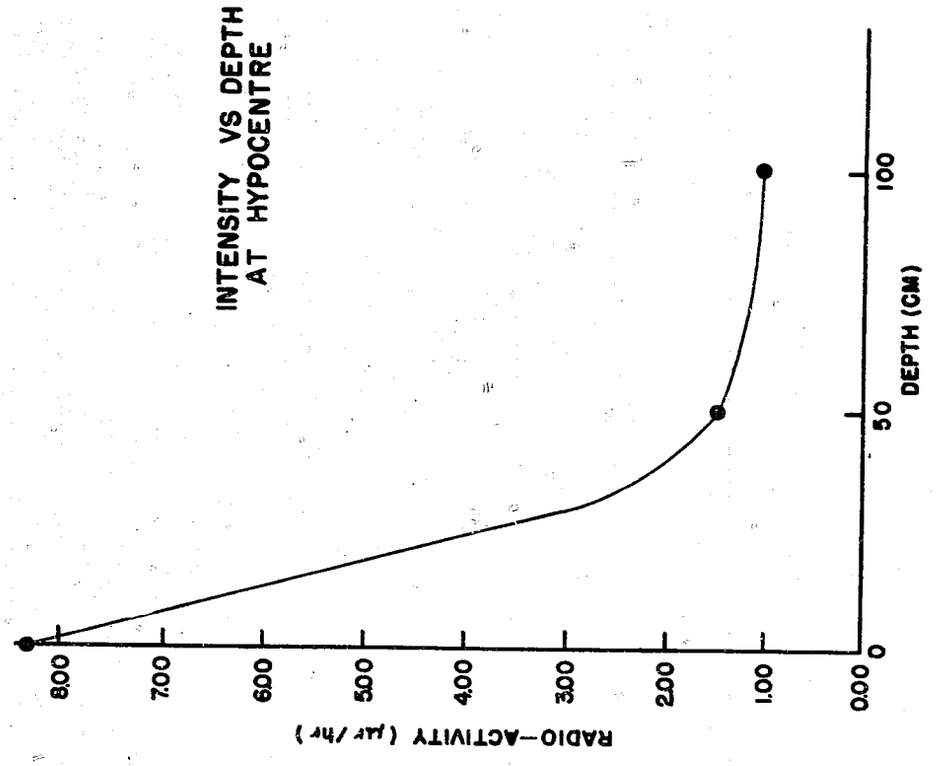


Figure 4
RESIDUAL RADIO-ACTIVITY A
7 DECEMBER 1945

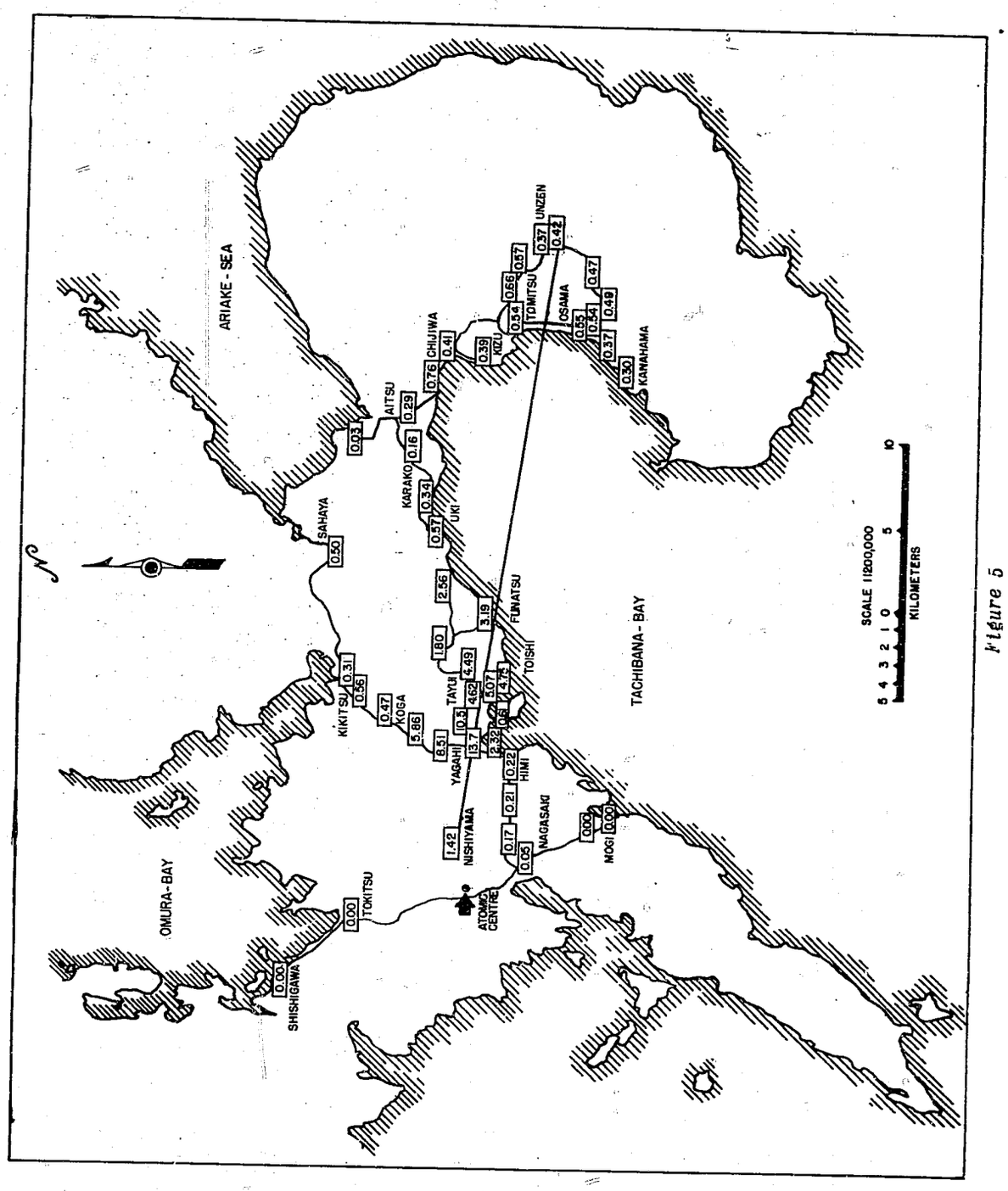


Figure 5
RESIDUAL RADIO-ACTIVITY IN NAGASAKI AND ENVIRONS (μr/hr)
25 DECEMBER 1945 - 9 JANUARY 1946