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OPERATION SANDSTONE

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DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW

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ORO 32458

Observation of the YOKE DAY Atomic Cloud from the U.S.S. Mt. Mc Kinley. Shipboard theodolites, normally used for observing weather balloons, were a convenient instrument for obtaining elevation and azimuth angle data for the atomic clouds by ships of Joint Task Force SEVEN.

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Meteorological Report

on the

VISIBLE ATOMIC CLOUDS

Operation SANDSTONE

Eniwetok Atoll, Marshall Islands

15 April, 1 May, and 15 May 1948

Prepared as Part of the Scientific Meteorological Program
by the
Meteorological Staff, Joint Task Force SEVEN

DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW

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Preface

The secondary mission of the meteorological staff of Joint Task Force SEVEN was the implementation of a scientific meteorological program. For logistic reasons, this mission was limited to whatever scientific observations could be made by the meteorological personnel and equipment already in the test area because of the operational requirements of the Task Force. The program which was planned included documentation of all meteorological reports, observations on the rate of rise and height of the atomic clouds, volume of the clouds, microbarograph observations in order to obtain preliminary estimates of the bombs' energies, energy estimates of the bombs from thermodynamic considerations, cloud trajectory calculations, and investigations of atmospheric turbulent diffusion.

This report is concerned primarily with the data which were collected on the visible atomic clouds. The meteorological observations contained here are those for the test days only. The surface, upper wind, upper air, and aircraft observations for the entire duration of the Operation SANDSTONE have been collected and will be made available in a publication with no security classification. The amounts of energy released by the bombs will be considered only insofar as they affect the atomic cloud formations. The meteorological microbarograph is not a suitable instrument for measuring pressure waves from atomic weapons and other meteorological methods of studying the energies of the weapons are not conclusive enough to be considered at this time. In this report no attempt will be made to discuss the radiological or chemical properties of the clouds. The phenomena described are those which could be seen or photographed.

Prior to Operation SANDSTONE, almost no numerical data had been collected on atomic clouds. Photographs were the best means of studying atomic cloud behavior, but the lack of photogrammetric data made this difficult. In particular, no photographs showed the dispersion of the clouds by the upper winds, and very little was known of the manner in which atomic clouds were dispersed. Actually, almost nothing was known about how dust or smoke clouds would be dissipated if carried to high altitudes. Therefore, it was important that data be obtained not only to determine the differences, if any, between the clouds produced by the three weapons tested, but also to learn about the general behavior of atomic clouds.

Original planning assumed that photographs would be available throughout the entire life of the visible atomic clouds, but H-hour for all tests was in the early morning darkness just prior to dawn, and photographs of the stages of most rapid rise of the clouds were not possible. Photographs show the atomic clouds during the first fifteen to thirty seconds when in the fireball stage, or show the clouds later when at about highest altitudes, or when being dispersed. The SANDSTONE Operation did not produce pictures of rising cloud mushrooms such as were typical of the CROSSROADS Operation. Many cloud pictures were attempted during the first test and the majority were unusable or photographically disappointing. For that reason, fewer cloud pictures were attempted during the second test, and almost no cloud pictures were made during the third test.

As part of the scientific meteorological program, weather observers were requested to make observations of atomic clouds by means of their theodolites and to use sketches to show points at which the theodolites were aimed or how the clouds were shaped. Also, they were asked to write verbal descriptions of all atomic phenomena observed. As the clouds could be seen and sketched, but not photographed, this report is the only record of the clouds between the extinguishing of the fireballs and the time that the highest portions became lighted by the rising sun.

To understand this report, it is necessary to know only a few details of the tests conducted during Operation SANDSTONE. Three atomic weapons were tested. The first was tested on 15 April 1948, designated as XRAY DAY; the second was tested on 1 May 1948, designated as YOKE Day; and the third was tested on 15 May 1948, designated as ZEBRA Day. H-hours were at 0617, 0609, and 0604 hours local time, respectively. All three of the weapons were fired near the tops of identical towers approximately 200 feet high. Therefore, all bursts were air bursts and the clouds produced were similar to the ABLE Day cloud at Bikini.

All air bursts have produced what have become known as mushroom clouds. However, the atomic clouds produced XRAY, YOKE, and ZEBRA Days differed in several noteworthy respects. These differences were due primarily to the differences in energies released rather than to any marked differences in properties of the atmosphere. Estimates of energies released by each weapon are outside the scope of this paper, but a better understanding of the clouds is possible if the energies are roughly compared. The XRAY Day weapon appeared to release somewhat more energy than did the air burst at Bikini; the YOKE Day weapon was somewhat more violent than that of XRAY Day; and the ZEBRA Day weapon was perhaps less violent than the ABLE Day bomb. The ZEBRA Day cloud attained a much lower altitude than either the XRAY or the YOKE Day clouds.

Clouds from air bursts have begun with the same sequence of events. These include the incomparably brilliant flash of an atomic weapon, the condensation cloud, the fireball phenomena, and the mushroom cloud. These phenomena, which were described many times in the reports of Operation CROSSROADS, were reported at all three tests during Operation SANDSTONE. Differences occurred only in size or degree. Uninformed observers at seventeen, thirteen, and nine miles for the three tests, respectively, saw no marked difference between the major atomic phenomena and could not compare the energies of the weapons. Also, photographs from CROSSROADS and SANDSTONE of the condensation clouds and fireballs look nearly the same. Therefore, no attempt will be made to describe phenomena which are not noteworthily different from that reported at Bikini.

If it had been possible to establish two theodolites on a base line three to five miles long and make calculations by means of base line triangulation, much of the discussion and more than a few of the charts in this report could have been omitted. Such a base line was not possible as all observers were concentrated toward Eniwetok for simplification of the radiological safety problem. Observers might have been placed on ships outside of the lagoon, but the problem of moving or training such observers did not seem worthwhile in view of the difficulties and the probabilities of obtaining usable data. Much of this report is concerned with describing the methods used for determining the dimensions of the atomic clouds from what is assumed to be a single observation point. Meteorological data such as upper air soundings and upper winds are used to estimate measurements which could normally be obtained by the use or more than one theodolite station.

In view of the continued requirements for atomic cloud data of a meteorological nature, and in view of the radiological hazard and difficulties associated with establishing suitable observing sites, the procedures used in making the fullest possible use of the data obtained at Eniwetok are described in great detail.

It was found, when the problem of reporting on the atomic clouds was approached, that the most effective way to describe the clouds and tell how they were affected by meteorological elements, or to tell how the clouds were observed, is by means of pictorial presentations. Therefore, except for the brief descriptions of the clouds in the beginning, and the conclusions and recommendations at the end, this report consists of diagrams, charts, sketches, and photographs. Each set of figures or pictures is preceded by a brief explanation, and then the situation for XRAY, YOKE, and ZEBRA Days is illustrated in turn.

The main body of the report is followed by three appendices. These do not describe the atomic clouds, but give additional information pertinent to a study of the clouds. They present, in the order given, a discussion of the observational techniques, working charts, and theodolite data; the weather observations for the test periods; and the meteorological charts for the test periods.

The need for the scientific meteorological program was foreseen by Colonel B. G. Holzman, U.S.A.F., Staff Meteorologist, Joint Task Force SEVEN. Colonel Holzman organized and gave guidance and support to the entire program which included the collection and analyses of the data and the publication of this report.

Major Delmar L. Crowson, Deputy Staff Meteorologist, assisted in every way in the collection of data, prepared originally the surface weather data charts found in Appendix III, and carried out the administrative details required for the publication of this report.

Lieutenant Ernest F. Lilek, U.S.N., Assistant Staff Weather Officer, aided in the collection of data from the ships of the Task Force and was responsible for the analyses of the upper air charts which appear in Appendix III and the trajectory studies beginning on page 43.

The collection of meteorological and atomic cloud data in the Eniwetok Area, except that aboard the U.S.S. Mt. McKinley, was accomplished by the following officers: Major L. H. Pribble, U.S.A.F., Weather Officer, Weather Detachment Eniwetok; Lieutenant T. P. Mullins, U.S.N., Aerological Officer, U.S.S. Albemarle; Ensign E. L. Snopkowski, U.S.N., Aerological Officer, U.S.S. Bairoko; and Chief Aerographer, L. D. Blakely, U.S.N., Aerological Officer, U.S.S. Curtiss.

The Chief of the U. S. Weather Bureau has given full cooperation and has furnished the services of qualified Weather Bureau personnel upon request. Dr. Harry Wexler, Chief of the Special Scientific Services Division, U.S. Weath Bureau, has been available for consultation and Mr. Fred White of that Divisio has proofread the text and has offered beneficial suggestions in the compilatio of the publication.

The offices used for the preparation of the printed report were thos of the Headquarters, 1009th Special Weapons Squadron where suitable security measures for safeguarding Restricted Data exist. The meteorological section of the Special Weapons Squadron gave the fullest cooperation possible. This Headquarters also furnished stenographic assistance.

The monitoring of the scientific meteorological program; the collection of the scientific data; and the preparation of this publication (including the performing of the calculations, the writing of the text, the drawing of the figures, and the assembling of contents of the pages for photo-offset printing) were done by Mr. Paul A. Humphrey, Meteorologist, of the U. S. Weather Bureau.

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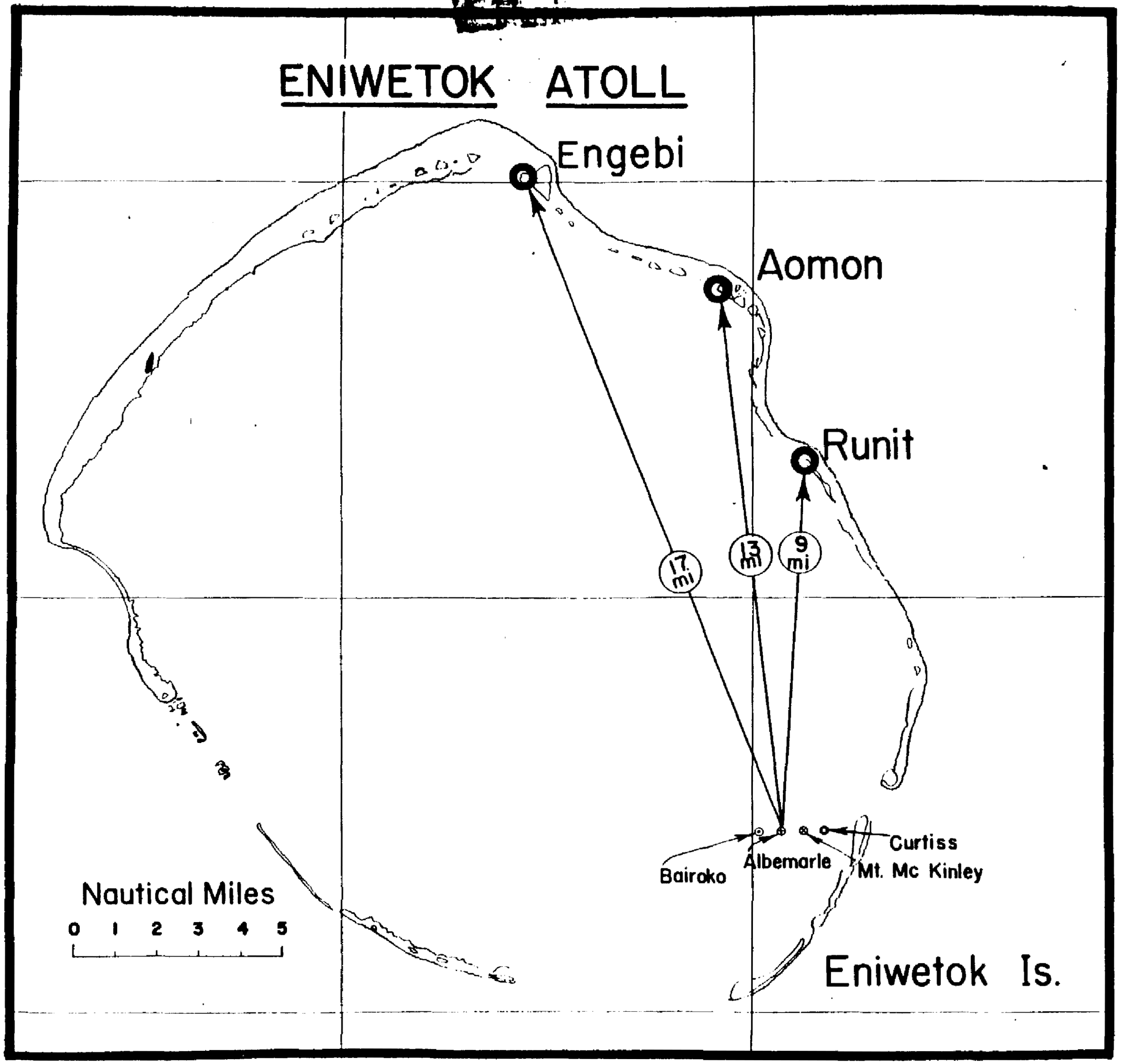

Map of Eniwetok Showing Locations of Observing Ships

The four observing ships of Joint Task Force SEVEN, the U.S.S. Albemarle, the U.S.S. Bairoko, the U.S.S. Curtiss, and the U.S.S. Mt. McKinley, were anchored in the same anchorages during the three tests. The difference in the respective positions of the ships for each test did not vary much more than a ship's length. The bows of the ships were headed into the easterly trade winds so that theodolites were set up on the port side. With the constant wind and still water of the lagoon, the ships did not swing more than a few degrees during any particular set of observations and the deck was almost as steady as firm ground.

Only one distance for each test has been used for all four ships. When the distances of the test sites were measured from each ship, it was found that for practical purposes whole miles, rather than miles and fractions of miles, would give sufficiently accurate results.

Proper distance is an important consideration when making meteorological observations of atomic phenomena. On XRAY Day, with the test site at Engebi, the island was below the horizon; and nothing could be seen below the tops of the cumulus clouds which were in the vicinity of the test site. On YOKE Day, Aomon was just on the horizon but because of darkness and the small cumulus clouds it was not possible to report surface phenomena near the test site with assurance. On ZEBRA Day, Runit was easily seen when light was available. The flood lights near the base of the tower were in plain view before H-hour. At the distance of 9 miles the bases of the cumulus clouds appeared well above the horizon so that it was not difficult to see beneath them.

For observations of surface or low altitude phenomena the shorter distances are preferable; however, for the observation of clouds after they reach maximum altitude the longer distances are preferred. If the cloud is near, as was the ZEBRA Day cloud, it is not possible to sight on the top of the highest part. Theodolites must be aimed toward the underneath side of the cloud. Perhaps the optimum distance for general observation from the surface is near 12 miles.

It should be noted that all distances used in this report are nautical miles.

With regard to orientation, the positions of the ships were very favorably located with respect to the upper winds. The cloud material moved off to the east and west from the test sites so that it was in sight for about three hours, and there was a minimum of radiological hazard.

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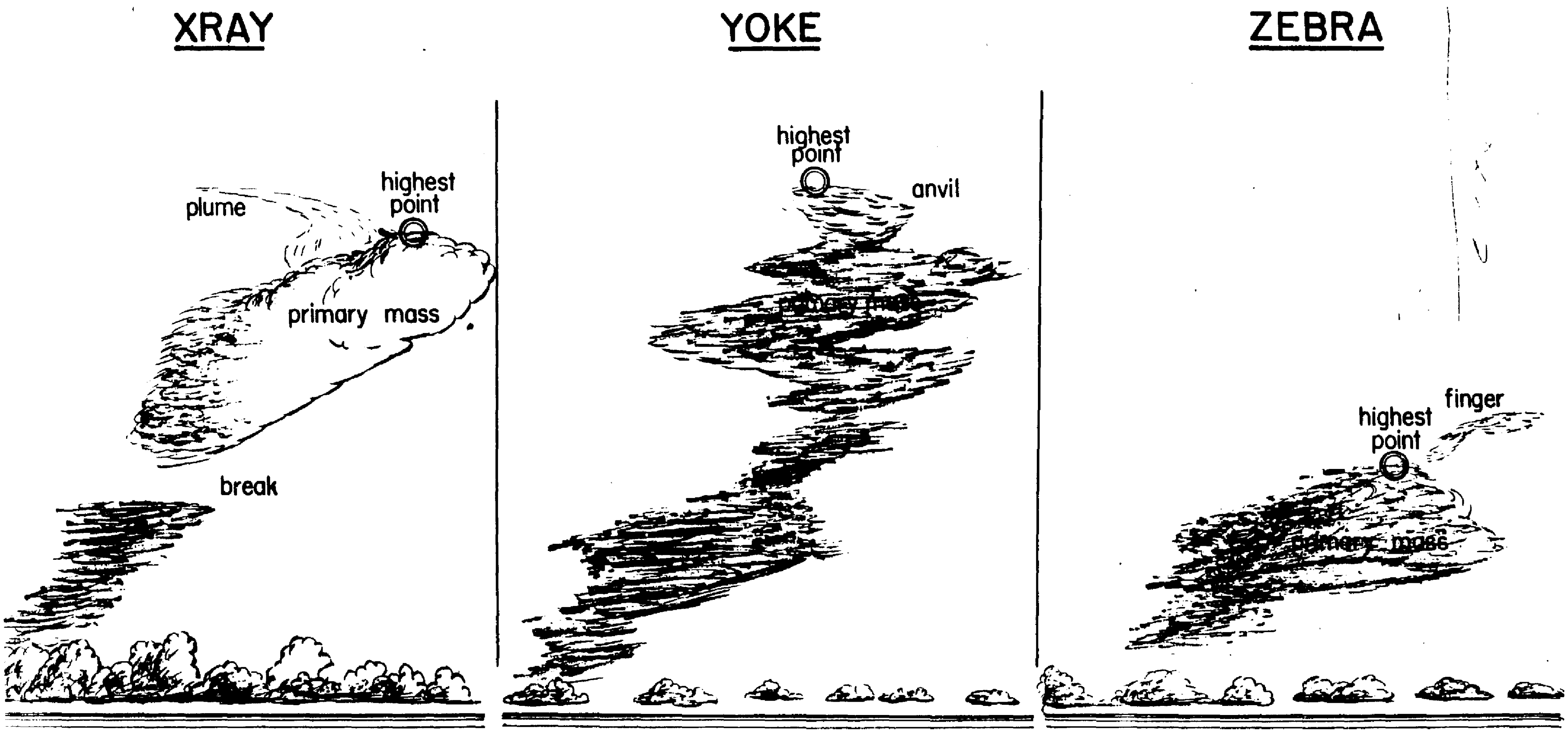

— Identification of the three atomic clouds — Time: H-hour plus 15 min.

Descriptions of the Atomic Clouds

On the opposite page are shown outline sketches of the three clouds as they appeared at 15 minutes after H-hour. When seen at this stage, the clouds each had the features by which they are most easily identified. Prior to this time, the clouds had somewhat the same characteristics. That is, they consisted of a globular mass on a thick stem. Afterwards, they were in various stages of diffusion; but at 15 minutes past H-hour the differences between the clouds were unmistakable.

With all three clouds, the part of the cloud referred to as the "primary mass," or the "primary portion," is that part of the cloud which seemed to have come from the initial hot gas bubble, which had been either the head of a mushroom cloud or which had risen because of its own high temperatures. At 15 minutes past H-hour, the primary mass of the XRAY Day cloud was globular and somewhat resembled the top of a swelling cumulus cloud; that of YOKE Day seemed to consist mostly of smoke and dust and was not easy to distinguish from the stem because of the irregularities of the cloud; and that of ZEBRA Day was something like the remains of an oversized smoke ring. Observers were instructed to aim their theodolites at each side of the primary mass in order that the diameter of the radioactive cloud could be roughly calculated.

The words "highest point" also require explanation. When the primary masses were rising, the highest point was simply what appeared to be the top of the globular mass, or mushroom. However, unexpected changes which confused the observers, took place in the tops of all of the clouds. The XRAY Day cloud developed a wing-shaped sheet of cirrus which is referred to as a "plume;" the YOKE Day cloud spread at the top so that it had the "anvil" shape of a cumulonimbus; and the ZEBRA Day cloud had a projection, or "finger," which pushed out through the primary mass. In the case of the XRAY Day cloud, some of the observers shifted their aiming point from the primary mass to the near edge of the plume, since the elevation angle of the edge of the plume was larger. They also shifted to the end of the finger on ZEBRA Day for the same reason. It is only through the use of the original sketches that it is possible to tell how the theodolites were aimed. The point referred to as the "highest point" is meant to be the highest part of the primary mass; however, in the case of the YOKE Day cloud, the primary mass is so poorly defined that it is impossible to determine whether or not the elevation angle for the top of the anvil is the same as that for the top of the primary mass. In the case of the ZEBRA Day cloud, the top of the finger-like projection is actually the part of the cloud highest in elevation, but the plume and the anvil of the XRAY Day and the YOKE Day clouds are only signs that the top parts of the clouds are spreading out against the base of the stratosphere. As one of the purposes of the theodolite observations was to obtain the true altitude of the radioactive clouds, the fact that some observers shifted to minor features of the clouds was undesirable. However, where data can be obtained for the minor features without the loss of information for the primary masses, such data should be collected.

That part of the atomic clouds which is referred to as the "stem" of the cloud (not labeled on the sketches) is what is below the primary mass. The stem of the clouds consisted of material swept up from the surface or left behind as the primary mass cooled in rising.

The XRAY Day cloud had another feature besides the plume not common to the other two clouds. That is, it had a distinct "break" between the primary portion and its stem.

Phenomena common to all air bursts of atomic weapons which should be mentioned as part of a meteorological report on atomic clouds are discussed below in the approximate order of their occurrence.

H-hour was marked by the indescribably brilliant flash. On all three tests, observers actually felt the radiant heat on their faces for a brief instant, but the heat was of too short duration to be recorded on any ordinary meteorological equipment. (No observer should look directly at the test site at H-hour without a suitable dark filter for his eyes, and no ordinary instrument should be pointed at the flash.)

Immediately following the flash, the growth of the hemispherical condensation cloud begins. It grew at approximately the speed of sound as the drop of atmospheric pressure behind the explosion wave caused condensation of water vapor. The determination of the exact dimensions of these special clouds were not part of the meteorological program as their sizes are important considerations in energy calculations; however, for the purposes of comparison, it will be stated that the XRAY and the ZEBRA Day condensation clouds were about 5 miles in diameter and the YOKE Day cloud was nearly 6 miles in diameter. In each case, the condensation clouds had nearly smooth white sides and were brilliantly lighted from within. They appeared to be nearly hemispherical, but the YOKE condensation cloud was distinctly flattened on the top side. It was difficult to see the bottom of the XRAY Day condensation cloud because of distance and natural clouds, and the base of the YOKE Day cloud seemed to rest nearly on the surface; however, the base of the ZEBRA Day condensation cloud was at about 2,000 feet, so that it was possible to see under it and to see the flames around the base of the fireball. The condensation clouds disappeared from the middle outward so that to a surface observer these clouds seemed to vanish instantaneously. From the air, the clouds had the shape of a doughnut, with the incandescent gases of the fireball in the middle. (See Note Below)

After the condensation cloud disappeared, the incandescent gases which formed the atomic cloud were seen. The colors of these hot gases changed from nearly white, to yellow, to orange, and then to red in about 20 seconds. The closer the test site, the brighter the flames in the fireball appeared and the longer they seemed to last. The quantity of the material in the YOKE Day cloud was noticeably greater than that of the XRAY Day test; and on YOKE Day, the flames seemed to spread over the island and linger momentarily before starting upward. At about H-hour plus 10 seconds, the fireballs were nearly spherical except for their flattened tops, and they seemed to rest on a pedestal of smoke and dust which had been swept up behind them as they began their rapid rise.

As the brighter colors of the fireballs faded, the soft, blue-violet luminescence of the clouds was revealed. This glow seemed to occur both within the clouds and in the air which was closely surrounding. The intensity of this luminescence and its duration is greatly dependent upon the distance of the observer from the cloud. The luminescence of the XRAY Day cloud faded gradually and disappeared in about two minutes, whereas the glow of the YOKE and the ZEBRA Day clouds lasted about four minutes. The fact that the clouds were self-luminous is important to visual observations as features of the clouds could be seen even before the morning twilight became effective. It is presumed that the ABLE Day cloud at Bikini also possessed this property of luminescence, but that the strong sunlight prevented the glow from being seen.

While the luminescence was being observed, the pressure wave associated with the sound of the explosion arrived. On XRAY Day, the pressure wave arrived at the observing ships in about one and one-half minutes, on YOKE Day, the wave arrived in about one minute, and on ZEBRA Day, the elapsed time was 45 or 50 seconds. There was no feeling of physical push from any of the pressure waves and no feeling of discomfort. Ordinary meteorological instruments were not significantly affected by the pressure waves. The ordinary microbarograph is designed to resist sudden pressure changes. However, specially built microbarographs on the U.S.S. Mt. McKinley without damping mechanism showed pressure changes for the three tests of 2.5, 7, and 9 millibars, respectively.

The sounds of the three weapons were as follows: On XRAY Day the sound was a deep rumble resembling heavy thunder, whereas on YOKE Day, the sound was a resounding "pop" which was much different from the sound of the XRAY Day weapon. The sound on the YOKE Day weapon was similar to the sudden report, considerably magnified, of a paper bag which is forcefully burst in a small room. Of possible interest is the fact that the sound did not seem to come from any particular direction. An observer not knowing the direction of the test site would not have been able to point to its source. The ZEBRA Day explosion sounded much like the "bang" of an eight-inch gun, if the gun were heard from several hundred feet away. Although the XRAY Day explosion had a rumbling sound, there were no reverberations on YOKE and ZEBRA Days.

Note: The condensation cloud grew to full size and disappeared in 5 or 6 seconds.

Description of the XRAY Day Cloud

The atomic cloud pushed through the deck of broken cumulus clouds almost immediately and was above the highest cumulus shortly after the first minute. During the period of most rapid rise, the cloud showed the internal circulation which was observed at Bikini and was in the characteristic mushroom shape. As on ABLE Day at Bikini, several short cloud streamers, or spurs, seemed to project outward at an angle from the bottom of the cloud at the time it was rising most rapidly. Also, as at Bikini, when the top of the cloud reached 40,000 feet at approximately H-hour plus 5 minutes, an ice cap was seen to form. The darkness prevented careful observations, and all of the observers did not report this ice cap phenomena.

At the sixth minute, the cloud top was approximately 44,000 feet and the sketches show that the cloud consisted of two major portions, the mushroom with its tapering stalk and a large cumulus-type cloud from which the stalk appeared to extend. This lower cloud portion reached up to an estimated height of 15,000 feet and was mingled with the other lower clouds so that it was mostly obscured. As the mushroom continued to rise, it began to move eastward with the prevailing southwesterly winds. This drift to the eastward began between the third and fourth minute when the cloud reached approximately 30,000 feet. Meanwhile, the lower portion was drifting westward, and the stalk or stem was elongating and becoming smaller in diameter.

At nine minutes and thirty seconds past H-hour the U.S.S. Albemarle observers recorded a clean break between the upper and lower cloud masses and this shear was estimated to occur at 20,000 feet. The stem of the cloud rapidly dispersed in this region of wind shear during the following three or four minutes, leaving an irregular patch of dust or smoke which separated itself from both the upper and lower portions of the cloud.

Between the twelfth and thirteenth minute, the mushroom reached its highest elevation. The highest elevation angle was recorded at this time. Almost immediately, a thin cirrus plume formed when a protuberance from the top-most part of the cloud extended up into the northeasterly wind which was in the stratosphere. To a ship-borne observer, this cirrus-like plume first appeared to extend upward and westward from near the center of the globular mass of cloud which had shortly before been the rising mushroom. The base of the plume became broader while the tip remained pointed so that the general effect was that of a bird's wing extending horizontally from the cloud in the direction of the ships.

The upper portion of the atomic cloud was estimated to be approximately 5.5 miles in diameter at the time it reached maximum altitude, and its center was 19 miles distant from the observing ships. After reaching maximum elevation, the upper cloud mass moved with a wind from 230 degrees at approximately 25 knots, as the wind-shaped sheet of cirrus above trailed behind.

The XRAY Day cloud disappeared from view in the following manner. The lower cumulus-type portion of the cloud remained visible until about H-hour plus twenty minutes and then was lost to observers because of other clouds. The stalk of the mushroom formed a broad, irregular shaped area of fine dust and smoke which appeared to disperse itself in the region of wind shear. This smoky patch disappeared at about H-hour plus two hours. Meanwhile the primary portion maintained its general shape but appeared to become thin and sheet-like so that it closely resembled cirrocumulus. Finally, at approximately H-hour plus three hours even this most prominent part of the atomic cloud could not be distinguished by surface observers.

Description of the YOKE Day Cloud

When the condensation cloud vanished, the flaming gases which composed the fireball were seen. The flames around the base of the fireball seemed to spread out over the island and appeared to linger momentarily before starting upward. The quantity of constituents in the fireball appeared considerably greater than on the XRAY Day test. There was an extremely rapid increase in volume and lateral spreading of the top in this early stage. In about 10 seconds the ball of cloud had grown to a diameter of one mile. After this initial rapid expansion, the diameter increased more slowly. At the end of one minute, it is estimated that the mushroom top was about two miles in diameter. The brilliant yellows and oranges changed to red as the incandescent gases cooled in about 20 seconds. From about H-hour plus two minutes to H-hour plus five minutes, the cloud was rising as a large spherical mass on a broad stalk. At first, it began to take the characteristic mushroom shape but for some reason, perhaps its size, the cloud was not able to maintain the ring shaped internal circulation seen in previous clouds. The primary portion rose more nearly as a gigantic bubble of gas. Instead of the cloud material cascading down the side of the mushroom and being drawn back into the bottom as on XRAY Day, the YOKE Day cloud left a relatively thick trail of dust and smoke in its wake. By the time it reached maximum altitude, there appeared to be a diminution in volume of the hot bubble because of the large quantity of material left behind. There also seemed to be less moisture condensation associated with this cloud. Instead, it appeared to be more of a smoke cloud.

After H-hour plus five minutes, the stalk of the mushroom showed a bend to the east as the strong westerly winds became effective, and at H-hour plus 12 minutes the cloud reached its maximum altitude of 55,000 feet. When this altitude was reached, the cloud consisted, from the surface upward, of a thick vertical mass estimated to be one and one-half miles in diameter which extended to 15,000 feet; a slanting column, tilted toward the east, of irregular patches of reddish-brown smoke and dust; and the upper dominant mass which was about five miles in diameter and three miles thick. All parts of the cloud were connected together, and there was never a clear break as occurred on XRAY Day.

At about H-hour plus 16 minutes, a swelling cumulus cloud with a top at 9,000 or 10,000 feet had formed near the zero island. This cloud moved with the easterly winds and was lost among other clouds at the end of fifteen minutes. Also, at 16 minutes after H-hour, the highest portion of the atomic cloud was in the form of an anvil top, similar to that found on a cumulonimbus. This anvil is thought to have been caused by a spreading out of the top of the cloud as it flattened itself against the stratospheric inversion. The top of the cloud seems to have reached the base of the stratosphere in about 12 minutes, but the anvil took about four minutes to form. The spreading out of the top of the atomic cloud has been taken to be an indication of when the cloud arrived at maximum altitude. The highest part of the atomic cloud remained in this anvil shape until about the twenty-fifth minute past H-hour.

At H-hour plus one hour, the highest portion, or former "anvil," seemed to contain the only moisture in the entire cloud. It appeared to have stretched out into a rectangular patch of cirrocumulus; whereas the remainder of the cloud maintained its reddish-brown color and smoky, dusty appearance. In one hour, the cloud had been drawn out by the structure of the upper winds into a ribbon which had extremities about 50 miles apart. This ribbon varied in width and density, but remained unbroken. Generally speaking, it zig-zagged downward in a slanting line from east to west and reached completely across the northern sky. Its actual shape is shown later in a sketch (page 50) and in a photograph (page 68).

In one hour the cloud had moved away until it was less than 10 degrees above the horizon; and after two hours it appeared at such a low angle, and was so dispersed, that its general form could not be determined.

Description of the ZEBRA Day Cloud

The ZEBRA Day cloud in its initial stages was about nine miles away. Perhaps because of its nearness and the unobstructed view, the flames in the fireball seemed brighter and appeared to last longer than those of previous weapons. During the first two minutes, the cloud was rising almost straight up. The cloud had the familiar mushroom form, but the head of the cloud did not have a well-defined circulation after the second minute. At the end of the third minute, the upper part of the cloud began to move toward the east, as it became subjected to the westerly winds. From the third minute until after the eighth minute, there was little change in the shape of the atomic cloud. It continued to rise and was bent more and more toward the east. By the ninth minute, the finger-like projection which rose out of what had been the primary portion could be seen plainly. It appeared that a relatively smaller bubble of hotter gases was contained within the primary portion of the atomic cloud, and that this relatively hot bubble did not cool as rapidly as the remainder of the cloud. When the primary cloud mass stopped rising, this bubble continued its rise for an additional 5,000 feet before cooling to the temperature of the surrounding air.

This projected portion of the cloud rose until about the twelfth minute when it began to spread out. At about the tenth or eleventh minute, the top of the cloud had moved to the east of the broad stem, and observers on the U.S.S. Bairoko were able to look up into the base of what had been the rising mushroom head. The observers on the Bairoko stated that the cloud, viewed from the bottom, had a hollow appearance and looked somewhat like a smoke-ring. There was more cloud material in the edges of the cloud than in its center. At the fifteenth minute, the finger-like part of the cloud appeared to break away, but it never did get far from the main body of the cloud. It was noticed, about this time, that the lower extremity of the atomic cloud ended at the region of shear between the easterly and westerly winds, near an elevation of 7,000 feet. As far as could be seen, there appeared to be no cloud material which could be definitely observed as the atomic cloud below that level. From the fifteenth minute up to one hour past H-hour, the cloud consisted of three primary parts. They were a cloud streamer, the remains of the uppermost finger-like projection; a large globular mass, the primary portion; and the long tenuous stem.

After one hour, the edges of the atomic cloud began to be indistinct, and the cloud began to blend with the thin cirrus clouds which almost completely covered the sky. Then, at one and one-half hours, the outline of the cloud became indefinite. Finally, at H-hour plus two hours, only a light tan patch remained of the primary cloud mass; and no other parts of the atomic cloud could be seen.

This cloud seemed to be entirely composed of smoke and dust with no suggestion of moisture. No ice cloud or cirrus veil on the top of the mushroom was reported.

DIAGRAMS DESCRIBING THE THREE ATOMIC CLOUDS

Operation SANDSTONE
Eniwetok Atoll, Marshall Islands
1948

XRAY DAY - 15 April, H-Hour 0617

YOKE DAY - 1 May, H-Hour 0609

ZEBRA DAY 15 May, H-Hour 0604

Dates and Times are LOCAL for the Eniwetok Area

Upper Wind Vectors

To begin a study of the behavior of atomic clouds it is necessary to know what the upper winds were which affected the clouds and to consider how those winds acted on the visual airborne material produced by the atomic explosions.

An examination of all of the wind soundings for the three test days shows that the upper winds were of the same general pattern on all of the test days. At low levels the winds were easterly, and at progressively higher levels the winds veered through south into southwest or west.

The absence of winds from a northerly direction were a radiological safety requirement. It was not practical to evacuate all personnel from Eniwetok, and it was known that the tests would be greatly hindered if installations on Eniwetok became radiologically contaminated. For this reason, an area in the southeastern part of the atoll, including Eniwetok and Parry Islands, was selected for anchorages of the observing ships; and the tests were conducted on days when there was no northerly component in the upper wind directions which might carry radiologically active material southward.

By chance, the winds on the dates originally selected for XRAY and ZEBRA days were operationally suitable. However, prior to 30 April, the day originally scheduled for YOKE DAY, there was a high frequency of northwesterly winds in the anti-trades at levels between 20,000 and 30,000 feet. In fact, prior to the actual YOKE DAY, there were fourteen impossible firing days because of wind conditions.

On 29 April, the upper winds showed a transitional zone of variable winds with northerly components between 15,000 and 30,000 feet; and since there was no justification for believing that a rapid change in the wind structure was imminent, there was considerable doubt expressed at the morning briefing that the winds would change sufficiently to meet radiological safety requirements. There was, nevertheless, a reasonable expectation that these awkward winds would tend to veer in such a manner that the northerly components would be eliminated within 48 hours. Thus, unfavorable winds caused the postponement of YOKE DAY until 1 May. By the time of the briefing on the morning of the new YOKE minus one day, the upper winds had altered sufficiently to indicate that a new air flow was beginning to predominate, and a forecast of favorable winds could be given. Since meteorological conditions were also indicative of suitable cloud conditions, the test was scheduled for, and conducted on 1 May.

Therefore, in these tests the upper wind conditions which determined the shapes of the clouds and the spread of the radioactive material were predetermined by the relative positions of the test sites and the area which had to be kept free of radiological contamination.

On XRAY DAY, nine minutes approximately after H-hour, the atomic cloud sheared and broke apart at about 20,000 feet and the drone aircraft stationed at that altitude could not make a penetration as there was no cloud visible at that altitude on which the aircraft could be vectored. For that reason, closer attention was paid to the probable shape of the atomic clouds in the staff briefings on YOKE and ZEBRA days; and diagrams were presented at the briefings on those days which pictorially showed how the atomic clouds would look from the observing ships. These diagrams were drawn in similar manner to the diagrams labeled <u>Vertical Projection Looking North</u> that are in the upper right hand corner of the following three pages except that the dashed line connecting the arrow heads was replaced by a rough outline of an atomic cloud. This led to an incorrect prediction of the shape of the ZEBRA DAY cloud because the atomic cloud on that day did not go as high as the XRAY and YOKE clouds, or to as high an altitude as was indicated on the diagram; however, on YOKE DAY the shape of the cloud was remarkably like the predicted shape. Further use of these vertical projections for predicting the shape of atomic clouds from upper winds is believed to be worthwhile.

The winds which affected the atomic clouds have been estimated from the representative wind data which were obtained before and after H-hour. The examination of a number of wind soundings will give a truer picture of the air flow than a single sounding at the time in question. This is true because there are many approximations inherent in any particular sounding which result from the accepted manner in which soundings are made and upper winds calculated. In estimating the wind directions and velocities which acted on the clouds, consideration has been given to the trends and averages for particular levels, and to the winds between the 5,000 foot levels. (See Appendix II)

In using these wind data it is assumed that the estimated winds occurred at H-hour and endured for the three hours following. It is also assumed that the winds occurred over the entire Eniwetok area and acted on the cloud without regard to the relative distances of the parts of the clouds or their locations in the changing wind fields.

XRAY DAY — An examination of the upper winds shows that wind soundings above 55,000 feet cannot be estimated for H-hour. The winds for levels above 55,000 feet shown in the second 0800 (local time) sounding are not believed to be representative of the winds at H-hour.

The method of formation of the wing-like plume which grew out of the XRAY DAY cloud has been studied, and it is thought that it was produced after a part of the top of the cloud protruded through the tropopause into the stratosphere. With winds which were nearly calm at the base of the stratosphere, the plume would have been formed as the primary mass moved away in the stronger winds. A trail of cirrocumulus type cloud was formed in this region of wind shear at the tropopause.

The shear zone between 20,000 and 25,000 feet may be seen on the diagram labeled <u>Vertical Projection Looking North</u>. At this altitude the winds changed from easterly to westerly, and the visible cloud separated. This separation of the cloud was thought to be caused by the energy of the weapon, the altitude of the burst, the character of the surface, and other such factors rather than the wind shear; however, the wind shear did contribute to the separation.

YOKE DAY — The cloud which formed on the second test was a more or less continuous column from the surface to about 55,000 feet. The estimated winds on this day must closely approximate the actual winds for photographs of the atomic cloud show that the cloud was shaped just as would be expected from the wind vectors.

ZEBRA DAY — The third atomic cloud reached an altitude between 30,000 and 35,000 feet. Therefore, it is not necessary to consider winds above 35,000 feet when studying this cloud. The shape of the cloud was approximately what might be expected from the wind vectors; however, in the case of this particular cloud, a better understanding of the shape may be obtained by examining the winds at 1,000 foot intervals between 10,000 and 20,000 feet. These intermediate winds were used in drawing the diagram labeled <u>Dimensions of Atomic Cloud at End of Three Hours</u> on Page 42.

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XRAY DAY

Upper Wind Vectors Affecting the Atomic Cloud at H-Hour

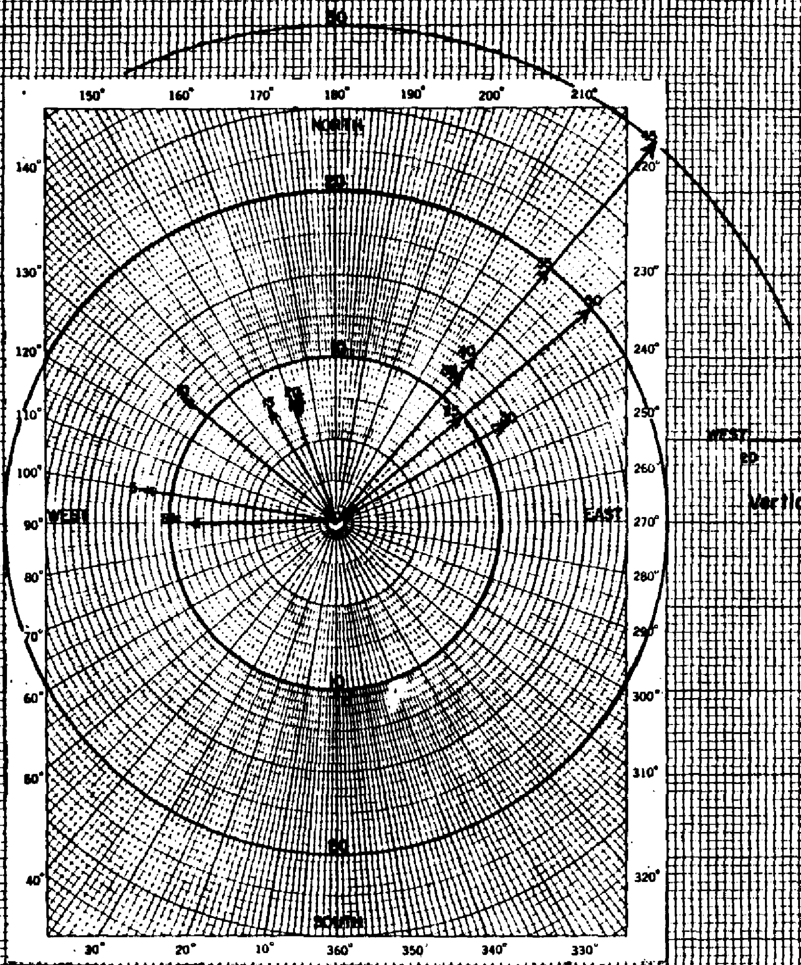
Wind Velocities are in KNOTS.

Lengths of Vectors are in NAUTICAL MILES.

UPPER WINDS USED TO DETERMINE WINDS AT H-HOUR

Sfc.	0300 0605	0300 0808	0300 0908	H-Hour Estimated 0909	0800 0910	0800 1208	1600 0911
5	1010	1010	1012	1012	1011	1114	0712
10	1407	1410	1410	1312	1313	1212	1211
15	1609	1608	1608	1508	1408	1409	1408
20	2205	2406	1815	1608	1402	2706	2103
25	2414	2411	2410	2310	2210	2906	2610
30	2715	2613	2510	2412	2113	2415	2715
35	2022	2121	2222	2220	2118	2012	2225
40	2125	2128	2208	2213	2218	2037	1427
45		2325		2230	2232	2319	2327
50		2325		2320	2318	2512	2123
55				2212		2212	1310
60						2116	
65						1913	
70						0605	
75						2310	

The wedge-like plume which formed on the top of the atomic cloud was shaped by a zone of wind shear at the tropopause and a layer of very light winds in the stratosphere. The vectors for this wind structure are not shown.



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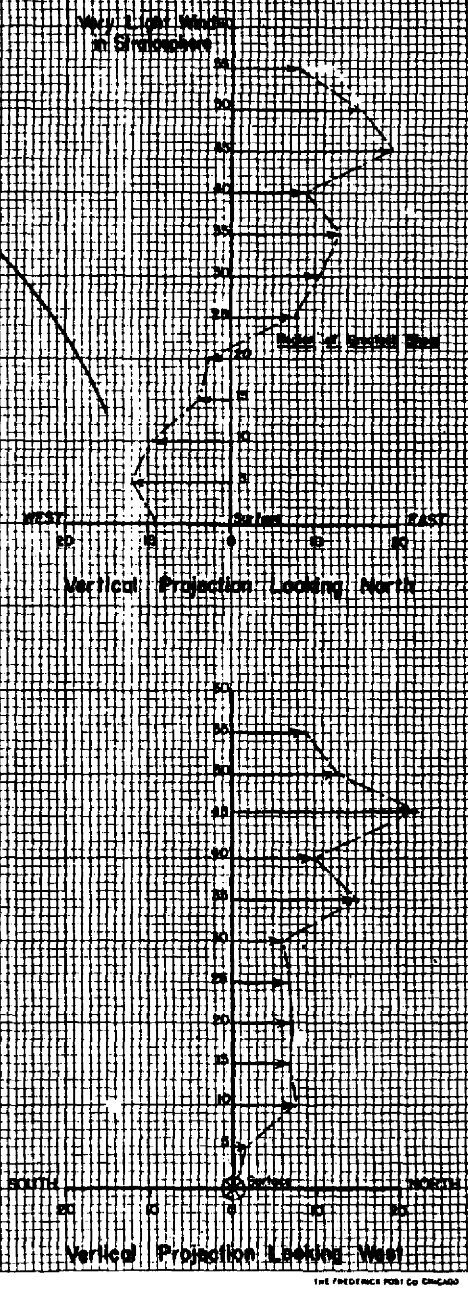

Vertical Projection Looking North

Vertical Projection Looking West

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YOKE DAY

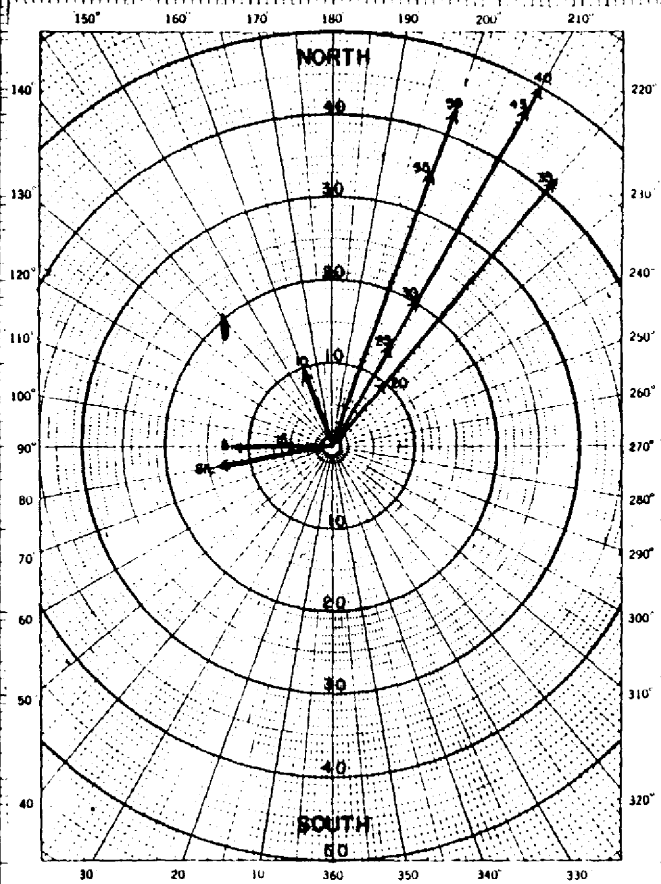
Upper Wind Vectors Affecting the Atomic Cloud at H-Hour

Wind Velocities are in KNOTS

Lengths of Vectors are in NAUTICAL MILES

UPPER WINDS USED TO DETERMINE WINDS AT H-HOUR

	0300	0600	Estimated H-Hour	1000
Sfc.	0912	0813	0814	0816
5	0914	0916	0912	1010
10	1010	1310	1610	2010
15	0203	0706	0906	1107
20	2310	2606	2210	1714
25	2022	2116	2114	2112
30	2331	2224	2121	2018
35	2246	2245	2242	2138
40	2143	2165	2150	2136
45	2238		2147	2050
50	2048		2043	2146
55	2035		2035	



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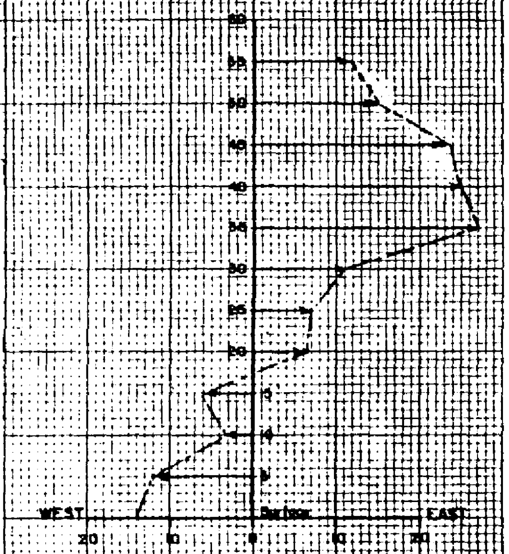
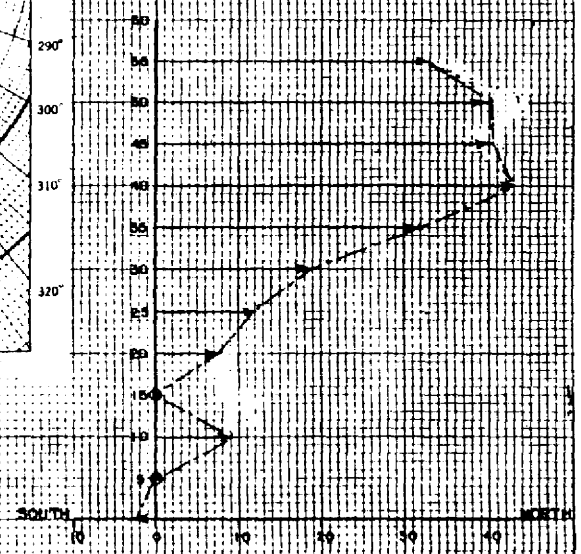


Vertical Projection Looking North



Vertical Projection Looking West

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ZEBRA DAY

Upper Wind Vectors Affecting the Atomic Cloud at H-hour

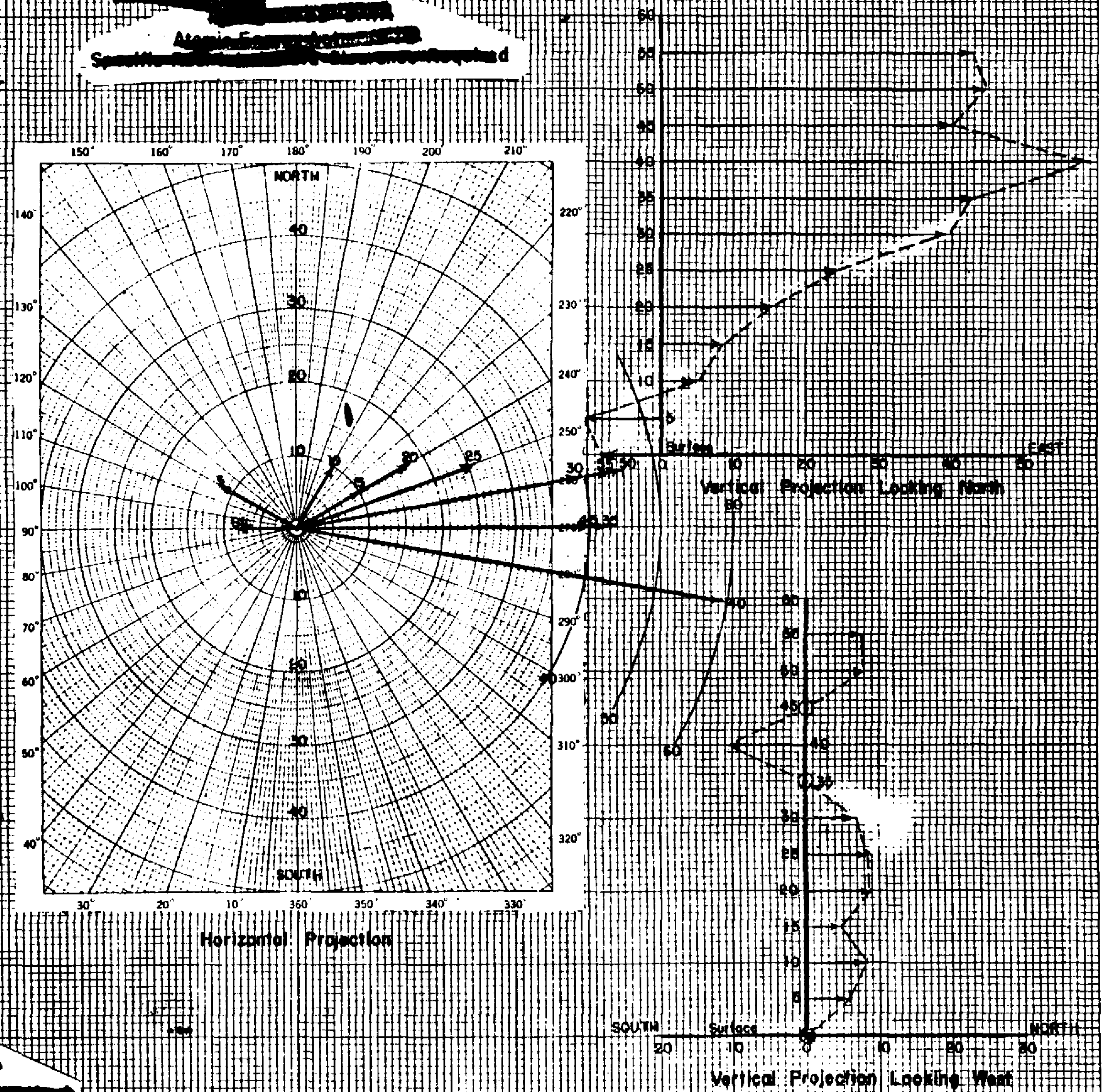
Wind Velocities are in KNOTS

Lengths of Vectors are in NAUTICAL MILES

UPPER WINDS USED TO DETERMINE WINDS AT H-HOUR

	0200	0300	0400	0600	H-hour Estimated	0800	0900
Sfc.	0806	1010	0708	0809	0908	1008	0908
5	1606	1212	1506	1311	1212	1115	1112
10	2211	1716	2213	2211	2110	1910	2012
15	2207	2216	2210	2712	2410	2406	2407
20	2519	2310	2517	2418	2418	2517	2621
25	2521	2312	2326	2527	2526	2525	2531
30	2541	2416	2527	2743	2640	2639	2738
35	2550	2316	-	2843	2743	2640	2938
40	2867	-	-	2772	2860	2942	2949
45	2644	-	-	2735	2740	-	2748
50	2764	-	-	-	2655	-	2648
55	2647	-	-	-	2653	-	(2659)*

* — Data for 54,000 feet instead of for 55,000 feet.



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Upper Air Soundings

It was not practical to obtain upper air soundings exactly at H-hours so the soundings reaching the highest altitudes have been plotted for just before and after the times the atomic clouds were rising.

An examination of the surface temperatures and the temperatures at 400 millibars permits a quick comparison and shows that the lapse rates were nearly the same on each of the three days. The small irregularities in the temperature curves can hardly be said to have affected the formation of the atomic clouds in a significant manner.

The small figures to the left of the temperature-height curve indicate relative humidity. These data are thought to be less representative than the actual temperature data, particularly near the surface; and not much can be deduced by studying the relative humidities produced by the rain showers which occurred just before H-hour on XRAY DAY.

The most significant feature of the upper air soundings with respect to the formation of the atomic clouds is the indicated height of the tropopause. During the time of the tests the height of the tropopause seemed to be consistently between 54,000 and 56,000 feet. On XRAY and YOKE DAYS it is assumed that the strong temperature inversion which exists at the tropopause stopped the already decelerating atomic clouds, and that the tops of these clouds came to rest at the base of the stratosphere.

XRAY DAY– The most significant sounding available before the tests, the sounding made at 0300 local time, did not reach the tropopause. The 0800 local time sounding did apparently reach the tropopause at 56,100 feet, but the point given above that level appears to be in error. The temperature curve is dashed where it is believed to be doubtful.

YOKE DAY– Unfortunately on YOKE DAY there was no sounding which showed the character of the tropospheric inversion, but the 0300 local time sounding does show that the temperature stopped decreasing above 54,100 feet. Because of normal conditions over tropical areas in the latitude of Eniwetok, it may be assumed that the temperature-height curve turns sharply at the tropopause and that the shallow isothermal layer is actually part of the large stratospheric inversion. Therefore, in the calculations which follow, it is further assumed that the YOKE DAY cloud stopped rising at approximately 55,000 feet.

ZEBRA DAY– On this day the height of the tropopause is clearly shown to be 54,420 feet on the 0300 local time sounding, but this value was of no use in the cloud calculations because the cloud did not reach an altitude above 35,000 feet.

It may be noted that a slight temperature inversion is shown by the 29,100 and the 29,900 foot levels at 0600 local time. This inversion may have slowed the ZEBRA DAY cloud, but it is not believed that such a small inversion would have had noticeable effect on vigorously rising clouds such as those on XRAY and YOKE DAYS.

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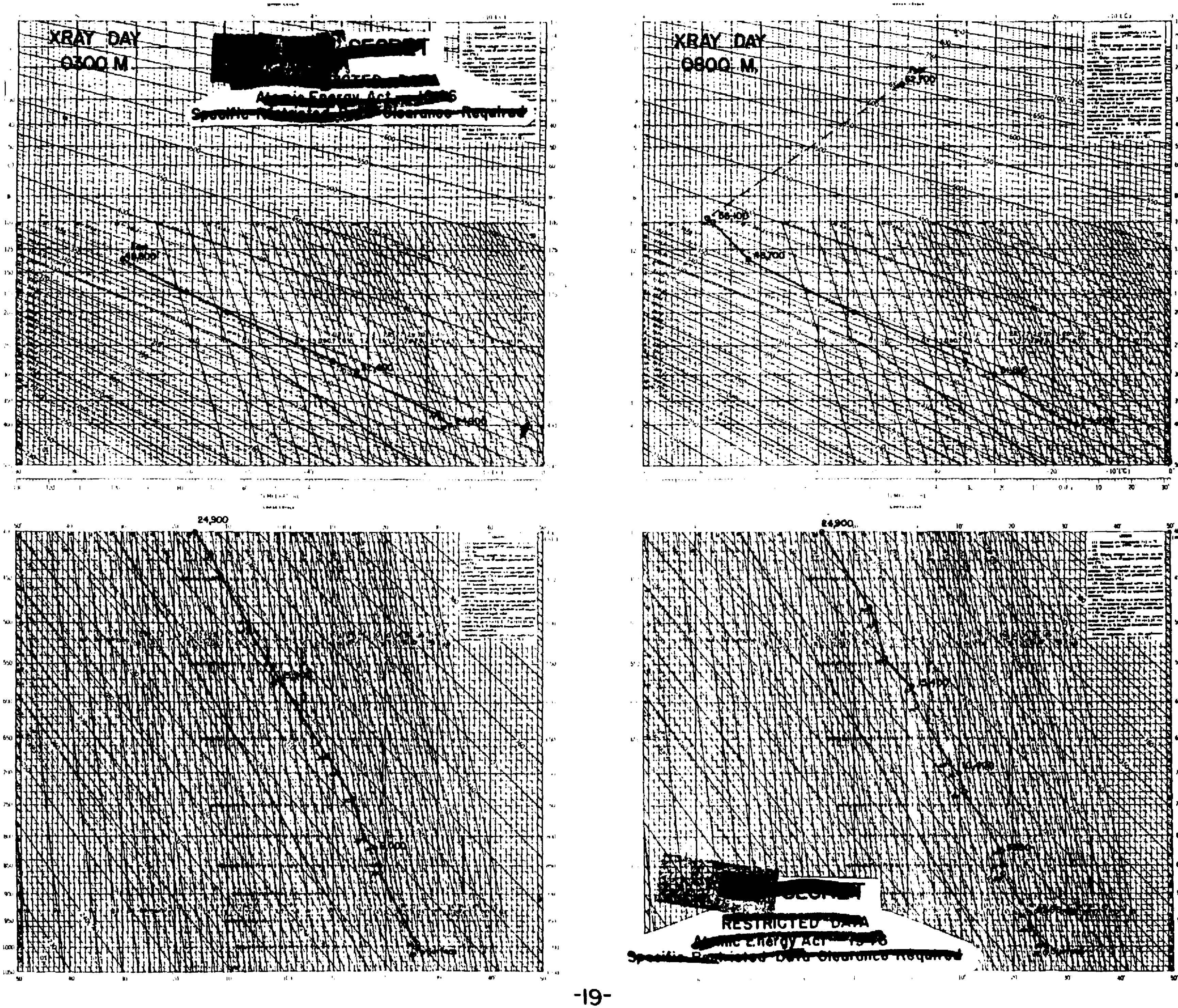
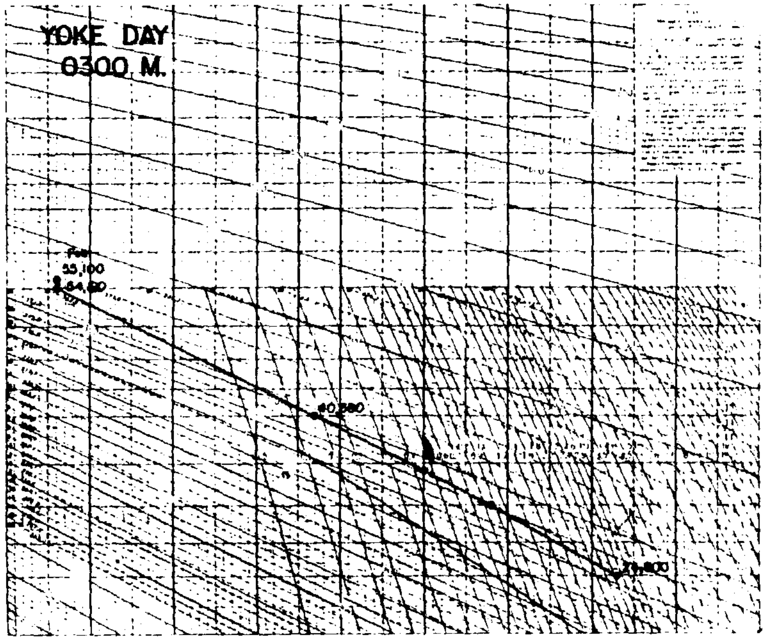
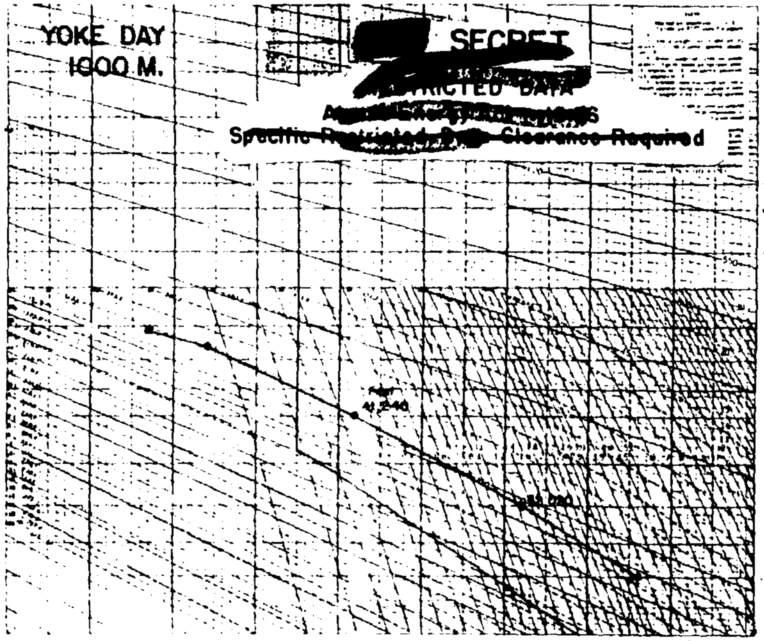
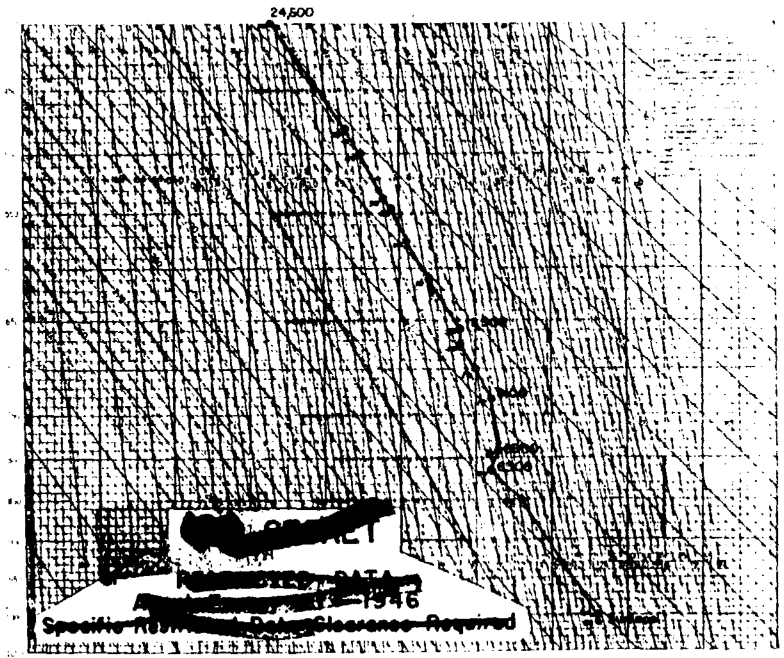

XRAY DAY
0300 M.
XRAY DAY
0600 M.
24,900
24,900


YOKE DAY
0300 M.


YOKE DAY
1000 M.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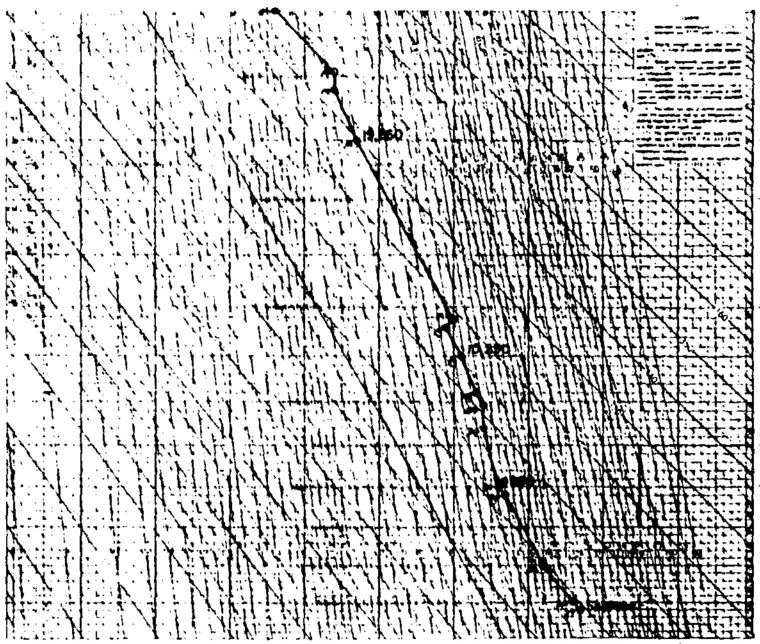
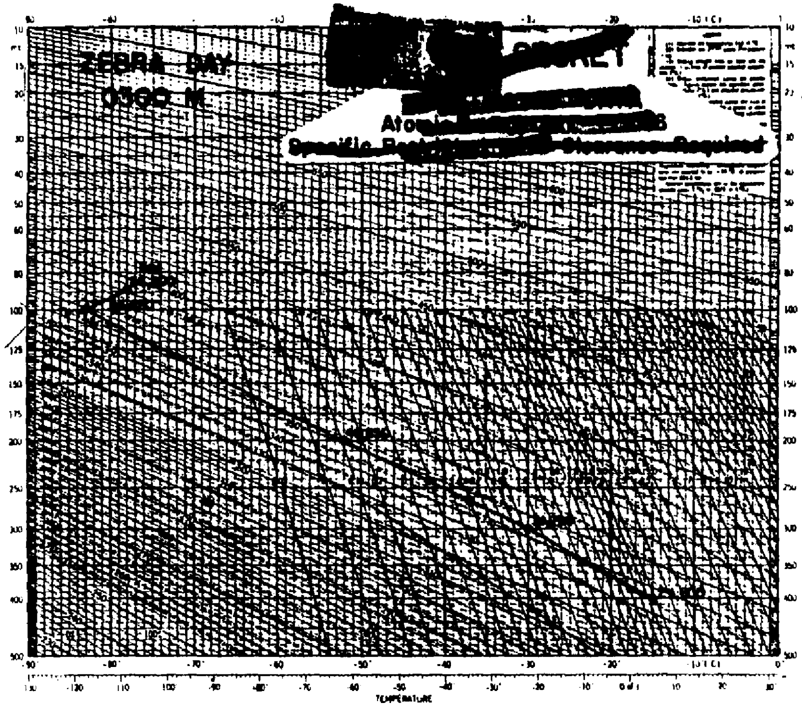
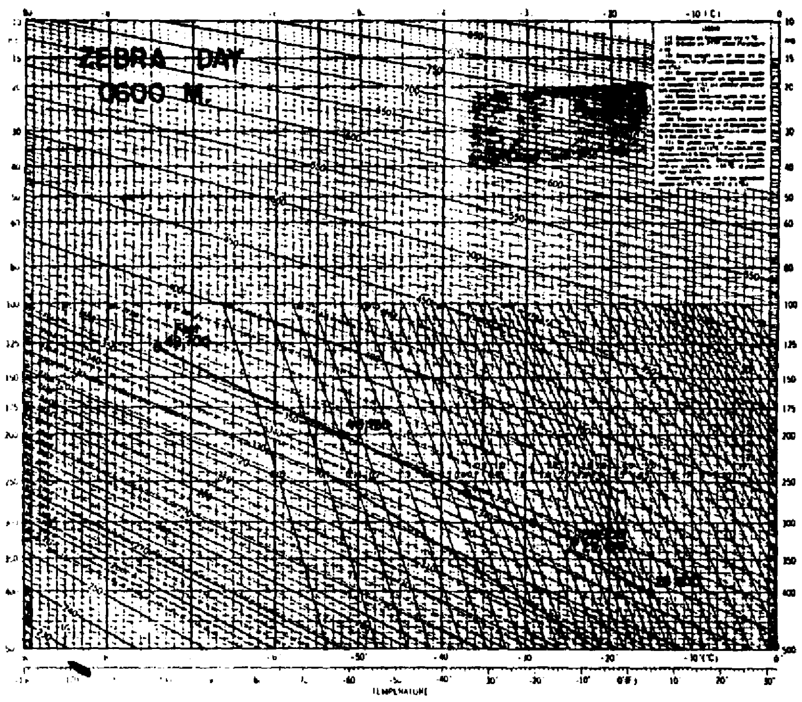
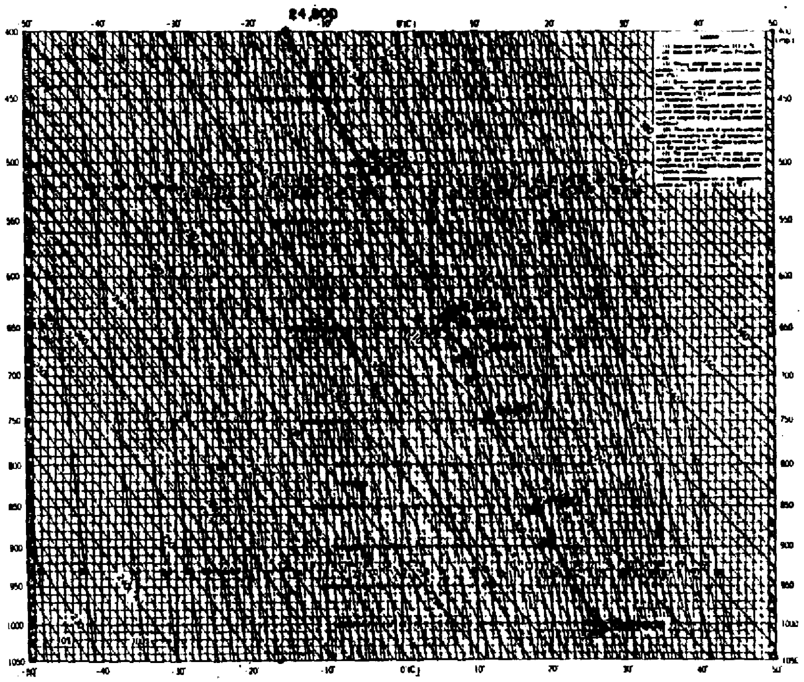



ZEBRA DAY
0300 M.


ZEBRA DAY
0600 M.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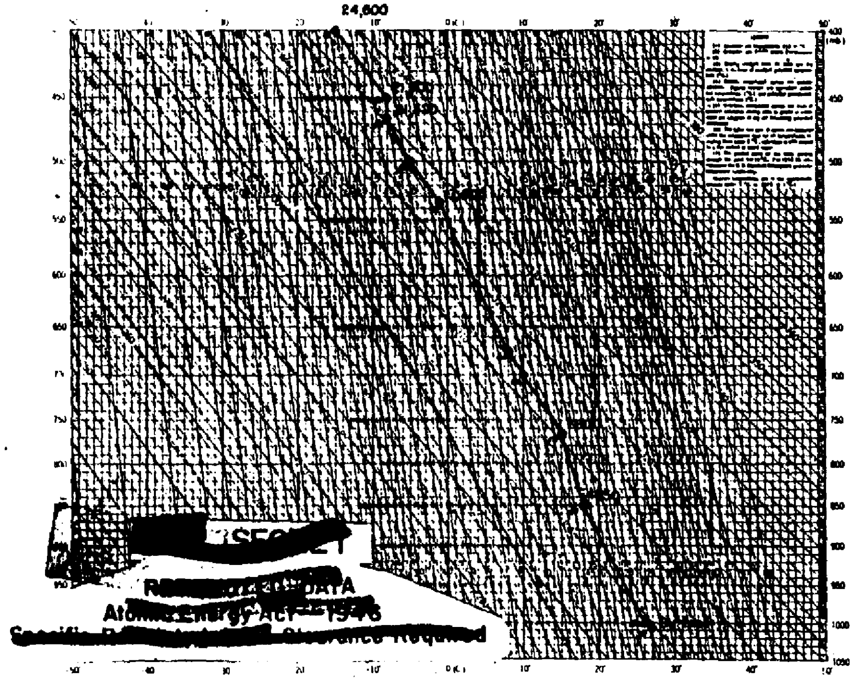
24,600

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Rates of Rise of the Atomic Clouds

The curves which are titled as the rates of rise of the atomic clouds combine the graphs of the elevation angles of the tops of the primary parts of the atomic clouds (see pages 11, 13, and 15 of Appendix I) with horizontal distances. These curves show approximately the time when the cloud reached a particular altitude and may be used to calculate how fast the clouds were rising at any particular time. These curves are considered to be useful in planning aircraft operations or scientific work when atomic clouds are expected.

The altitude of the clouds at each minute was found by simple trigometric methods; however, the horizontal distances used in these calculations were not easily determined. If the types of data available for calculations are reviewed, it will be seen that the elevation and azimuth angles, the upper winds, the height of the tropopause, and the approximate times the clouds reached maximum altitudes, are the only known factors. Unfortunately, the angles are from what must be assumed to be a single theodolite station. With the available data, it is impossible to fix the positions of the top of the clouds in space with the exception of the locations of the XRAY and YOKE day clouds at the times when these clouds may be assumed to have reached the tropopause. Other values for horizontal distances must be arrived at by methods which appear to be most reasonable.

Different methods have been used for each of the three clouds, and these methods will be explained below as each cloud is discussed.

It may be noted that the curves are dashed at low elevations. This is because the atomic clouds were rapidly expanding as well as rising when they were first formed. Theodolite data are not believed to be reliable until after the first minute.

XRAY DAY—From sketches of the cloud showing the formation of the plume, it seems that the atomic cloud reached the tropopause and stopped rising about twelve and one half minutes after H-hour. The height of the tropopause on this day was about 56,000 feet or 9.2 miles. With the elevation angle of 26.0°, this puts the cloud at a horizontal distance of 18.9 miles. The distance of the test site was 17 miles and since the cloud was acted on by easterly and then westerly winds, the azimuth angles of the cloud show little or no change in the first three minutes. Therefore, it is assumed that the top of the cloud was still at 17 miles at the third minute. From the third minute until the cloud reached the tropopause, it is assumed that the horizontal motion was uniform and in a straight line. This means that the horizontal distance is assumed to be increasing at the rate of .2 mi/min during the time that the cloud was rising. It is believed that the nature of the upper winds was such that the actual motion was more or less uniform and that the curve drawn gives a reasonably accurate representation of the behavior of the cloud.

YOKE DAY—The sketches of the top of the cloud show that it began to spread out into an anvil form about 12 minutes after H-hour. The height of the tropopause was between 55 and 56 thousand feet, so it is assumed that the cloud reached 56,000 feet or an altitude of 9.2 miles at that time. Examination of the graph for the elevation angle (see page 13, Appendix I) shows how the elevation angle of 23.5 degrees was obtained. It is thought that this elevation angle is more reasonable than the 24.5 degree angle obtained directly. The shape of the cloud was such that it was impossible to sight on the true top of the cloud and it is assumed that the theodolites were sighted on the near edge. The elevation angles of the top of the cloud and the near edge would have approached equality as the cloud moved away from the observer. The dashed section of the elevation angle curve is believed to represent the most probable elevation angles for the top of the cloud and the solid line represents the elevation angles of the edge of the cloud. This lower elevation angle gives a reasonable looking rate of rise curve. The angle 24.5 degrees does not.

As in the case of the XRAY day cloud, there seemed to be little horizontal movement during the first few minutes. The distance of the test site was 13 miles, so it has been reasoned that the cloud was at this distance during the first four minutes. After the fourth minute, it was assumed that the cloud moved in a straight line, but at varying distances each minute depending on the azimuth angles.

To obtain what seems to be the best possible approximations of the horizontal distances, the triangular diagram shown above the rate of rise curve was constructed. This diagram has been drawn to scale by means of points representing the test site, the horizontal distance of the cloud at the time that it reached its highest point, and the azimuth angles of the center of the cloud top. The horizontal distances were obtained by noting the lengths of the azimuth angle lines for each minute.

ZEBRA DAY—The atomic cloud on ZEBRA day did not reach the tropopause and for this reason it is difficult to fix the horizontal distance of the top of the cloud at the time that it reached its highest elevation. All that is known are the azimuth angles and the distance of the test site. Fortunately, the upper winds were such that the path of the rising cloud would have much the same even though the rates of rise might have varied considerably. By means of the triangular diagram shown above the curve, it may be seen that the most probable position of the cloud top at the time that it reached highest elevation is somewhere between 10 and 12 miles. The upper winds could not have carried the cloud far enough north for it to have been as far as twelve miles away, and the winds were too strong to have only carried the cloud to a distance of 10 miles. The best estimate of distances which can be obtained is 11 miles, and this is the distance which has been used to determine the position of the cloud top at each minute. The behavior of the ZEBRA day cloud was unusual in that it rose to about 28,000 feet in eight minutes and then a finger of the cloud rose out of the primary mass for an additional 5000 feet. There were two rates of rise, one for the primary mass and one for the cloud projection. The azimuth angles for the primary mass have been obtained from page 27 of Appendix I but the azimuth angles for the finger-like projection have been obtained from the cloud sketches.

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XRAY [redacted]

Rate of Rise of Atomic Cloud

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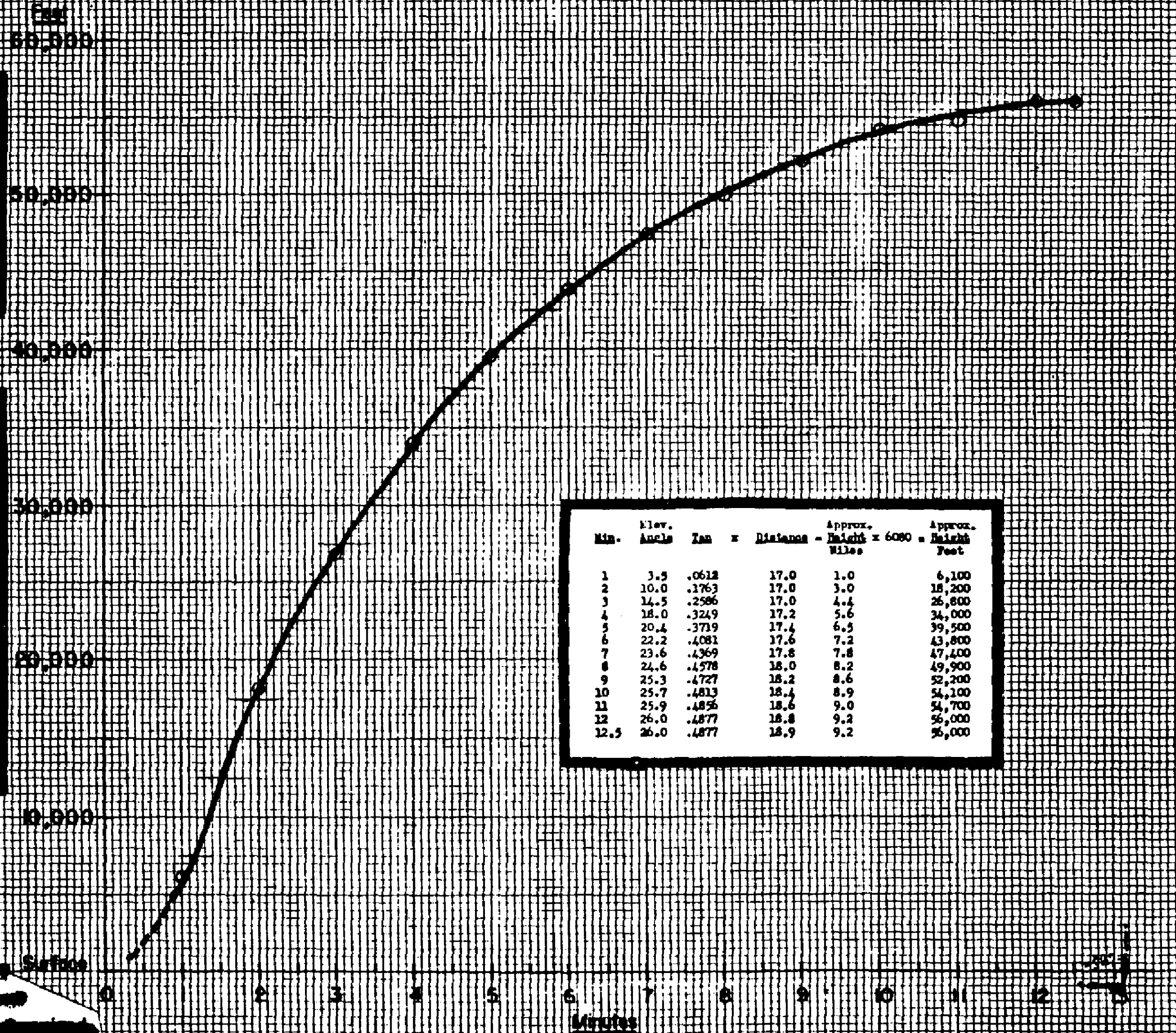

Time Required to Reach Given Altitude

Altitude (feet)	Time (Minutes)
10,000	1.4
15,000	1.7
20,000	2.2
25,000	2.8
30,000	3.4
35,000	4.2
40,000	5.1
45,000	6.3
50,000	8.0
55,000	10.7
56,000	12.5

RATE OF RISE IN KNOTS

Altitude (feet)	Vertical Distance (feet) /	Time (Minutes)	X.00987* =	Vertical Velocity (knots)
10,000	10,000	.8	=	123
15,000	"	.8	=	123
20,000	"	1.1	=	90
25,000	"	1.2	=	82
30,000	"	1.4	=	70
35,000	"	1.7	=	58
40,000	"	2.1	=	47
45,000	"	3.1	=	32
50,000	"	4.4	=	22
55,000	2,000	2.5	=	8
56,000	zero	—	=	0

* —.00987 equals Minutes per Hour divided by Feet per Nautical Mile.

Except for the 55,000 foot level, the above times were obtained by taking the difference between the time required to reach the altitude 5,000 feet above the altitude in question and the time required to reach the altitude 5,000 feet below. For the 55,000 foot level the difference in times for the 56,000 and the 54,000 foot levels were used. The vertical distance is 2,000 feet instead of 10,000 feet as in the case of the other levels.

Min.	Elev. Angle	Tan	x	Distance	=	Approx. Height Miles	x 6080	=	Approx. Height Feet
1	3.5	.0612		17.0		1.0			6,100
2	10.0	.1763		17.0		3.0			18,200
3	14.5	.2586		17.0		4.4			26,800
4	18.0	.3249		17.2		5.6			34,000
5	20.4	.3719		17.4		6.5			39,500
6	22.2	.4081		17.6		7.2			43,800
7	23.6	.4369		17.8		7.8			47,400
8	24.6	.4578		18.0		8.2			49,900
9	25.3	.4727		18.2		8.6			52,200
10	25.7	.4813		18.4		8.9			54,100
11	25.9	.4856		18.6		9.0			54,700
12	26.0	.4877		18.8		9.2			56,000
12.5	26.0	.4877		18.9		9.2			56,000

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YOKE DAY

Rate of Rise of Atomic Cloud

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Time Required to Reach Given Altitude

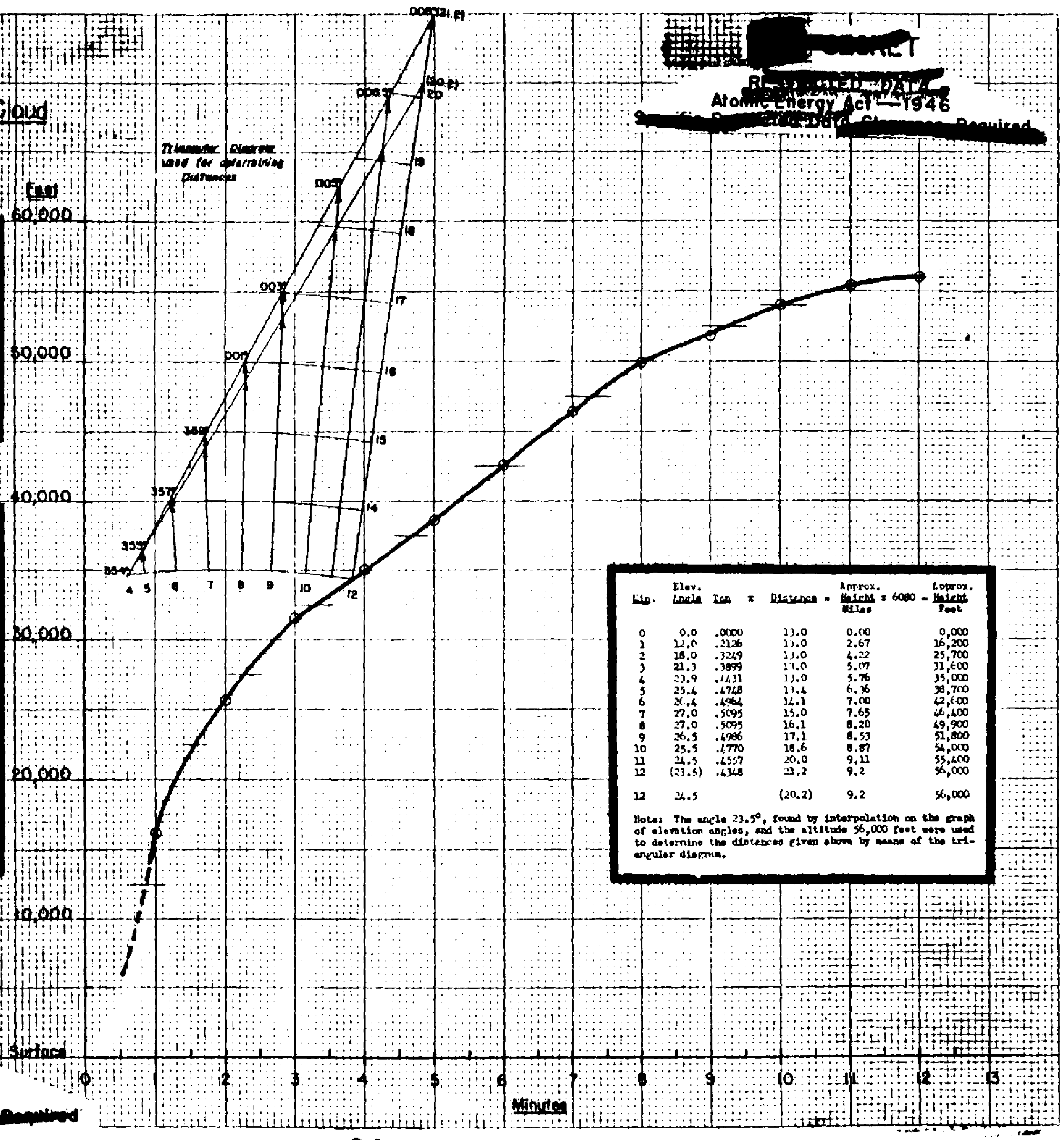
Altitude (feet)	Time (Minutes)
15,000	1.0
20,000	1.3
25,000	1.9
30,000	2.7
35,000	4.0
40,000	5.3
45,000	6.6
50,000	8.0
55,000	10.7
56,000	12.0

RATE OF RISE IN KNOTS

Altitude (feet)	Vertical Distance (feet)	/ Time (Minutes)	x .00987*	= Vertical Velocity (knots)
20,000	10,000	.9		110
25,000	"	1.4		70
30,000	"	2.1		47
35,000	"	2.6		38
40,000	"	2.6		38
45,000	"	2.7		37
50,000	"	4.1		24
55,000	2,000	2.0		10
56,000	zero	—		0

* — .00987 equals Minutes per Hour divided by Feet per Nautical Mile.

Except for the 55,000 foot level, the above times were obtained by taking the difference between the time required to reach the altitude 5,000 feet above the altitude in question and the time required to reach the altitude 5,000 feet below. For the 55,000 foot level the difference in times for 56,000 and 54,000 foot levels were used. The vertical distance is 2,000 feet instead of 10,000 feet as in the case of the other levels.



Min.	Elev. Angle	Tan	x	Distance	=	Approx. Height Miles	x 6080 =	Approx. Height Feet
0	0.0	.0000		13.0		0.00		0,000
1	12.0	.2126		13.0		2.67		16,200
2	18.0	.3249		13.0		4.22		25,700
3	21.3	.3899		13.0		5.07		31,600
4	23.9	.4431		13.0		5.76		35,000
5	25.4	.4748		13.4		6.36		38,700
6	26.4	.4964		14.1		7.00		42,600
7	27.0	.5095		15.0		7.65		46,400
8	27.0	.5095		16.1		8.20		49,900
9	26.5	.4986		17.1		8.53		51,800
10	25.5	.4770		18.6		8.87		54,000
11	24.5	.4557		20.0		9.11		55,400
12	(23.5)	.4348		21.2		9.2		56,000
12	24.5			(20.2)		9.2		56,000

Note: The angle 23.5°, found by interpolation on the graph of elevation angles, and the altitude 56,000 feet were used to determine the distances given above by means of the triangular diagram.

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Atomic Energy Act 1946
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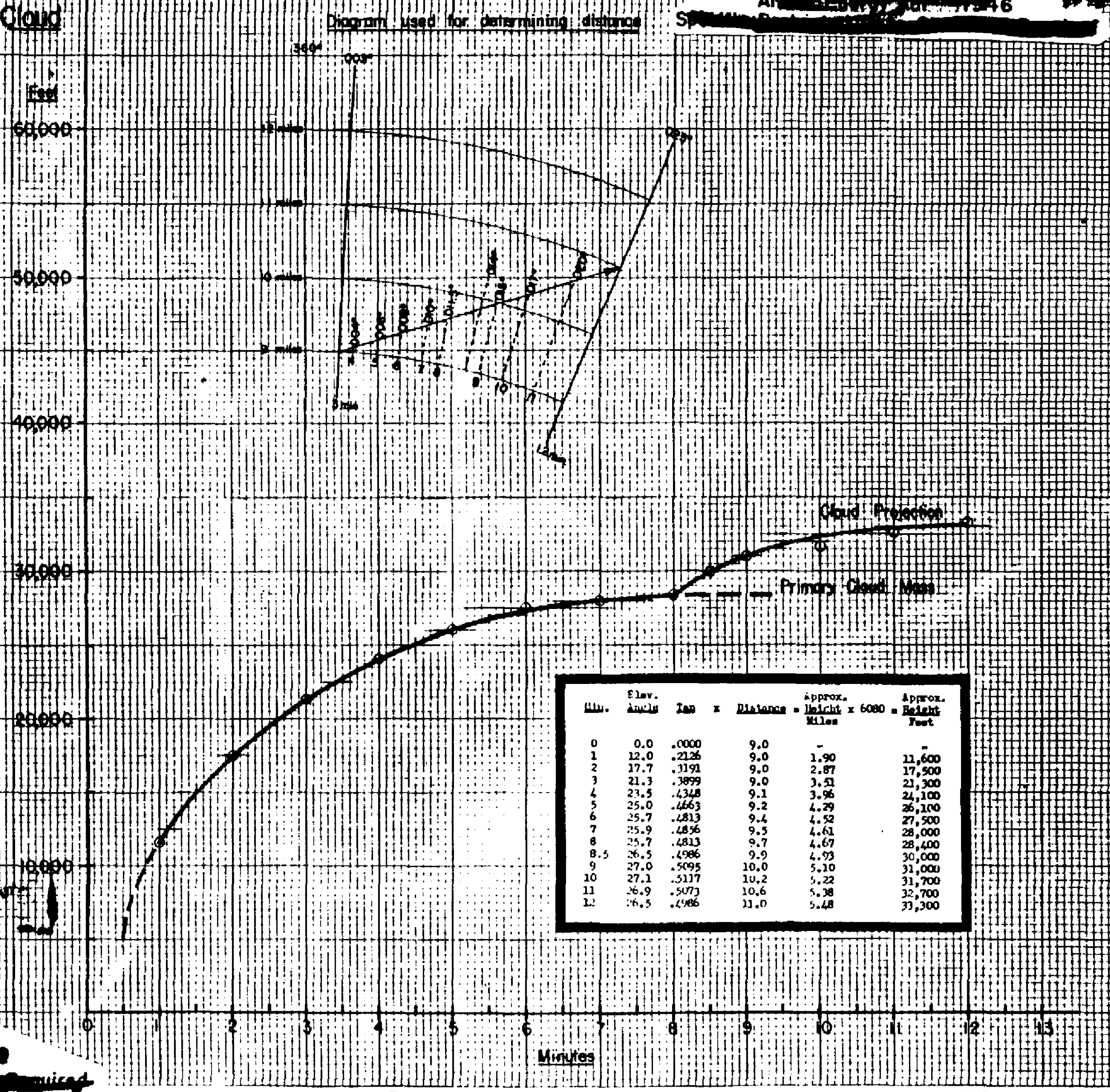
ZEBRA DAY

Rate of Rise of Atomic Cloud

[redacted] RESTRICTED DATA Atomic Energy Act 1946 [redacted]



Time Required to Reach Given Altitude

Altitude (feet)	Time (Minutes)
10,000	(0.8)
15,000	1.5
20,000	2.6
25,000	4.6
30,000	8.5
33,000	11 - 12

RATE OF RISE IN KNOTS

Altitude (feet)	Vertical Distance/Time (feet)/(Minutes)		X .00987* =	Vertical Velocity (knots)
10,000	10,000	(0.5)		(197)
15,000	"	1.8		55
20,000	"	3.0		33
25,000	2,000	1.0		20
26,000	"	1.2		16
27,000	"	1.8		11
28,000	"	3.0		6
29,000	"	0.6		33
30,000	"	0.8		24
31,000	"	1.2		17
32,000	"	2.5		8
33,000	"	near zero		near zero

* — .00987 equals Minutes per Hour divided by Feet per Nautical Mile.

Min.	Elev. Angle	Tan	x	Distance	= Approx. Height Miles	x 6080	= Approx. Height Feet
0	0.0	.0000		9.0	-		-
1	12.0	.2126		9.0	1.90		11,600
2	17.7	.3191		9.0	2.87		17,500
3	21.3	.3899		9.0	3.51		21,300
4	23.5	.4348		9.1	3.96		24,100
5	25.0	.4663		9.2	4.29		26,100
6	25.7	.4813		9.4	4.52		27,500
7	25.9	.4856		9.5	4.61		28,000
8	25.7	.4813		9.7	4.67		28,400
8.5	26.5	.4986		9.9	4.93		30,000
9	27.0	.5095		10.0	5.10		31,000
10	27.1	.5117		10.2	5.22		31,700
11	26.9	.5073		10.6	5.38		32,700
12	26.5	.4986		11.0	5.48		33,300

[redacted] SECRET [redacted] RESTRICTED DATA Atomic Energy Act 1946 [redacted]

Locations of Centers of Rising Atomic Clouds

After preparing the rates of rise curves for the three atomic clouds, the curves were used to determine the combined effect of the upper winds on the rising clouds. If the position of a cloud top at the time that it reached highest altitude as determined from the rate of rise curve and the winds is approximately the same as that computed from the height of the tropopause and the theodolite data, it is reasonable to assume that the actual position of the top was somewhere close to those points. It is also reasonable to assume that the rate of rise curves gives a satisfactory representation of the actual behavior.

The small circles within the solid black line show the position of the top of the cloud at each 5,000 foot elevation and the dashed arrow is a vector representing the total movement in miles and the direction of the cloud top from the test site.

The spacing between the concentric circles is .5 of a mile in the case of the XRAY DAY diagram and 1 mile on the other two diagrams.

A comparison of the calculated positions of the cloud tops by different methods is given in the next set of diagrams titled <u>Determination of Altitude of Atomic Cloud</u>.

XRAY DAY

Location of Center of Rising Atomic Cloud from H-hour until H-hour plus 12.5 Minutes

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A[redacted] Act 1946
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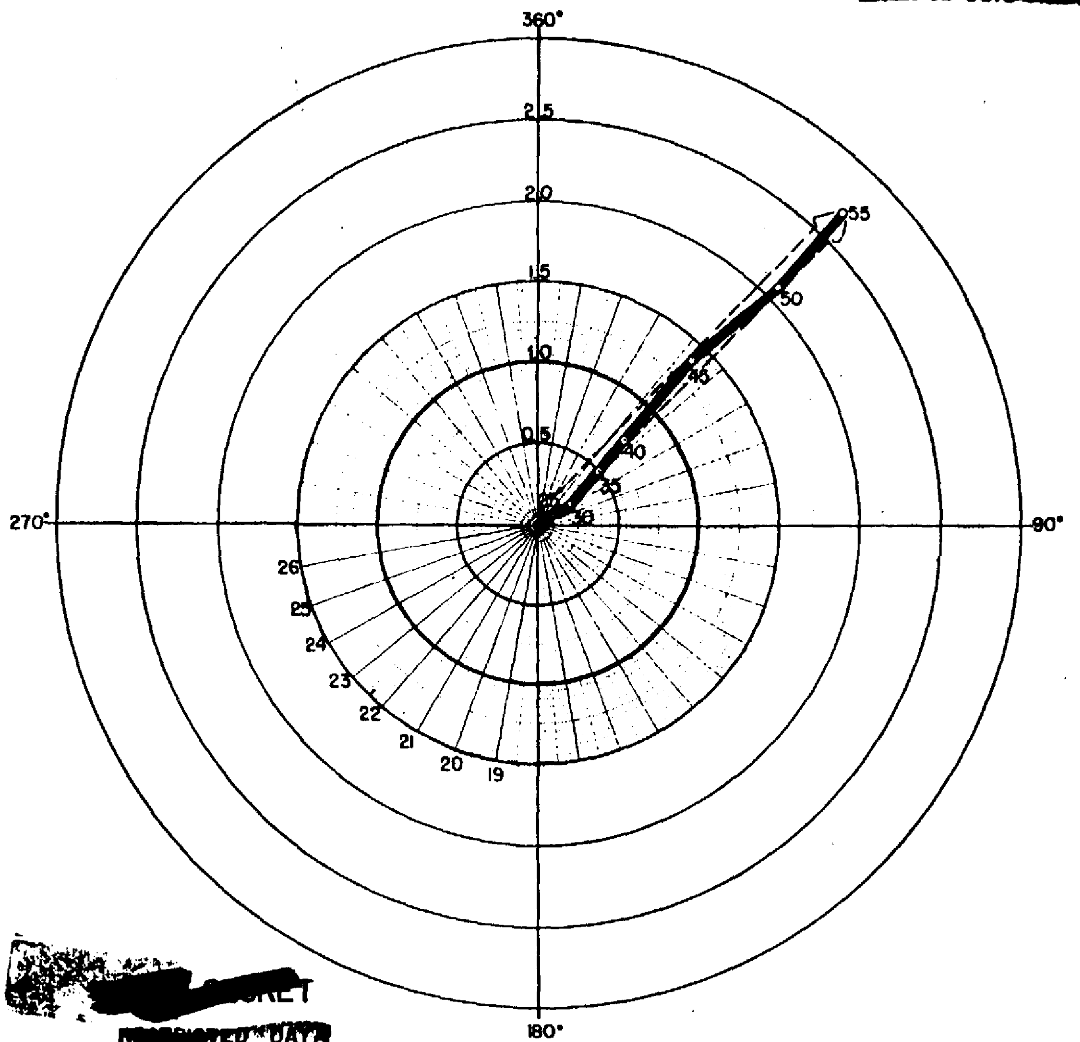
METHOD OF COMPUTING LOCATION OF CENTER OF ATOMIC CLOUD TOP AT TIME IT REACHED HIGHEST ALTITUDE

As the atomic cloud was acted upon by the upper winds during the 12.5 minutes that it was rising, the top of the cloud was displaced about 2.7 nautical miles along a vector directed from 224° by the time that it reached maximum altitude. This results in an increase in distance between the cloud and the theodolite observation stations which must be considered if the true altitude of the cloud is to be determined.

The position of the cloud has been calculated by joining together vectors which are directed in accordance with the upper wind at the 5,000 foot level in question and which are proportional in length to the time that the cloud required to pass through the altitude interval.

The radii of the circles are in nautical miles, and the individual vectors are identified by figures signifying thousands of feet.



MINUTES THAT WIND ACTED ON CLOUD AT EACH 5,000 FOOT LEVEL

The graph _Azimuth Angles of Primary Cloud Mass_ shows that the atomic cloud mass moved very little horizontally during the first three minutes. It seemed to be only slightly affected by the easterly winds which prevailed below 25,000 feet. Therefore, data for the first three minutes have not been considered in these calculations. The time intervals given below have been determined by dividing the curve shown on the page _Rate of Rise of Atomic Cloud_ into 5,000 foot segments, 2,500 feet on either side of the altitude in question, and reading off the intersections of the plotted curve with the time ordinates. These time intervals are considered to be the number of minutes that the upper winds acted on the cloud at each 5,000 foot level.

Feet	Minutes
25,000	(3.1 - 2.5) = 0.6
30,000	(3.8 - 3.1) = 0.7
35,000	(4.6 - 3.8) = 0.8
40,000	(5.7 - 4.6) = 1.1
45,000	(7.0 - 5.7) = 1.3
50,000	(9.1 - 7.0) = 2.1
55,000	(12.5- 9.1) = 3.4

UPPER WINDS AT H-HOUR

Altitude	Degrees	Knots
25,000	230	10
30,000	240	12
35,000	220	20
40,000	220	13
45,000	220	30
50,000	230	20
55,000	220	12

LENGTHS OF VECTORS IN NAUTICAL MILES

Altitude	Hours		Knots		Nautical Miles
25,000	0.6/60	x	10	=	.10
30,000	0.7/60	x	12	=	.14
35,000	0.8/60	x	20	=	.27
40,000	1.1/60	x	13	=	.24
45,000	1.3/60	x	30	=	.65
50,000	2.1/60	x	20	=	.70
55,000	3.4/60	x	12	=	.61

[redacted]RET
[redacted] DATA
[redacted] 1946
[redacted]

Length of calculated vector 2.7 n. miles, direction — from 224°

YOKE DAY

Location of Center of Rising Atomic Cloud from H-hour until H-hour plus 12.0 Minutes

METHOD OF COMPUTING LOCATION OF CENTER OF ATOMIC CLOUD TOP AT TIME IT REACHED HIGHEST ALTITUDE

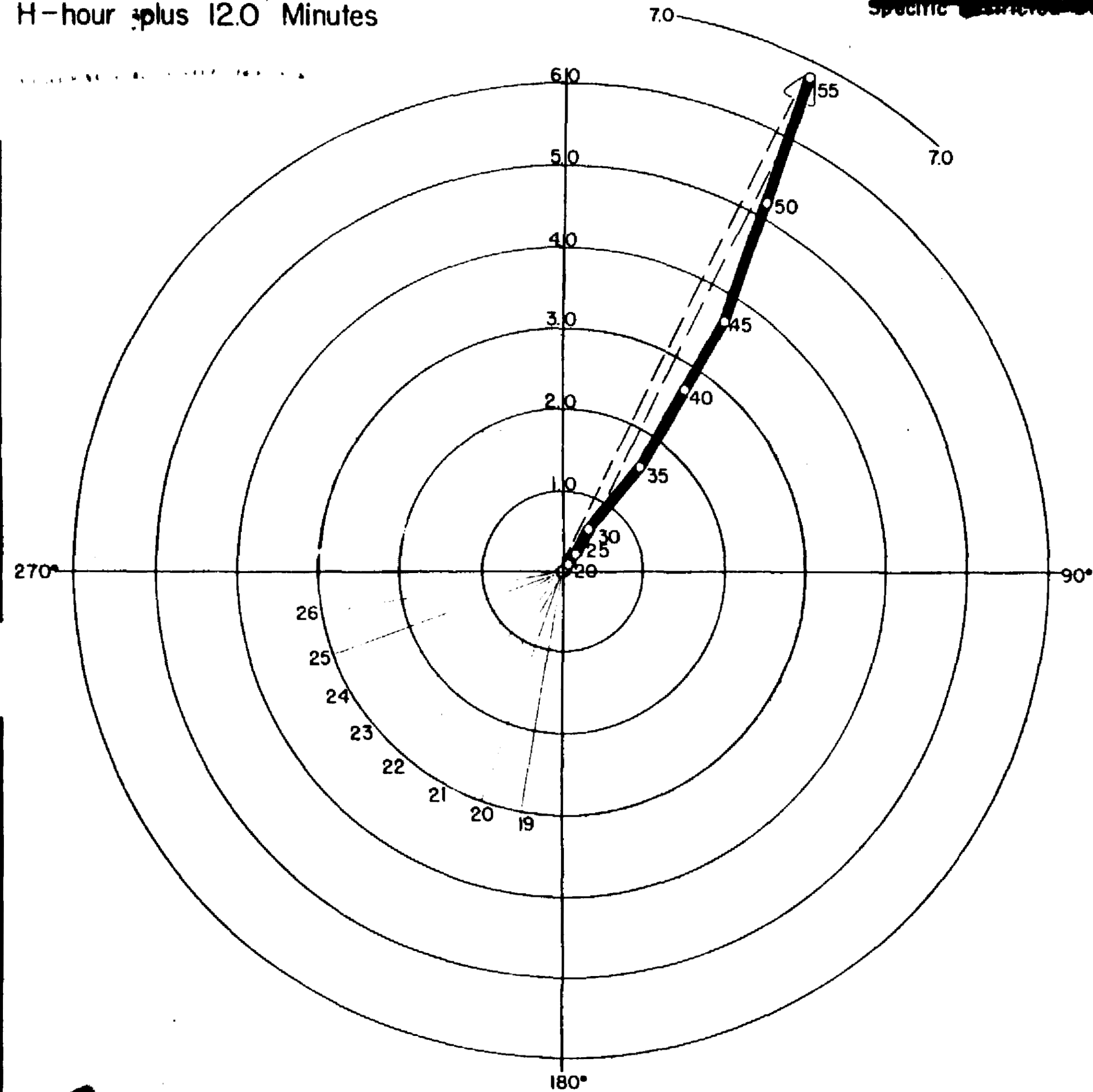
As the atomic cloud was acted upon by the upper winds during the 12.0 minutes that it was rising, the top of the cloud was displaced a considerable distance from the test site by the time that it reached maximum altitude. Wind soundings were not obtained at H-hour. Therefore it is necessary to use estimated wind directions and velocities based on winds at 0400 and 1000 hours. These estimated wind data give a movement of 6.8 miles in a direction from 207°. This increase in distance between the cloud and the theodolite observation stations must be considered if the true altitude of the cloud is to be considered.

The position of the cloud has been calculated by joining together vectors which are directed in accordance with the upper wind at the 5,000 foot level in question and which are proportional in length to the time that the cloud required to pass through the altitude interval.

The radii of the circles are in nautical miles, and the individual vectors are identified by figures signifying thousands of feet.

UPPER WINDS AT H-HOUR

Altitude	Degrees	Knots
15,000	90	06
20,000	220	10
25,000	210	14
30,000	210	21
35,000	220	42
40,000	210	50
45,000	210	44
50,000	200	47
55,000	200	35



MINUTES THAT WIND ACTED ON CLOUD AT EACH 5,000 FOOT LEVEL

The graph of the azimuth angles of the primary cloud mass shows that the atomic cloud moved very little horizontally during the first four minutes. Because of the relatively light winds at lower levels and the rapid rise of the atomic cloud, wind data below 20,000 feet have not been considered in these computations. The time intervals given below have been determined by dividing the curve shown on the page <u>Rate of Rise of Atomic Cloud</u> into 5,000 foot segments, 2,500 feet on either side of the altitude in question, and reading off the intersections of the plotted curve with the time ordinates. These time intervals are considered to be the number of minutes that the upper winds acted on the cloud at each 5,000 foot level.

Feet	Minutes
20,000	(1.56 - 1.08) = 0.48
25,000	(2.26 - 1.56) = 0.70
30,000	(3.28 - 2.26) = 1.02
35,000	(4.68 - 3.28) = 1.40
40,000	(5.99 - 4.68) = 1.31
45,000	(7.28 - 5.99) = 1.29
50,000	(9.23 - 7.28) = 1.95
55,000	(12.00- 9.23) = 2.77

LENGTHS OF VECTORS IN NAUTICAL MILES

Altitude	Hours		Knots	Nautical Miles
20,000	0.48/60	x	10 =	.12
25,000	0.70/60	x	14 =	.16
30,000	1.02/60	x	21 =	.36
35,000	1.40/60	x	42 =	.98
40,000	1.31/60	x	50 =	1.09
45,000	1.29/60	x	44 =	.95
50,000	1.95/60	x	47 =	1.53
55,000	2.77/60	x	35 =	1.62

Length of calculated vector — 6.8 n. miles, direction — from 207°

ZEBRA DAY

Location of Center of Rising Atomic Cloud from H-hour until H-hour plus 12.0 Minutes

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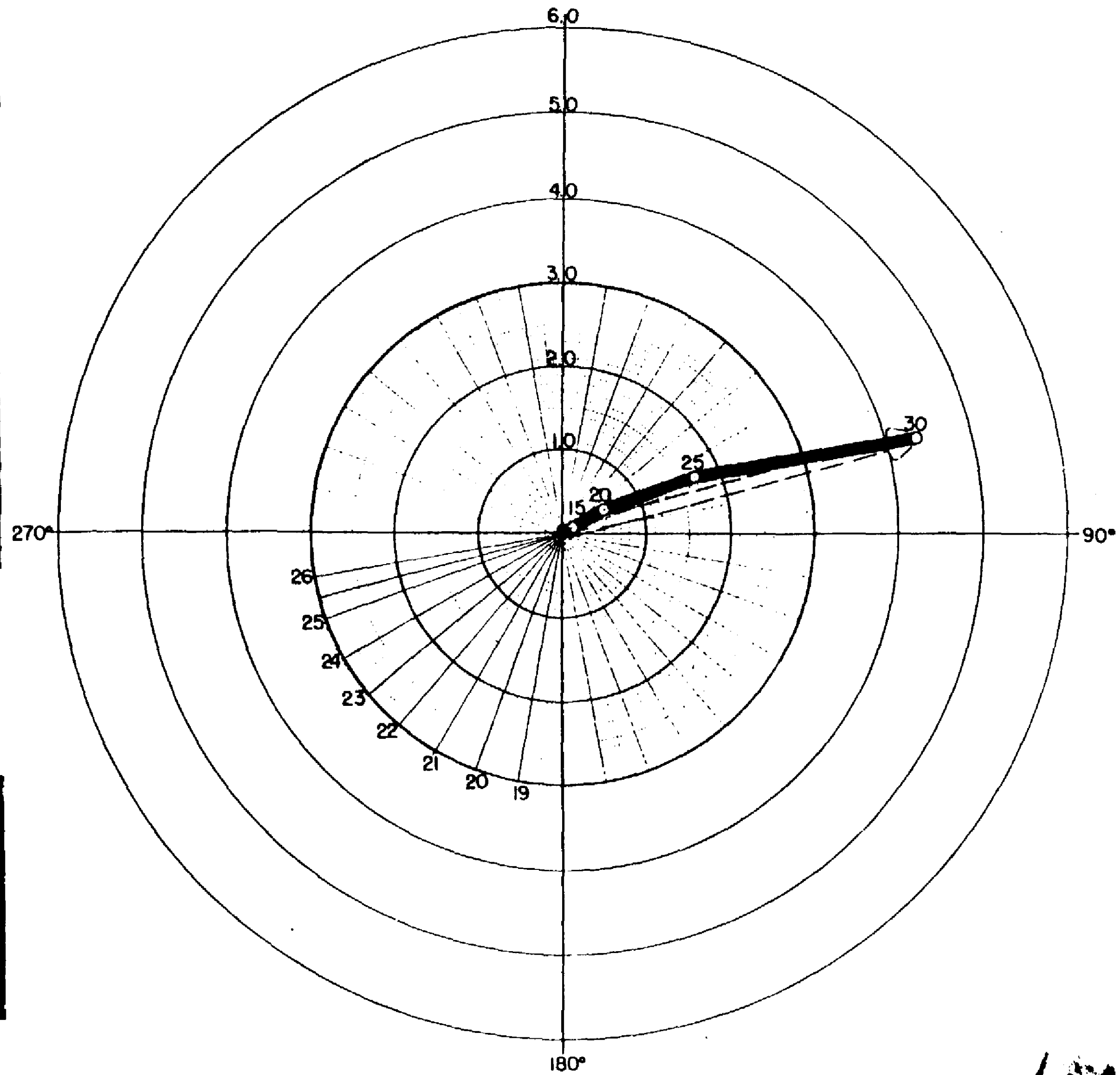
METHOD OF COMPUTING LOCATION OF CENTER OF ATOMIC CLOUD TOP AT TIME IT REACHED HIGHEST ALTITUDE

As the atomic cloud was acted upon by the upper winds during the 12.0 minutes that it was rising, the top of the cloud was displaced a considerable distance from the test site by the time that it reached maximum altitude. The upper winds at H-hour have been estimated by considering data obtained several hours before and after H-hour. These estimated wind data give a movement of 4.4 nautical miles in a direction from 255°. This increase in distance between the cloud and the theodolite observation stations must be considered if the true altitude of the cloud is to be considered.

The position of the cloud has been calculated by joining together vectors which are directed in accordance with the upper wind at the 5,000 foot level in question and which are proportional in length to the time that the cloud required to pass through the altitude interval.

The radii of the circles are in nautical miles, and the individual vectors are identified by figures signifying thousands of feet.



MINUTES THAT WIND ACTED ON CLOUD AT EACH 5,000 FOOT LEVEL

The graph of the azimuth angles of the primary cloud mass shows that the atomic cloud moved very little horizontally during the first three minutes. Because of the relatively light winds at lower levels and the rapid rise of the atomic cloud, wind data below 15,000 feet have not been considered in these computations. The time intervals given below have been obtained by dividing the curve shown on the page <u>Rate of Rise of the Atomic Cloud</u> into 5,000 foot segments, 2,500 feet on either side of the altitude in question, and reading off the intersections of the plotted curve with the time ordinates. These time intervals are considered to be the number of minutes that the upper winds acted on the cloud at each 5,000 foot level. Data up to 25,000 feet have been used for the primary cloud mass and data for 30,000 feet have been used for the cloud projection.

Feet	Minutes	
15,000	(2.0 - 1.1)	- 0.9
20,000	(3.4 - 2.0)	- 1.4
25,000	(8.0 - 3.4)	- 2.6
30,000	(12.0-10.2)	- 4.0

UPPER WINDS AT H-HOUR

Altitude	Degrees	Knots
10,000	210	10
15,000	240	10
20,000	240	18
25,000	250	26
30,000	260	40
35,000	270	43

LENGTHS OF VECTORS IN NAUTICAL MILES

Altitude	Hours		Knots		Nautical Miles
15,000	0.9/60	x	10	-	.15
20,000	1.4/60	x	18	-	.42
25,000	2.6/60	x	26	-	1.13
30,000	4.0/60	x	40	-	2.67

Length of calculated vector — 4.4 n. miles, direction — from 255°

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RE[redacted]DATA
Atomic Energy Act — 1946
Specific [redacted] Clearance Required

Determinations of Altitudes of Atomic Clouds

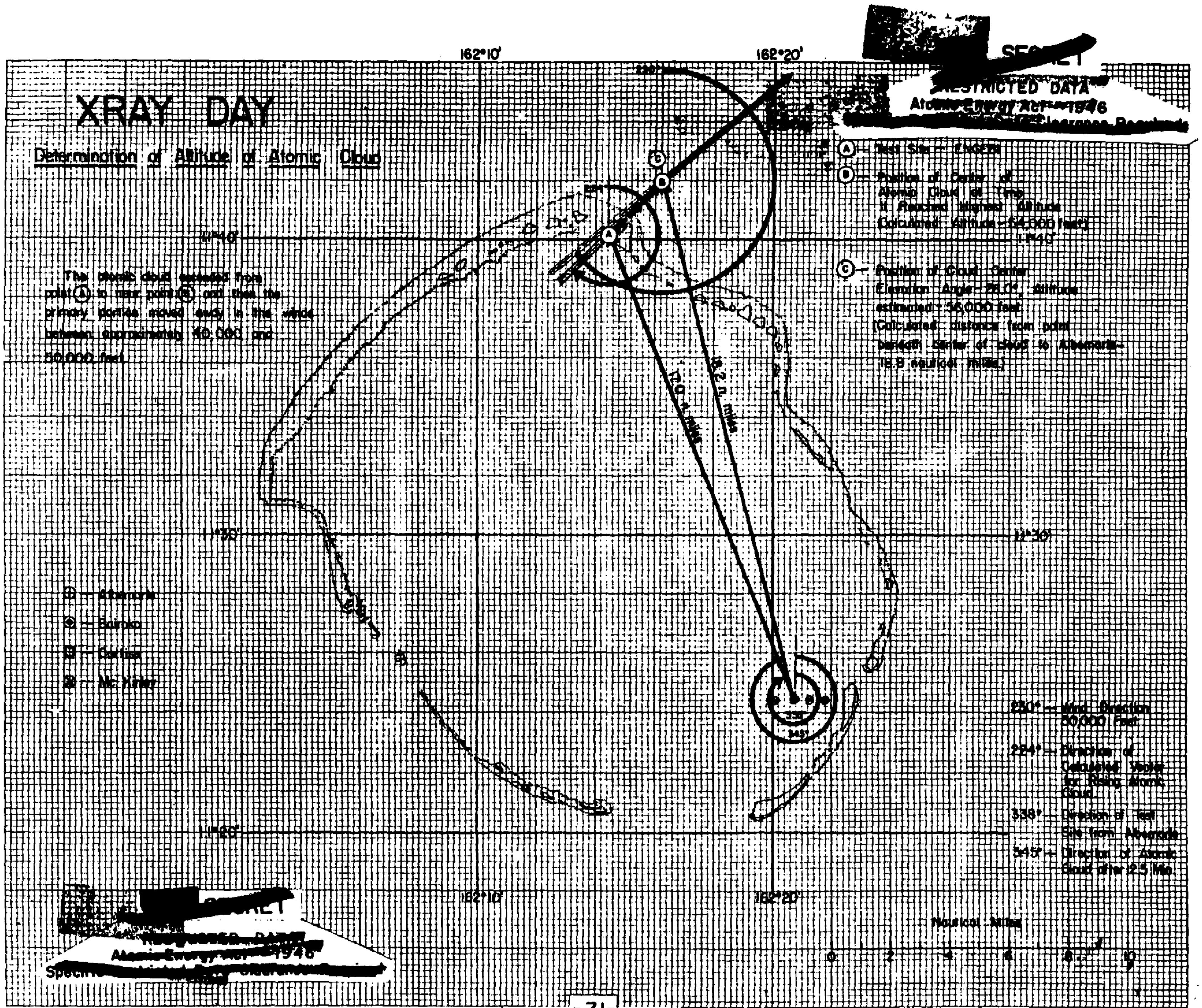
The positions of the tops of the atomic clouds at the time that they reached highest altitude have been calculated in two different ways. For XRAY and YOKE DAYS, one of these positions was determined from the height of the tropopause, the elevation angles, and the azimuth angles. For ZEBRA DAY, since the cloud could not have reached the tropopause, the estimate of the maximum altitude was more difficult. First, it was necessary to make an estimate of the position of the cloud top from its azimuth angle and its most probable direction of movement from the test site. (See page 22.) Then, with all three clouds, the second position was determined from the combination of the wind vectors and the rate of rise curves. If, on the chart, these second points fall close to the first, it is reasonable to assume that the clouds did reach the altitudes which were used in calculating the first points, and that for practical purposes the heights used in drawing the rate of rise curves may be considered to be the actual heights.

The charts of Eniwetok also provide a convenient means of showing the locations of test sites, the positions of the observing ships, and the most probable direction of movements of the primary masses of the atomic clouds after the tops had reached maximum altitude.

XRAY DAY— From the wind vectors and the rate of rise curve the top of the cloud is calculated to be 54,000 feet, or below the tropopause which was at 56,000 feet. Nevertheless, because of the plume which formed on this cloud, it is believed that at least some of the top of the cloud did extend through the tropopause. As may be noted on the chart, the distance between the two positions which have been calculated by using the two different elevations is less than a mile; and the difference in elevation as determined by either method of calculation is only 2,000 feet. The discrepancies are small enough to have been caused by the manner in which the theodolites were aimed. In further references the XRAY DAY cloud will be regarded as having reached 56,000 feet.

YOKE DAY— On the second test day the altitude of the cloud as calculated from the upper winds at H-hour is 50,200 feet, but the height of the cloud if it reached the tropopause would have been 56,000 feet. With the same elevation angle in either case, the horizontal distances would have been 19.0 and 21.2 miles, respectively. The first position represents the effect of an average wind of 34 knots whereas the second position represents the effect of an average wind of 46 knots. That is, a difference of 11 or 12 knots in combined effect of the upper winds would have accounted for the difference in the two positions. It is reasonable to assume that the actual winds at the time the cloud was rising were stronger than the estimated winds and that the altitude of the cloud is more nearly 56,000 feet than 50,200 feet. Since it is thought that the XRAY DAY cloud reached the tropopause, it is believed that the YOKE DAY cloud did also, even though there was no visible evidence. This is based on the assumption that the YOKE DAY weapon was more powerful than the XRAY DAY weapon and the temperature lapse rates on the two days were similar. In further considerations of the YOKE DAY cloud, it will be assumed that the wind carried the cloud to the approximate position of point "C" and that the cloud did reach 56,000 feet. However, in other considerations, it will be assumed that the winds which acted on the cloud were the estimated winds, that is, the winds which would have carried the cloud to point "B". For further discussion of the effect of the wind on the YOKE DAY cloud, see page 34.

ZEBRA DAY— Because of the cloud projection which rose out of the ZEBRA DAY cloud, it is necessary to know the position of both the primary cloud mass and the highest part of the cloud projection in order to fully understand the behavior of this atomic cloud. When the position of the highest part of the atomic cloud projection is computed by either the rate of rise curve and the wind vectors or from its most probable position on the basis of the upper wind directions, it is found to be in approximately the same place. For either point, the horizontal distance is 11.0 miles. Therefore, the maximum altitude of 33,000 feet calculated from this horizontal distance and the corresponding elevation angle is likely to be close to the actual elevation of the highest part of the cloud. It should be noted that the center of the primary mass of the cloud is estimated to be approximately a mile behind the top of the cloud projection. The direction of movement of the primary mass must be drawn from point "B" instead of from the cloud top as in the case of the XRAY and YOKE DAY clouds.



XRAY DAY
Determination of Altitude of Atomic Cloud
The atomic cloud ascended from point (A) to max. point (B) and then the primary portion moved east in the winds between approximately 40,000 and 50,000 feet.
(A) — Albemarle
(B) — Barnes
(C) — Curtiss
(D) — Mc Kinley
162°10'
162°20'
11°40'
11°30'
11°20'
18.2 n. miles
17.0 n. miles
(A) — Test Site — ENGEBI
(B) — Position of Center of Atomic Cloud at time it Reached Highest Altitude (Calculated Altitude – 54,000 feet)
(C) — Position of Cloud Center Elevation Angle – 26.0°, Altitude estimated – 56,000 feet (Calculated distance from point beneath center of cloud to Albemarle – 18.9 nautical miles)
230° — Wind Direction 50,000 Feet
224° — Direction of Calculated Vector for Rising Atomic Cloud
338° — Direction of Test Site from Albemarle
345° — Direction of Atomic Cloud after 2.5 Min.
Nautical Miles
0 2 4 6 8 10
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Atomic Energy Act 1946
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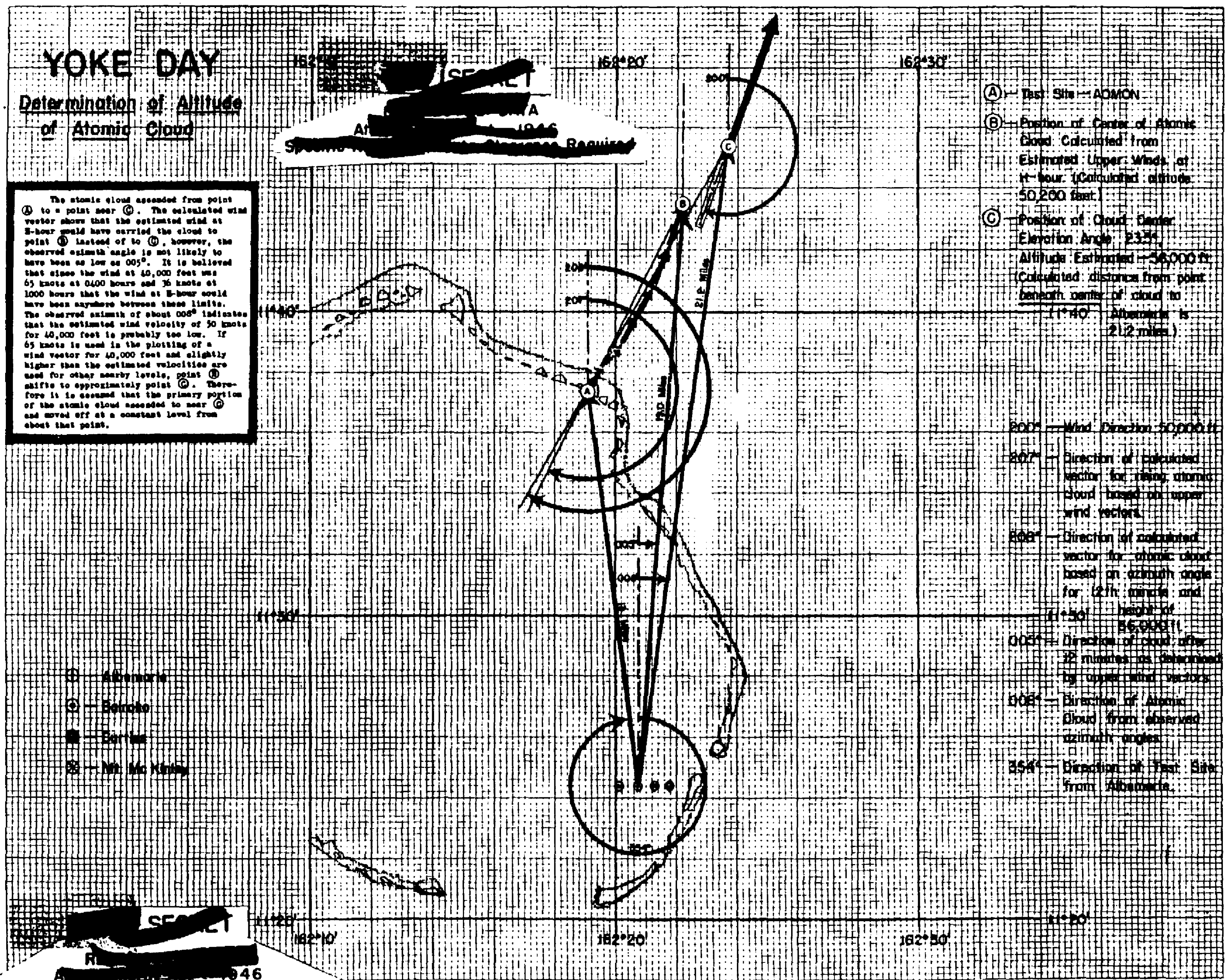
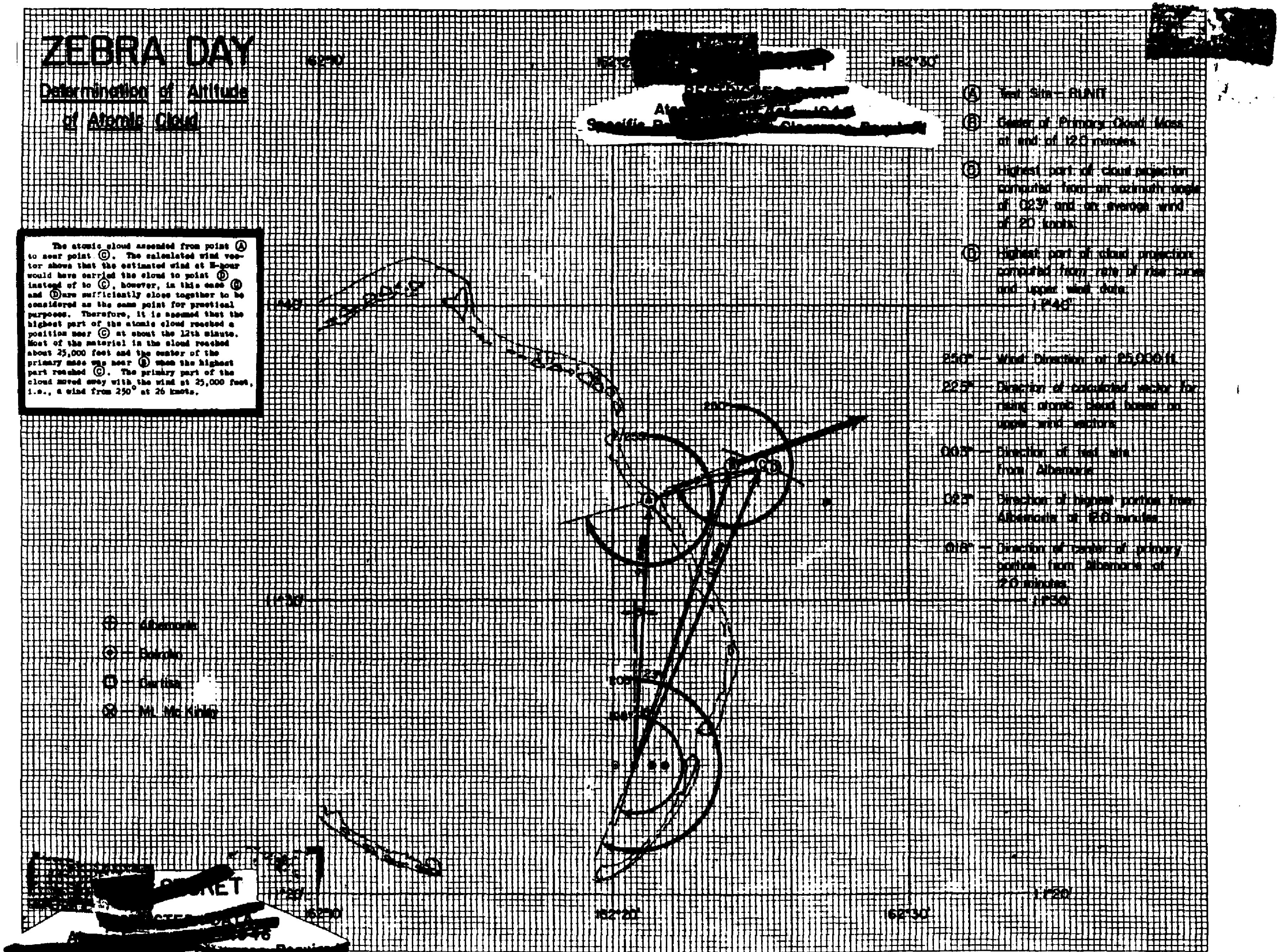


YOKE DAY
Determination of Altitude of Atomic Cloud
[redacted]
The atomic cloud ascended from point Ⓐ to a point near Ⓒ. The calculated wind vector shows that the estimated wind at H-hour would have carried the cloud to point Ⓑ instead of to Ⓒ, however, the observed azimuth angle is not likely to have been as low as 005°. It is believed that since the wind at 40,000 feet was 65 knots at 0400 hours and 36 knots at 1000 hours that the wind at H-hour would have been anywhere between these limits. The observed azimuth of about 008° indicates that the estimated wind velocity of 50 knots for 40,000 feet is probably too low. If 65 knots is used in the plotting of a wind vector for 40,000 feet and slightly higher than the estimated velocities are used for other nearby levels, point Ⓑ shifts to approximately point Ⓒ. Therefore it is assumed that the primary portion of the atomic cloud ascended to near Ⓒ and moved off at a constant level from about that point.
Mt. Mc Kinley
162°20'
162°30'
162°10'
11°40'
11°30'
11°20'
21.2 Miles
200°
207°
Ⓐ — Test Site — AOMON
Ⓑ — Position of Center of Atomic Cloud Calculated from Estimated Upper Winds at H-hour. (Calculated altitude 50,200 feet.)
Ⓒ — Position of Cloud Center Elevation Angle 23.5°, Altitude Estimated — 56,000 ft. (Calculated distance from point beneath center of cloud to Albemarle is 21.2 miles.)
200° — Wind Direction 50,000 ft
207° — Direction of calculated vector for rising atomic cloud based on upper wind vectors.
008° — Direction of calculated vector for atomic cloud based on azimuth angle for 12th minute and height of 56,000 ft.
005° — Direction of cloud after 12 minutes as determined by upper wind vectors.
008° — Direction of Atomic Cloud from observed azimuth angles.
354° — Direction of Test Site from Albemarle.
[redacted]


ZEBRA DAY
Determination of Altitude of Atomic Cloud
The atomic cloud ascended from point Ⓐ to near point Ⓒ. The calculated wind vector shows that the estimated wind at H-hour would have carried the cloud to point Ⓓ instead of to Ⓒ, however, in this case Ⓒ and Ⓓ are sufficiently close together to be considered as the same point for practical purposes. Therefore, it is assumed that the highest part of the atomic cloud reached a position near Ⓒ at about the 12th minute. Most of the material in the cloud reached about 25,000 feet and the center of the primary mass was near Ⓑ when the highest part reached Ⓒ. The primary part of the cloud moved away with the wind at 25,000 feet, i.e., a wind from 250° at 26 knots.
Ⓐ Test Site - RUNIT
Ⓑ Center of Primary Cloud Mass at end of 12.0 minutes.
Ⓒ Highest part of cloud projection computed from an azimuth angle of 023° and an average wind of 20 knots.
Ⓓ Highest part of cloud projection computed from rate of rise curve and upper wind data.
250° — Wind Direction at 25,000 ft.
225° — Direction of calculated vector for rising atomic cloud based on upper wind vectors.
063° — Direction of test site from Albemarle.
023° — Direction of highest portion from Albemarle at 12.0 minutes.
018° — Direction of center of primary portion from Albemarle at 12.0 minutes.
Albemarle
Bairoko
Curtiss
Mt. McKinley
162°10'
162°20'
162°30'
11°40'
11°30'
11°20'
[redacted]
SECRET
[redacted]

SEC[redacted]
R[redacted]
At[redacted]
[redacted] Required

Apparent Dispersions of Atomic Clouds

In planning for the Eniwetok tests considerable interest was directed towards the manner in which the atomic clouds would be dispersed in the atmosphere. The spreading out of the clouds is important because of radiological safety and long range detection considerations. Also, the behavior of atomic clouds offers a means of checking theories of diffusion and eddy conductivity in the free atmosphere.

Data on dispersion were obtained by instructing observers to sight on each side of the mushrooms or the primary cloud masses. It was thought that a rate of dispersion could be derived from the increase in size of these major cloud volumes. The azimuth angles for the sides of the primary masses for each minute have been plotted on the graphs shown on pages I-31, I-24, and I-27 of Appendix I. The points were connected by a smooth curve which represents the results from a single observing station in the position of the Albemarle. Considerable smoothing has been done in drawing these curves as the irregularities would not be significant in the computation of a rate of dispersion. After the most probable azimuth angles for each five minute interval were arrived at, the diagrams shown on pages 35, 36, and 37 were begun. First, the relative positions of the Albemarle and the primary masses at the times that they reached highest altitude were determined. Then lines were drawn for the azimuth angles at the five minute intervals, and the bisector of each of the angles formed by the sets of lines was found. These bisectors were drawn from the position of the Albemarle through the centers of the areas representing the primary masses, but they have been erased and do not appear on the final diagram. Next, the direction and velocity of movement of these primary masses were determined by trial and error methods. Straight lines were drawn through the positions of the cloud masses at the time that they reached maximum altitude and across the lines directed according to the azimuth angles. In each case a line could be drawn which was cut by the radiating azimuth angle lines at more or less regular intervals. These lines are parallel to the directions of the wind which acted on the cloud masses, and the lengths of the segments of the lines are proportional to the wind velocities which moved the cloud material. The directions and velocities obtained in this manner were then compared with the estimated winds and the most probable directions of movement decided upon. In this manner the locations of the centers of the cloud masses were fixed at five minute intervals. Then, with the centers located, circles could be drawn with circumferences on the two corresponding azimuth angle lines. In this way, the series of expanding circular areas was obtained. It was realized that the cloud areas were not actually circular, but a circle was thought to be the most feasible area which could be used. These circular areas have been outlined in a manner resembling the edges of clouds, and straight lines connecting their perimeters have been drawn. The intersection of such boundary lines gives an angle which appears to be useful in comparing the dispersion of the clouds. If the angle were significant, it would go a long way toward answering many problems of dispersion in the free atmosphere.

Further studies show that these dispersion diagrams have little practical significance. The fact that the azimuth angle data could be used in computations and that angles of dispersion could be obtained made the construction of these diagrams seen worthwhile. It was not until thought was given to the size and shape of the cloud at the end of three hours that it was discovered that these diagrams had little meaning. The theodolites were aimed at either side of the primary masses, which were ten to twenty thousand feet thick. In each case there were significant variations in wind directions and velocities in such a deep layer of air. Because of the winds alone there was considerable increase in the width of the clouds as seen by the observers. The theodolites were aimed at the edges which seemed furthest to the left and to the right. There was no way to direct them to sight on the cloud at any particular elevation and watch the dispersion at just that level. Consequently the altitudes for which azimuth angles were taken shifted in accordance with the winds. The level where the wind velocities were slowest is represented in the angles for the left side of the clouds and the level of highest winds is represented in the data for the right hand side. No true measure of dispersion was obtainable while the clouds were visible from Eniwetok. However, these diagrams were found to be useful in estimating the dimensions of the clouds as shown in the photographs.

XRAY DAY- Although most of the cloud material was concentrated at 40 to 50 thousand feet, the primary mass extended from about 25 to 55 thousand feet. The right edge of the cloud was probably close to 45,000 feet, but it is not possible to decide which level was sighted on as the extreme left edge, nor is it possible to tell when the observers shifted from level to level as they endeavored to keep that edge in their sights. For a better understanding of the actual behavior of the cloud see the diagram titled Dimensions of Atomic Cloud at End of Three Hours, page 38, and the photographs, pages 55 through 63.

YOKE DAY- At the time this cloud reached highest altitude there was no well defined primary mass at which theodolites could be sighted in order to obtain azimuth angle data. The irregular shape of the cloud is shown in the photographs on page 65. Then, as the cloud moved away it became shaped as shown in the photographs on pages 66, 67, and 68, and in the diagrams on pages 40 and 41. A theodolite aimed at the top of the cloud at 30 minutes past H-hour would be sighted on a level at about 50,000 feet for a left hand azimuth angle and at a level of about 35,000 feet for a right hand azimuth angle. The difference between the left and right hand azimuth angles is primarily a result of the difference in wind directions and velocities between these two elevations rather than the result of diffusion processes. Of the three clouds, the YOKE day cloud was least adapted to theodolite observations for dispersion studies.

It is interesting to note that the azimuth angles for the top part of the cloud indicate that it was acted on by an effective wind of 60 knots rather than a 43 knot wind such as was estimated to exist at 50,000 feet at H-hour. This effect of a 60 knot wind is more nearly in agreement with the 65 knot wind measured at 40,000 feet at approximately two hours before H-hour than with the estimated 43 knots. Also, the higher wind velocity indicates that the position of the top of the cloud probably was beyond point "B" and actually close to point "C" in the diagram titled Determination of Altitude of Atomic Cloud on page 32. This seems to be additional evidence that the cloud reached the tropopause. However, in studying the shape of the cloud at the end of three hours it is thought that the estimated winds are the most representative.

ZEBRA DAY- The last of the three clouds did have a primary mass which was more or less well defined, and it had left and right hand edges which were maintained so that successive observations could be made. However, the difference between the azimuth angles was largely dependent upon the fact that the wind velocity at 28,000 feet was greater than at 20,000 feet. See the diagram on page 42.

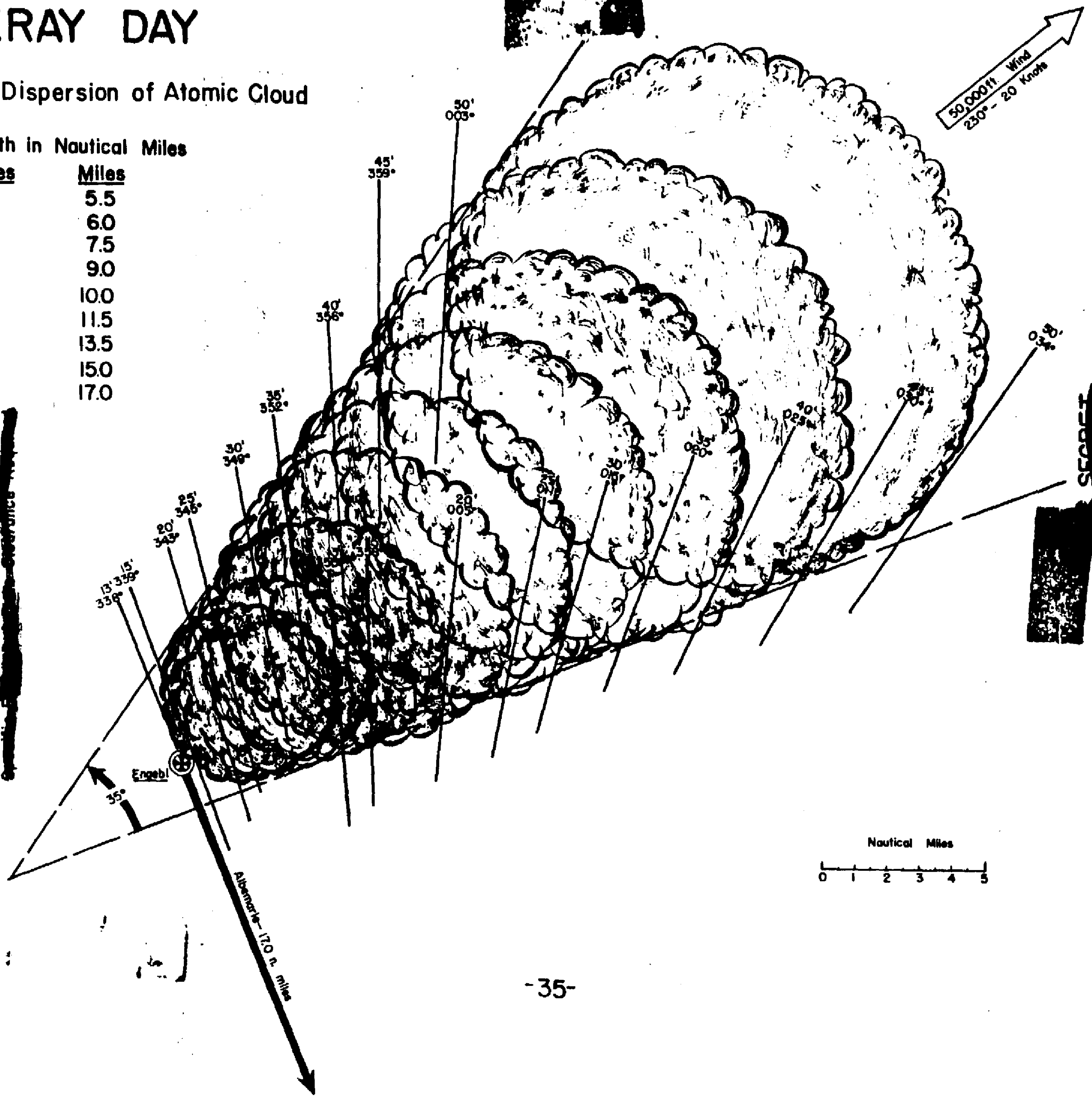
[redacted]
RE[redacted]
Ato[redacted]
[redacted]

XRAY DAY

Apparent Dispersion of Atomic Cloud

Cloud Width in Nautical Miles

Minutes	Miles
13	5.5
15	6.0
20	7.5
25	9.0
30	10.0
35	11.5
40	13.5
45	15.0
50	17.0



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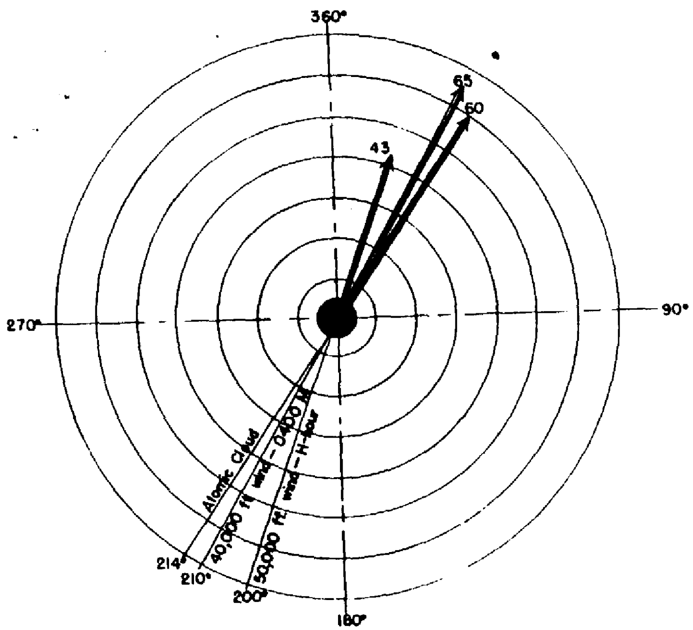
YOKE DAY

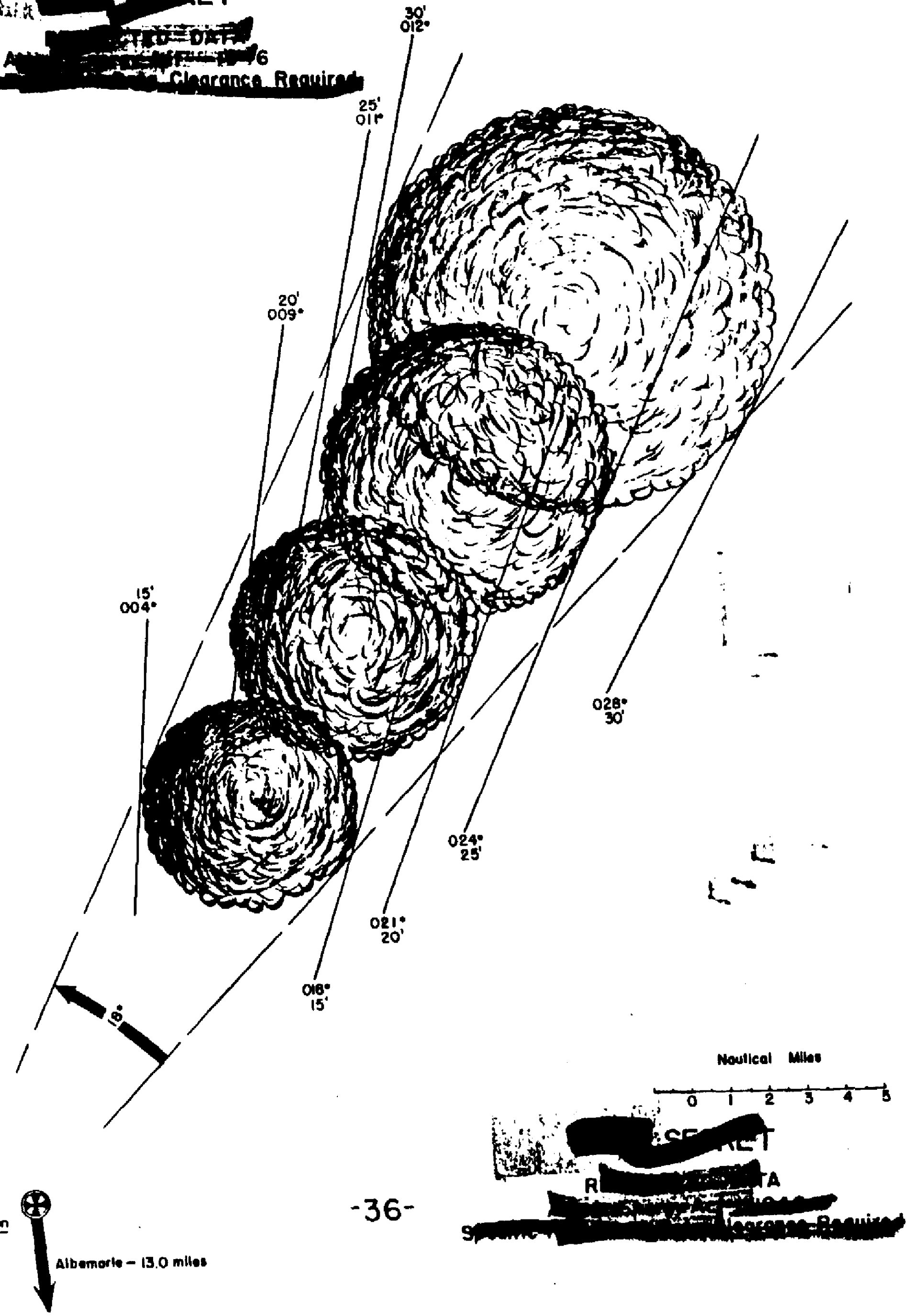
Apparent Dispersion of Atomic Cloud

[redacted] SEC[redacted]ET
[redacted]
[redacted] Clearance Required

Minutes	Miles
15	6
20	7
25	8
30	11

Cloud Width in Nautical Miles





[redacted] SEC[redacted]ET
R[redacted]TA
[redacted]
S[redacted] Clearance Required

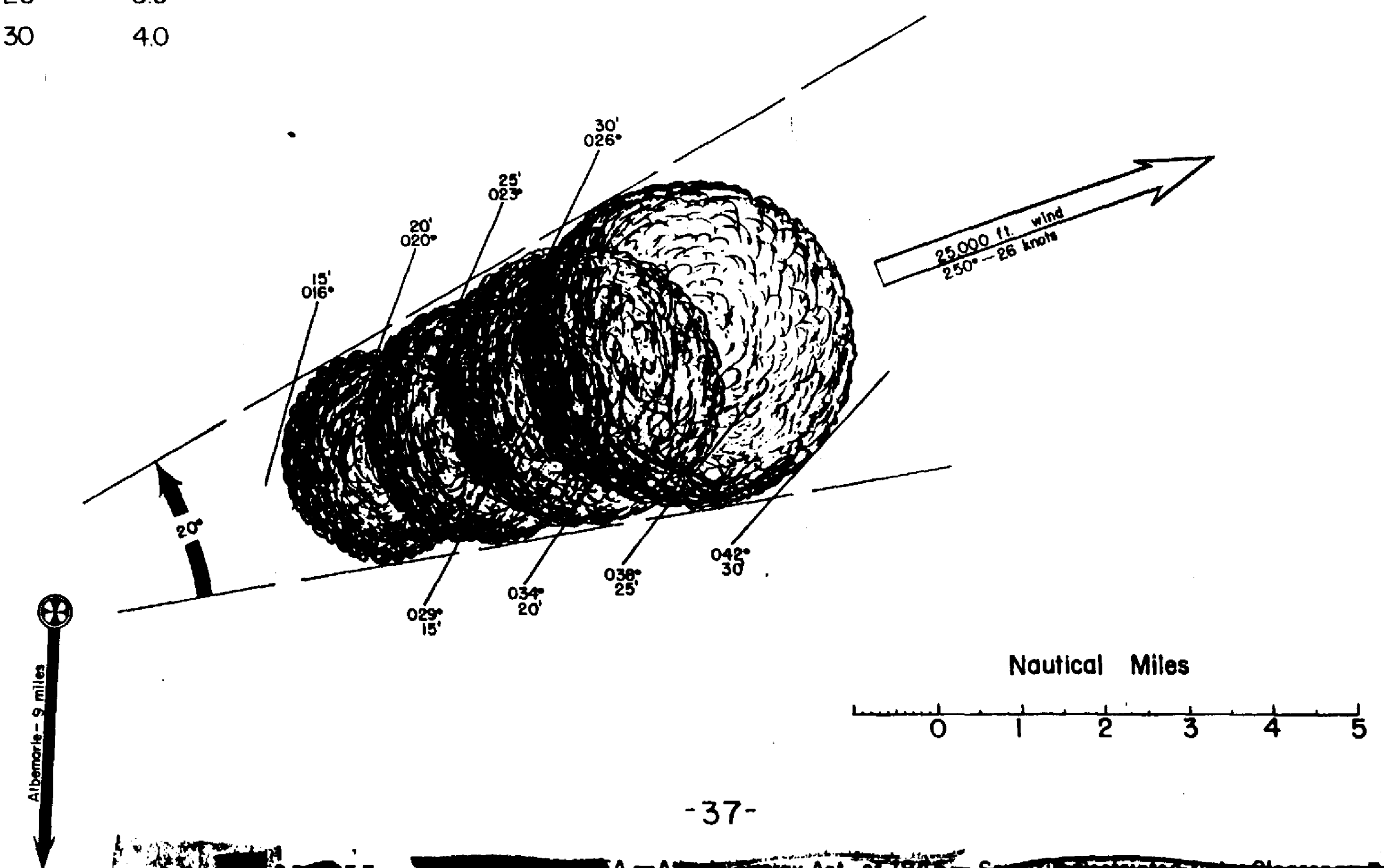
ZEBRA DAY

[redacted] SE[redacted]RET
[redacted]

Apparent Dispersion of Atomic Cloud

Cloud Width in Nautical Miles

Minutes	Miles
15	2.5
20	3.0
25	3.5
30	4.0



[redacted] E T [redacted] A — A[redacted] Energy Act of 19[redacted]

Dimensions of Atomic Clouds at End of Three Hours

The best understanding of how the atomic clouds were dispersed in the atmosphere is obtained from studies of the effects of the upper winds at all of the elevations at which cloud material occurred. As explained on page 34 under the title Apparent Dispersions of Atomic Clouds, an attempt was made to study the spreading of the primary masses of the clouds by means of theodolite data for each side of the primary masses. Azimuth angle data from theodolites do not take into consideration the differences in wind directions and velocities which occurred at different levels within the primary masses, and such data are greatly affected by this variation of wind with altitude. Also, practical considerations of atomic clouds require that the entire cloud columns be studied rather than just the primary masses. In these diagrams azimuth angle information has not been used. The shapes of the clouds have been determined from the estimated upper wind data, together with photographs and sketches. For a check, scale models were made from these diagrams and the models were compared with the photographs. As far as can be determined the shapes and dimensions of the clouds as shown in the diagrams are approximately the same as the actual clouds.

In order to perceive the effects of the wind it is necessary to study its effects for some period of time long enough for easily recognized changes in shape to occur. Here, a period of three hours has been used. After approximately three hours the shapes of the clouds could not be determined by ground observers or by photographs made from surface locations. Three hours is the longest time interval for which the calculated shapes can be compared with the actual shapes.

Upper wind data can be used to calculate the approximate dimensions of the clouds at any time after H-hour although no visual check of the shape of the clouds is possible. A calculation based just on upper wind data would necessarily assume that cloud material was not changing elevation because of fall-out or convective activity. Also, the dispersion at any particular elevation would either be neglected or roughly estimated. Inspection of photographs shows that fall-out of material from the upper parts of the atomic clouds was not perceptible during the first three hours.

The dispersion at any particular elevation because of eddy motions in the atmosphere is more important than fall-out in a study of the visible cloud. The process which is responsible for the dispersing of air-borne material because of circular motions, or eddies, is frequently referred to as "eddy conductivity." It is the factors which enter into considerations of eddy conductivity which determine the rate at which the cloud spreads at any one level. Some of these factors are the horizontal area of the cloud material, the amount of material above and below the level in question, the wind shear at that level, and the temperature lapse rate. Such factors determine the ease with which circular motions can occur. The eddy conductivity processes in the free atmosphere are not understood sufficiently to make application to this study of the atomic clouds. Molecular diffusion plays a part in the spread of the cloud, but the spread of material in this way is not thought to be significant when compared to the much greater dispersing effects of the winds.

The procedure used in the construction of these diagrams was to draw the wind vectors shown on pages 15, 16, and 17, to scale in order to represent a three hour movement on a chart of the Eniwetok area. The ends of these vectors represent the positions of the atomic cloud material at the respective elevations. The amounts of cloud material at these positions are simulated by the areas of the circles drawn around the ends of the vectors. The sizes of the circles were determined by means of the photographs and sketches. The amounts of cloud material at various elevations were estimated visually by comparing in a relative manner the width and thickness of the material with the overall size of the cloud. After the circles were drawn they were connected by tangents common to any two consecutive circles, and the area enclosed was shaded in. Where overlapping layers of cloud occur, additional shading has been added. At levels where there is no cloud material visible in the photographs, or where none was seen, the lines representing edges have not been removed, but there is no shading.

On these horizontal projections of the clouds, dimensions have been added. These dimensions are thought to be close to those of the actual clouds as they are largely a function of the wind directions and velocities. Errors in approximating the area covered by material at any elevation would not greatly affect the overall dimensions of a cloud. When dimensions are given for the length, width, or diameter of an atomic cloud, it should be realized that a very irregular shape is being described.

After producing the diagrams approximating the views which an observer would get by looking down on the clouds, the diagrams were used to produce a projection in the vertical. Such vertical projections very much resemble the views which were obtained from the ships or at Eniwetok. The width of the cloud in the vertical projections is the same as in the horizontal projections at the 5,000 foot intervals, but in between these elevations there there has been no attempt made to estimate the width. In other words, the ends of the lines representing the widths at 5,000 foot intervals in the vertical projection have been connected by straight lines. This gives the vertical projections a thinner appearance than was observed in the actual clouds. Even so, if these vertical projections are compared with the actual cloud sketches and photographs, it will be seen that there is a very close resemblance. In comparing the photographs and diagrams it should be remembered that there was a convergence of the lines which formed the photographic images at Eniwetok, or aboard one of the observing ships; whereas parallel lines in a north-south direction were used to produce the vertical projections. Some of the differences between the diagrams and the photographs are accounted for by this change in perspective.

XRAY DAY— As this cloud separated at approximately 20,000 feet, no shading is shown near this altitude. Also, since the photographs do not show the long arm of cloud sweeping back between 50,000 and 55,000 feet, the shading has been eliminated from that part of the vertical projections of the cloud. This part of the cloud was studied in the model of the cloud which was constructed. Either there was not enough cloud material at these altitudes to form this arm or the winds were different from those estimated. It is even possible that the moisture in this top part of the visible cloud evaporated so that it could no longer be seen after three hours.

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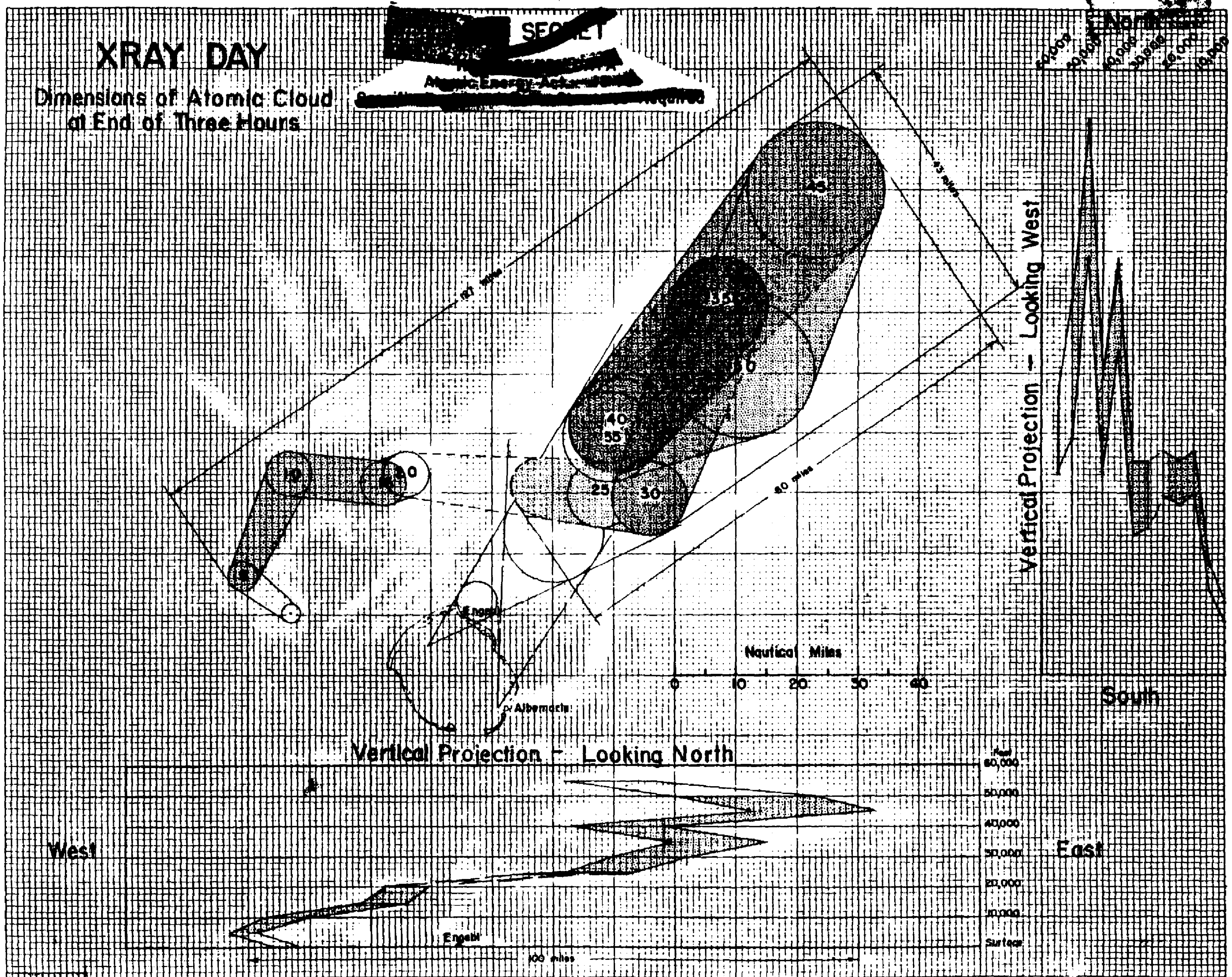


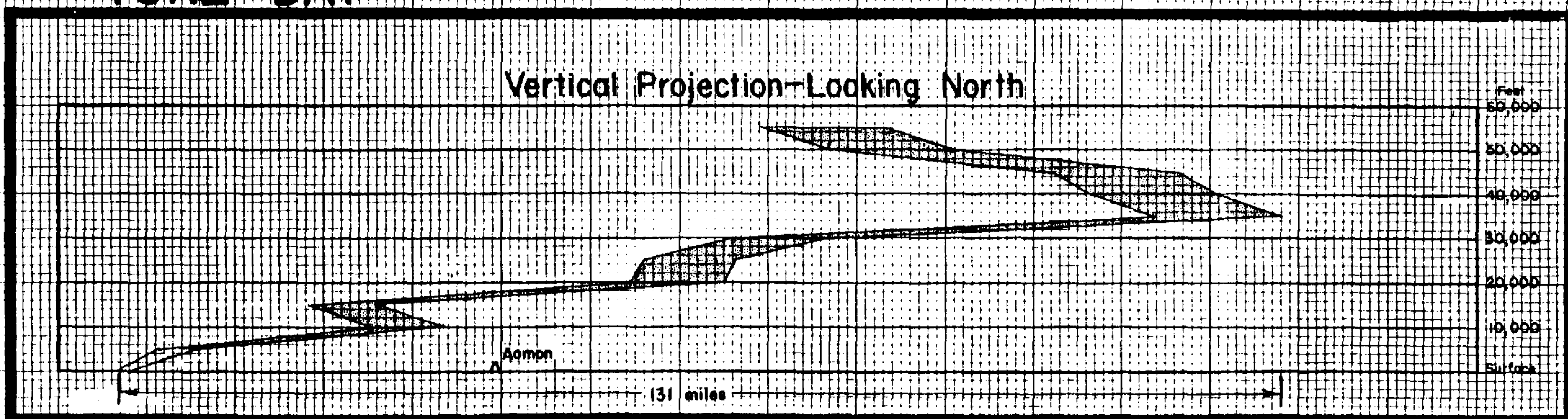
Dimensions of Atomic Clouds at End of Three Hours

(Continued from the previous page.)

YOKE DAY— Because of the marked increase in wind velocity up to about 40,000 feet and the decrease in velocity above this elevation, the atomic cloud was drawn out into a long ribbon which was hook-shaped near the top. An examination of this cloud shape will show the futility of an attempt to sight on a primary mass in order to determine a rate of dispersion which could be applied to any particular elevation. The actual YOKE cloud greatly resembled the diagrams, so it is thought that a true representation of the cloud has been constructed.

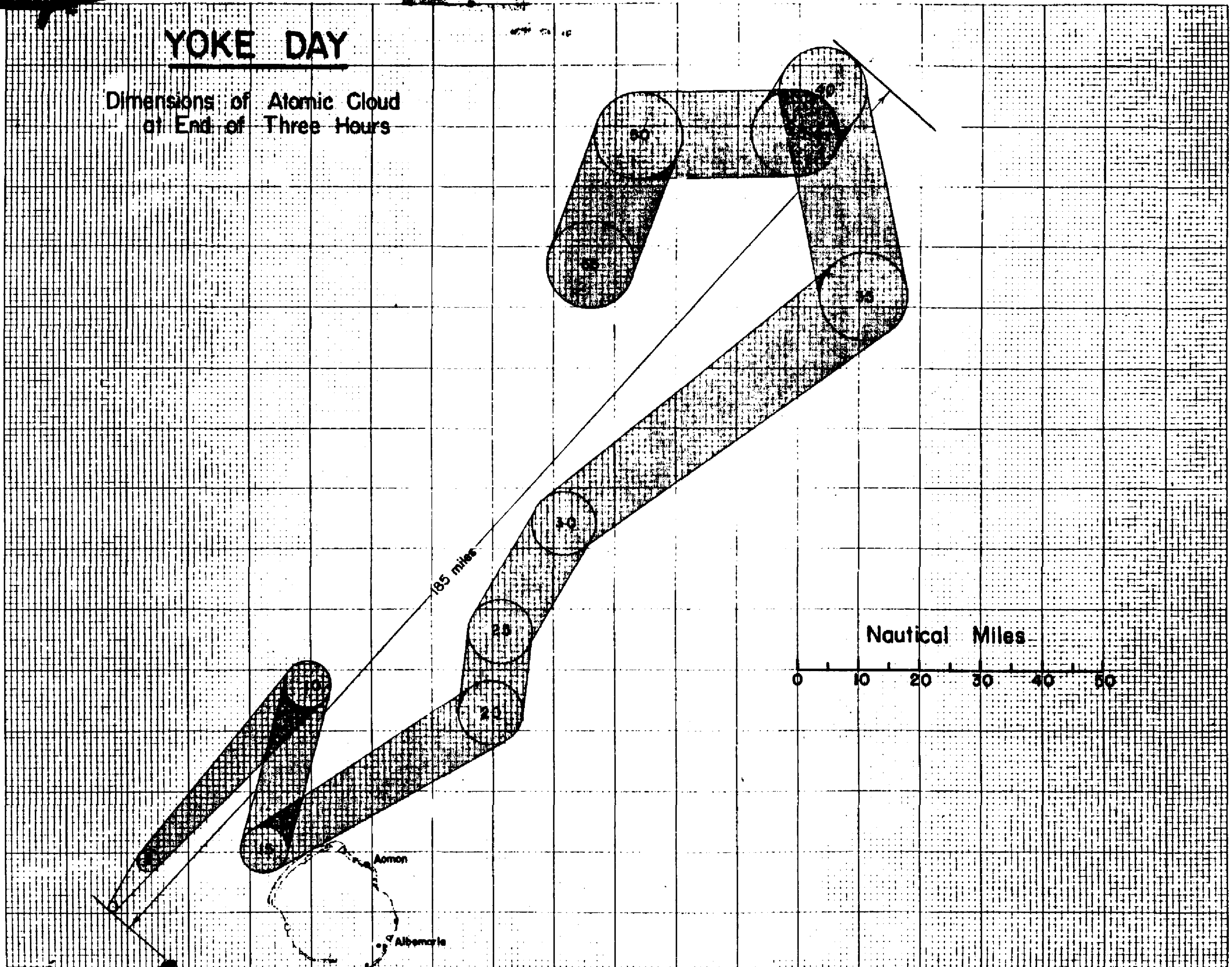
ZEBRA DAY— When the photographs of this cloud were examined, it was found to have a zig-zag appearance because of a loop-shaped structure near its middle. This loop could not be accounted for by drawing according to the estimated winds at just the 5,000 foot elevations. To construct the diagram between 10,000 and 20,000 feet the actual winds for the 0600 local time sounding were used, and vectors for every 1,000 foot interval were drawn. This produced a diagram which was remarkably like the actual cloud. No material was seen in this cloud below about 7,000 feet so no shading is used below that level. The finger-like projection which formed on this cloud has been constructed from the vectors for 30,000 and 35,000 feet.

YOKE DAY



YOKE DAY

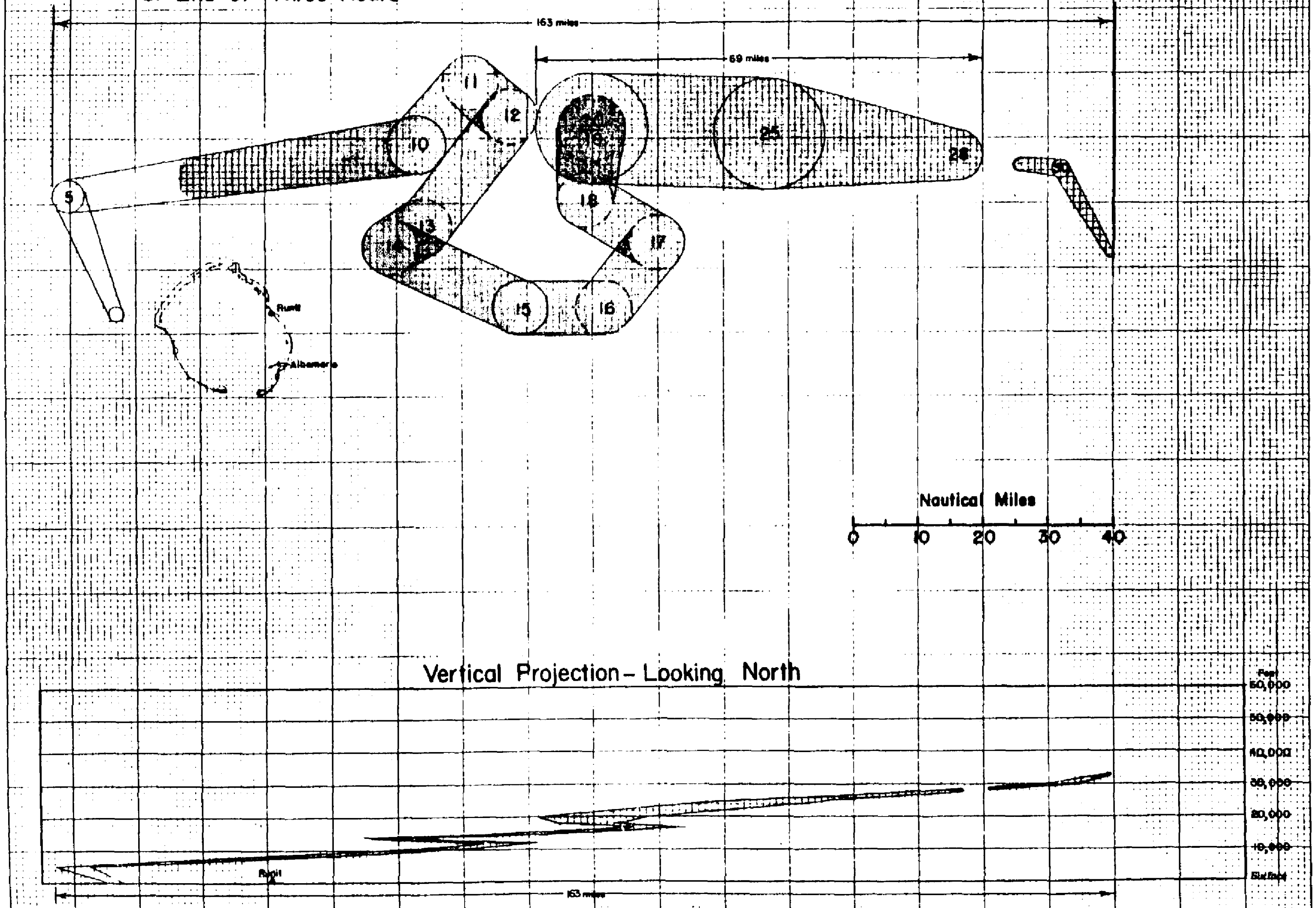
Dimensions of Atomic Cloud at End of Three Hours



[redacted]
RESTRICTED DATA
Atomic Energy Act - 1946
[redacted]

ZEBRA DAY

Dimensions of Atomic Cloud at End of Three Hours



Explanation of Trajectories

This report on the visible clouds could end with the descriptions of the clouds at the end of three hours, since after that time there are no records of the clouds having been seen. However, the report would seem unfinished if it ended without considering the obvious question of what happens to the airborne radioactive material after the clouds disappeared from the Eniwetok area. The charts which follow show how the cloud shapes in the preceding diagrams titled Dimensions of Atomic Clouds at End of Three Hours may have been acted on by the upper winds, and they give some indication of the manner in which the cloud material is assumed to have been spread over thousands of square miles.

Operational requirements for the long range detection program made it necessary to produce estimates of how the radioactive materials of the bomb clouds were transported through the atmosphere and to make day to day forecasts of where the material was likely to go. With present day knowledge and the available facilities for analysis, it was necessary to consider the atomic clouds as a set of points which were carried along at constant levels by the winds. The paths of these points are called trajectories; and on the lines representing these paths, the arrowheads indicate the locations of the points at 24 hour intervals. A trajectory analysis assumes that the cloud consisted of parcels which were gaseous in nature and which did not change elevation. Actually, the clouds contained a high percentage of solid particles which continued to fall out as the cloud was transported; and the rate that the solids settled out is unknown. It is not possible to determine at what altitude the material was at any particular time. Also, it is false to consider the clouds as sets of points since the horizontal dimensions of the clouds is important in determining how the clouds were acted upon. By the time the clouds had travelled across the Pacific, they had been affected by a multitude of diffusion processes. The altitude of the cloud material was changed by large-scale vertical turbulence such as is found in cumulo-form clouds; and the clouds were spread out over such a large area as to be dispersed by the eddy-diffusion effects of high or low pressure systems such as are shown on weather maps.

Another feature of a trajectory analysis which is unfavorable is that meteorological theory indicates that an air parcel, or cloud material which is moving as a gas, moves not at a constant elevation, or at a constant pressure level, but on "isentropic" surfaces. Isentropic surfaces are defined as surfaces of constant "potential temperature," and such a surface varies in altitude depending on the pressure-temperature characteristics of the atmosphere. This means that the gaseous cloud material probably underwent marked changes in elevation as constant potential temperatures were maintained. It also means that the wind patterns for large areas on isentropic surfaces may be somewhat different than on constant level or constant pressure surfaces. (The movement of the clouds on isentropic surfaces is the subject of a current investigation under the direction of Dr. H. Wexler of the U. S. Weather Bureau.)

Because of so many false assumptions, it would seem that trajectory studies are useless; but when used operationally in long range detection, trajectory analyses gave remarkably successful results. For this reason, and because constant level or constant pressure analyses are all that are available to date, these charts are included here.

Trajectories are drawn for parcels originating at the following pressure levels: 850, 700, 500, 300, and 200 millibars. These levels are at approximately 5,000; 10,000; 20,000; 30,000; and 40,000 feet, respectively. The data for these pressure surfaces are transmitted over worldwide meteorological networks; and since the heights of these pressure surfaces are necessary for estimations of upper wind conditions, the computations of trajectories are facilitated if these levels are used. By noting combinations of trajectories at these "standard" levels some idea of the trajectories for intermediate levels is obtainable; however, a study of the 25,000 foot trajectory for YOKE Day showed that it was quite different than either the 20,000 or the 30,000 foot trajectory. It was not possible to do any trajectory work at all above 40,000 feet because outside of the Eniwetok area there were no upper wind data above that altitude. Two sets of upper air charts drawn from observational data collected and analyzed on a 12 hour basis were used daily in trajectory computations.

The trajectories presented here are based on the data which were available to the Staff Meteorologist. Consequently, for the Marshall Island area, these charts are thought to be more accurate than any other similar charts; but they are less valuable as distance increases from the test sites. As the distance increased from Eniwetok there was an attenuation of the amount of meteorological data received. All of the soundings from the concentration of upper air stations operating in the Marshall Island area for the needs of the Task Force were available aboard the U.S.S. Mt. McKinley; but these data, except the soundings from Kwajalein, were not transmitted to units outside of the Marshall Islands.

The structure of the atmosphere over the Marshall Islands during the season of the SANDSTONE Operation and its effects in producing somewhat similar trajectories are worthy of note. During this period, easterly winds, the trades, are normally found from the surface to approximately 15,000 or 20,000 feet. At about that elevation there is a transitional region of variable winds. Above 20,000 feet the wind is westerly, and westerlies prevail to the stratosphere. Generally speaking, this caused the material below 20,000 feet to spread toward the Southwest Pacific or the Philippines and the material above 20,000 feet to spread toward Mexico or the United States. Such an upper wind structure is normal for the Marshall Island area during season when the trade winds predominate. A study, not included in this report, was made of the trajectory patterns for air parcels originating over Eniwetok daily for a period of 30 days beginning on March 22, 1948, and ending on April 20, 1948. This study showed that parcels originating over Eniwetok at altitudes from 5,000 to 10,000 feet normally moved westward and passed over the Philippine Islands within two weeks. Parcels at 20,000 feet did not move consistently in any particular direction. In this transitional zone, some of them moved to the east, some west, and a few moved into the southern hemisphere where upper air data were unavailable. The 30,000 and 40,000 foot trajectories invariably moved eastward, normally passing south of Hawaii, and reached Mexico within six to eight days after their origin at Eniwetok.

The effects of the trajectories on the tests days were to stretch out the cloud material to the west and to the east in a band which continually increased in length. If no fall out is considered, the cloud may be assumed to be a ribbon-like structure which was slanted downward from east to west. That is, the clouds even after several days maintained shapes similar to those shown in the vertical projections on the preceding pages.

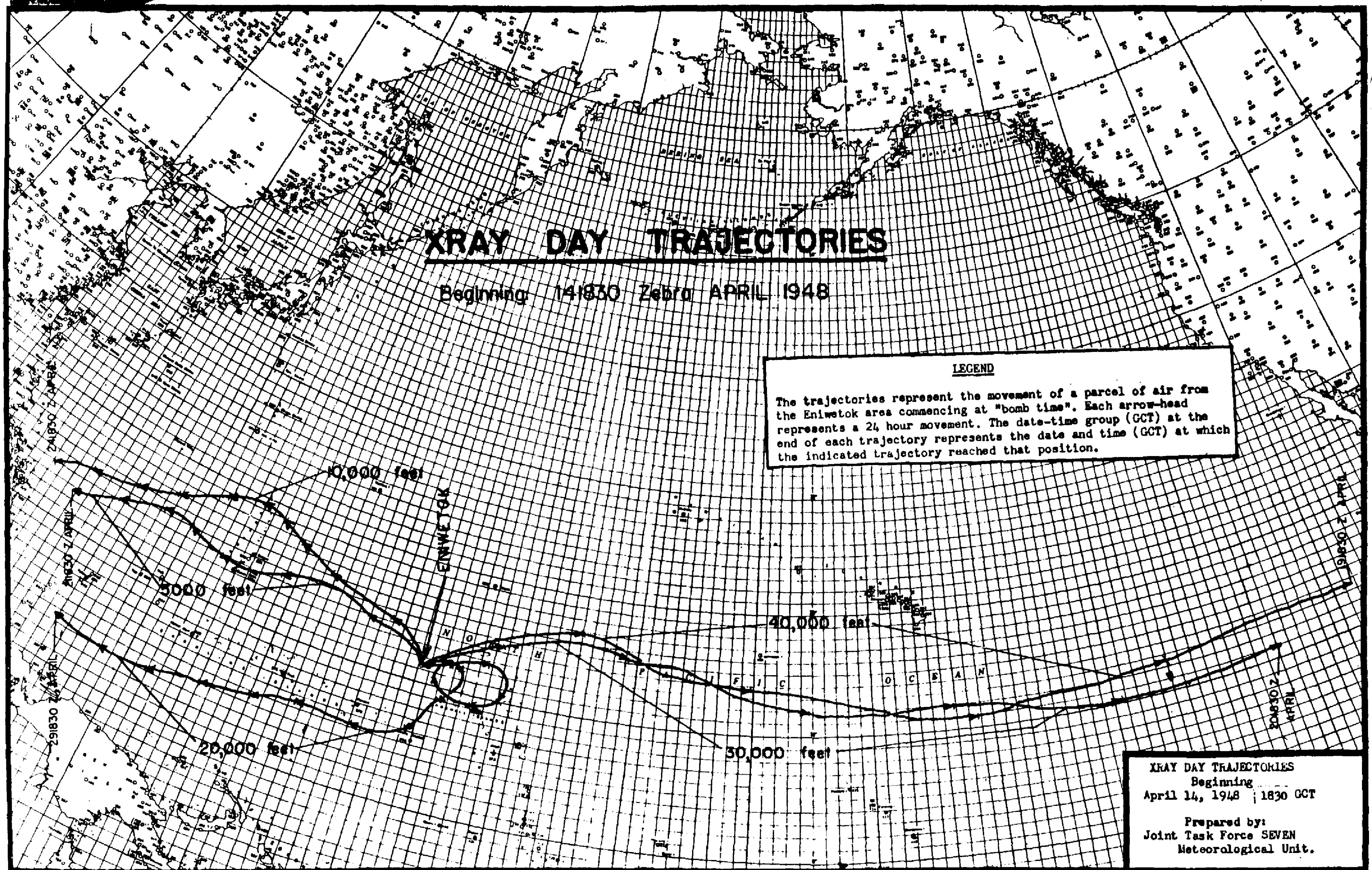
Explanation of Trajectories

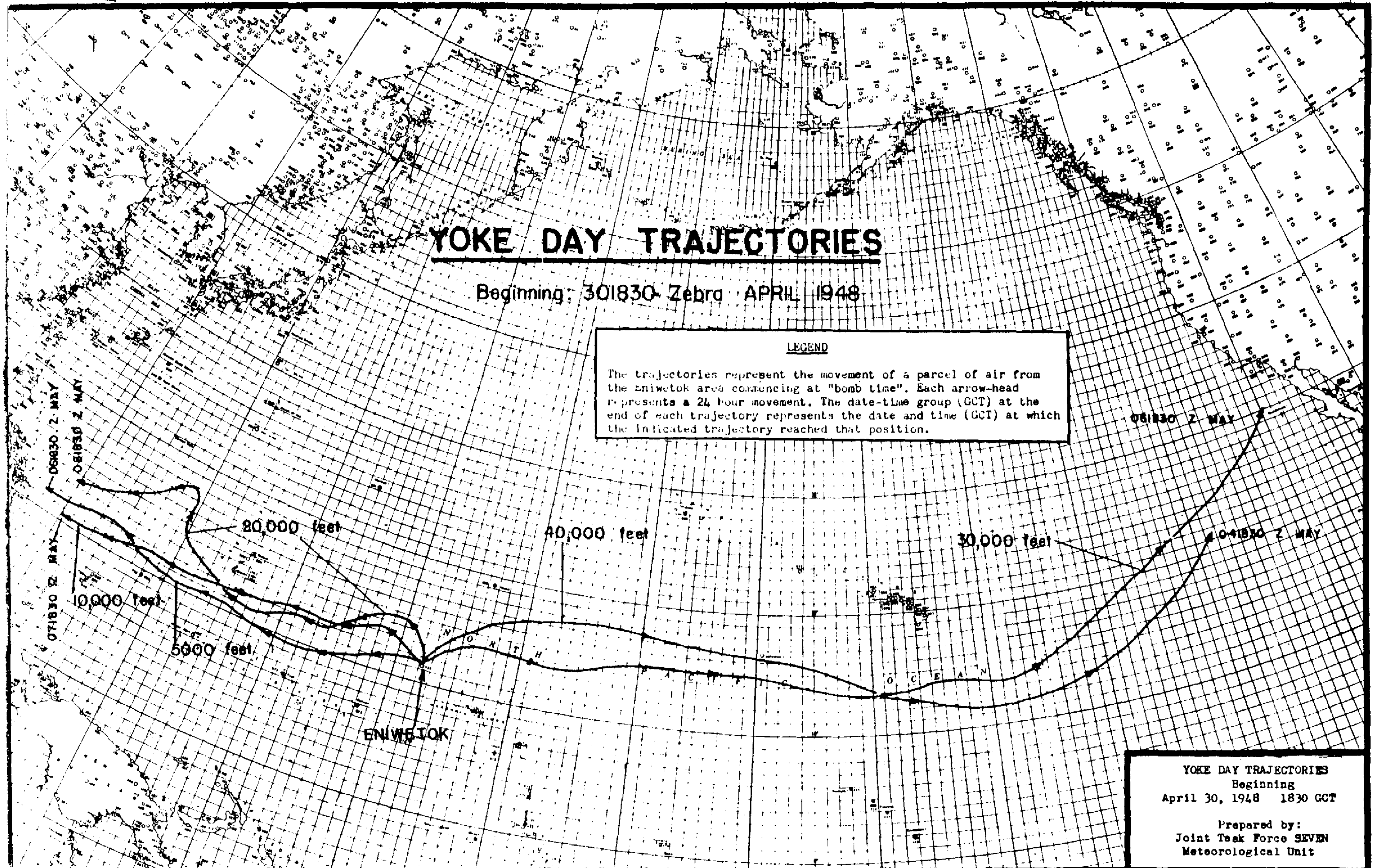
(Continued from previous page.)

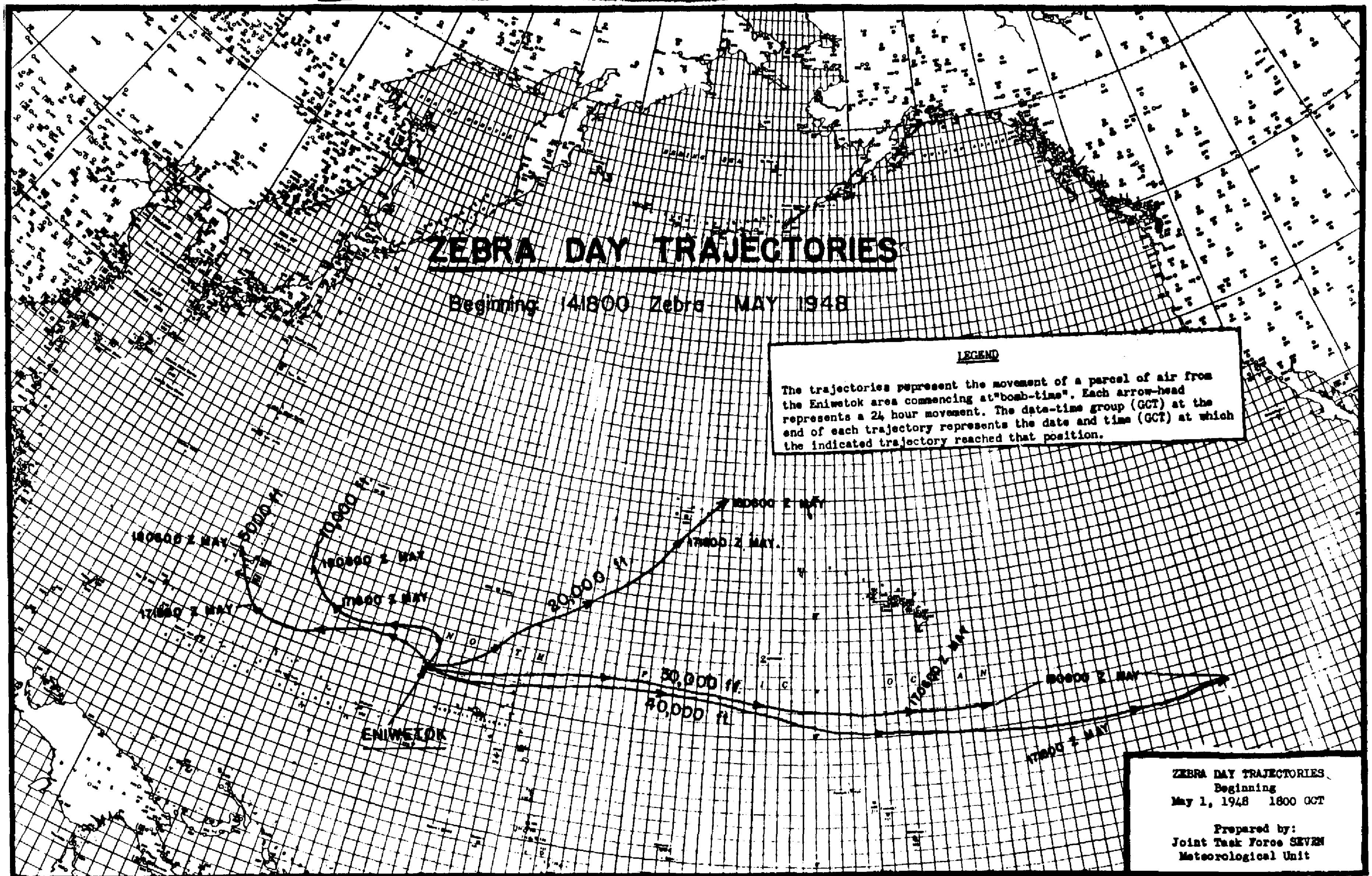
XRAY DAY— The upper winds over the Eniwetok area near bomb time on XRAY Day indicate that air parcels representing the cloud at the 5,000 and 10,000 foot elevations moved off at an approximate speed of 12 knots toward the west-northwest and northwest, respectively. The constant pressure charts for 850 and 700 millibars subsequent to bomb time show the material continued to move to the west at varying velocities with the 5,000 foot trajectory passing 300 miles north of Guam in about 5 days. This time difference was due to the lighter winds found at 10,000 feet in the area between Eniwetok and Guam. The 20,000 foot trajectory proved to be quite complex due to light and variable winds over the Marshall Islands on XRAY Day. By using the 500 millibar constant pressure chart, an average movement was computed which showed the material at that level started off to the east. However, on the following days, light and variable winds at that altitude persisted; so that the resulting trajectory indicated very little movement from the Eniwetok area for a period of approximately eight days. Due to the light and variable winds over such a long period of time, it was very doubtful as to when the material actually left the area. The 20,000 foot trajectory is, for this reason, of doubtful value. The 30,000 and 40,000 foot trajectories are much more representative. A study of the wind over Eniwetok on XRAY Day showed persistent west-southwest and southwest winds at these levels which caused the cloud materials to move off to the east-northeast and northeast at the velocities of 12 and 25 knots, respectively. Subsequent upper air charts show the material at 30,000 and 40,000 feet gradually shifting so that it headed in a more easterly direction with the 40,000 foot trajectory passing south of Hawaii in two and one-half or three days. The 30,000 foot trajectory passed south of Hawaii in approximately three and one-half to four days.

YOKE DAY- The trajectories for 5,000; 10,000; 30,000; and 40,000 feet followed a pattern similar to those for XRAY Day. A study of the winds aloft over Eniwetok for YOKE Day shows easterly (E to ESE) winds to near 16,000 feet shifting slowly through south to southwest at 30,000 feet and above. As might be expected, the 5,000 and 10,000 foot trajectories moved off to the west and west-northwest. Using the constant pressure charts to extrapolate wind velocities and directions, it was found that the 5,000 and 10,000 foot trajectories continued moving westward, passing south of Guam in approximately four days, and reached the Philippine Islands in approximately seven to eight days. The 20,000 foot trajectory started to the north from Eniwetok and was then caught in a belt of easterly winds. These easterlies caused the material at the level to veer to the west and reach the Guam area in approximately four days also. However, due to the variable wind conditions over Eniwetok on the test day, this trajectory could be considerably in error although there is less doubt about it than the trajectory for the same altitude on XRAY Day. The 30,000 and 40,000 foot trajectories moved off rapidly to the northeast from Eniwetok. The subsequent constant pressure charts for these levels showed the winds shifted slowly back to westerly and caused the trajectories to pass south of the Hawaiian Islands. The 40,000 foot trajectory passed the Hawaiian Islands area in approximately 48 hours while the 30,000 foot trajectory arrived 72 hours after bomb time.

ZEBRA DAY-A study of the upper winds over Eniwetok Atoll on ZEBRA Day shows the winds backing from southeasterly at 5,000 feet to southwesterly at 10,000 feet and then to west-southwesterly at 20,000 feet and above. The 5,000 foot trajectory went to the northwest after leaving Eniwetok and changed slowly to the west and west-southwest on the second and third day. Similarly, the 10,000 foot trajectory which started moving to the northeast changed rapidly to the west after 24 hours and continued on a westerly heading. However, on the third and fourth day following ZEBRA Day, a typhoon in the vicinity of Guam caused the 5,000 and 10,000 foot parcels to increase rapidly in velocity and move to the northwest. The 20,000 foot trajectory was less doubtful on ZEBRA Day than on the previous test days. Fairly strong and consistent winds at Eniwetok, plus a steady wind flow on the 500 millibar constant pressure chart, indicate that the trajectory moved directly towards Midway Island and reached Midway in 72 hours. The 30,000 and 40,000 foot trajectories left the Eniwetok area with moderately strong westerly winds and continued moving to the east. The 30,000 and 40,000 foot trajectories passed south of Hawaii in approximately 3 and 2 days, respectively.


XRAY DAY TRAJECTORIES
Beginning 141830 Zebra APRIL 1948
LEGEND
The trajectories represent the movement of a parcel of air from the Eniwetok area commencing at "bomb time". Each arrow-head represents a 24 hour movement. The date-time group (GCT) at the end of each trajectory represents the date and time (GCT) at which the indicated trajectory reached that position.
10,000 feet
5000 feet
20,000 feet
30,000 feet
40,000 feet
ENIWETOK
N O R T H P A C I F I C O C E A N
241830 Z APRIL
201830 Z APRIL
291830 Z APRIL
191830 Z APRIL
201830 Z APRIL
XRAY DAY TRAJECTORIES
Beginning
April 14, 1948 1830 GCT
Prepared by:
Joint Task Force SEVEN
Meteorological Unit.


YOKE DAY TRAJECTORIES
Beginning: 301830 Zebra APRIL 1948
LEGEND
The trajectories represent the movement of a parcel of air from the Eniwetok area commencing at "bomb time". Each arrow-head represents a 24 hour movement. The date-time group (GCT) at the end of each trajectory represents the date and time (GCT) at which the indicated trajectory reached that position.
061830 Z MAY
041830 Z MAY
061830 Z MAY
081830 Z MAY
071830 Z MAY
20,000 feet
40,000 feet
30,000 feet
10,000 feet
5000 feet
NORTH PACIFIC OCEAN
ENIWETOK
YOKE DAY TRAJECTORIES
Beginning
April 30, 1948 1830 GCT
Prepared by:
Joint Task Force SEVEN
Meteorological Unit


ZEBRA DAY TRAJECTORIES
Beginning 141800 Zebra MAY 1948
LEGEND
The trajectories represent the movement of a parcel of air from the Eniwetok area commencing at "bomb-time". Each arrow-head represents a 24 hour movement. The date-time group (GCT) at the end of each trajectory represents the date and time (GCT) at which the indicated trajectory reached that position.
ENIWETOK
5000 ft
10000 ft
20,000 ft
30,000 ft
40,000 ft
160600 Z MAY
171800 Z MAY
180600 Z MAY
171800 Z MAY
180600 Z MAY
171800 Z MAY
160600 Z MAY
171800 Z MAY
180600 Z MAY
171800 Z MAY
ZEBRA DAY TRAJECTORIES
Beginning
May 1, 1948 1800 GCT
Prepared by:
Joint Task Force SEVEN
Meteorological Unit

Sketches of the Atomic Clouds

As explained previously, it was not possible to make photographs during the time that the clouds were in the mushroom stage. For about the first ten seconds the clouds were in the fireball stage and were lighted from within by incandescent gases; but after these gases cooled, there was no light for photographic purposes until after sunrise. The blue-violet luminescence did not photograph or provide light so that photographs of the clouds could be obtained. However, the blue-violet glow did illuminate the clouds so that they were easy to see until they rose high enough to catch the first of the morning twilight. By the time the luminescence had faded, the upper parts of the clouds were high enough to catch sufficient light to show their details clearly.

Throughout the time that the clouds were visible, they were being rapidly sketched for the purpose of correlating theodolite data. These rough sketches are the only records of the shapes of the clouds during the time that it was impossible to make photographs. Therefore, since photographs of the mushroom stage are non-existent, it was decided to make the fullest use possible of the sketches in order to describe the complete histories of the clouds.

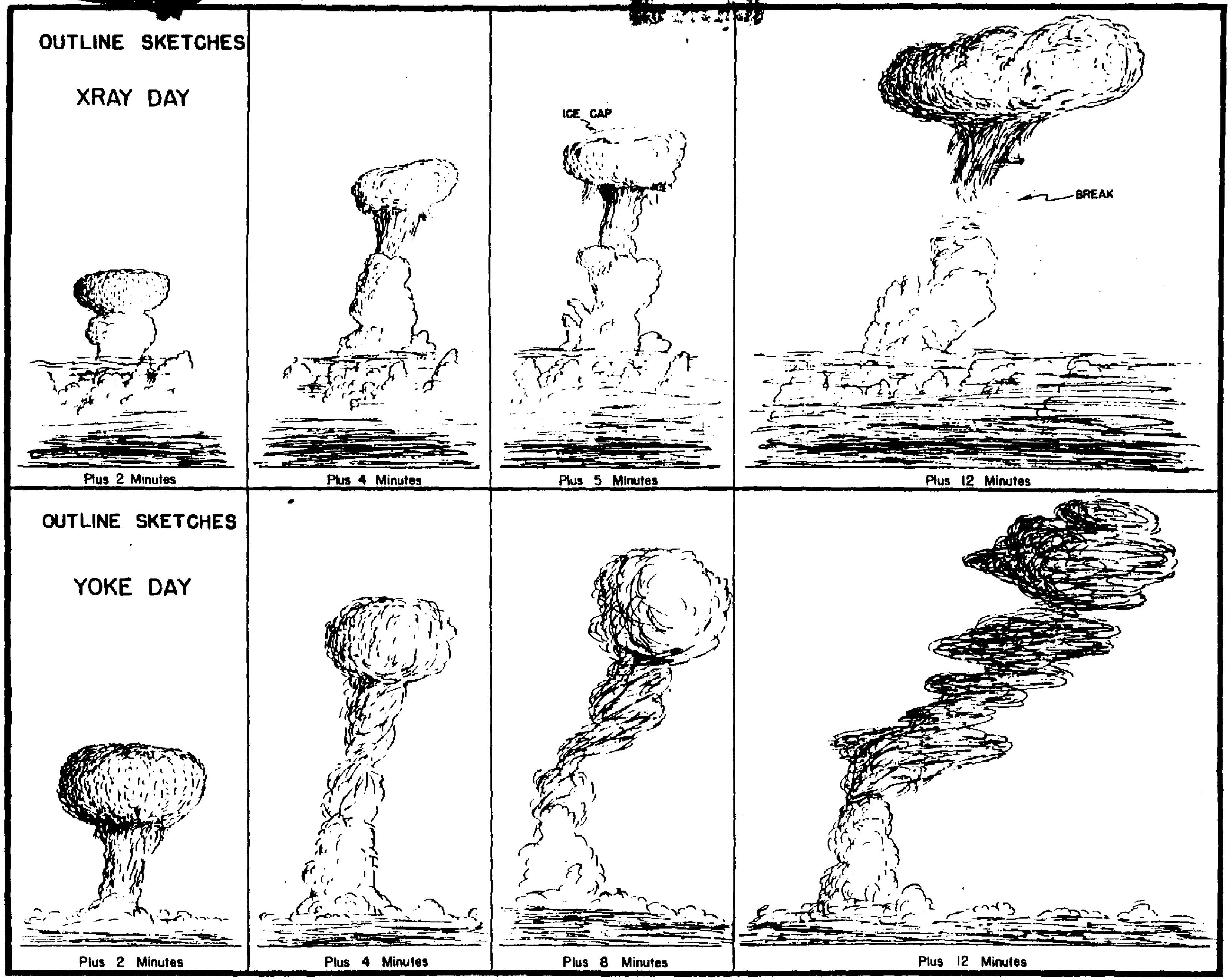
Most of the sketches were very crude since most of them were completed in less than one minute, and some of the sketches were affected by the preconceived ideas and imaginations of the observers; but by comparing three or more separate sets of sketches reasonably good pictures of the clouds were obtained.

XRAY DAY-As may be noted in the sketch, there was considerable natural cloudiness at H-hour. The tops of the cumulus averaged 8,000 feet and a few reached 10,000 or 12,000 feet. There were also fracto-cumulus, and thin stratus around the tops of the cumulus. Passing rain showers had occurred in the vicinity of the test site. The natural clouds, together with darkness obscured the atomic cloud at altitudes below 10,000 feet. The XRAY Day cloud had the most pronounced internal circulation characteristics of any of the mushroom clouds. In fact, the cloud very much resembled the ABLE Day cloud at Bikini. The sketches show several short cloud streamers, or spurs, projecting out of the bottom of the cloud as was seen at Bikini; and some of the observers recorded an ice cap, or a smooth veil of cirrus draped over the mushroom at about H-hour plus five minutes. As the cloud rose, the stalk or stem elongated and became smaller in diameter; and at nine minutes and thirty seconds past H-hour, the break which is shown between upper and lower cloud masses occurred. This separation occurred at about 20,000 feet. Just below this break, which occurred in a region of wind shear, the stem of the cloud dispersed and left an irregular patch of smoke and dust. The lowest part of the cloud, which greatly resembled the other large cumulus nearby, remained visible until H-hour plus twenty minutes and then became lost among the other clouds.

YOKE DAY- The quantity of gaseous constituents in the fireball appeared to be noticeably greater on YOKE Day than on XRAY Day. At first, the cloud began to take the characteristic mushroom shape; but for some reason, perhaps its size, the cloud was not able to form completely the ring shape circulation seen in previous clouds. The primary portion rose as a gigantic bubble of gas without a well defined internal circulation. By the time the cloud reached maximum altitude, there appeared to be a diminution in volume of the gas bubble because of the large quantity of material left behind in large irregular masses. This cloud seemed to contain little condensed water vapor. Instead, it seemed to consist almost entirely of dust and smoke. At H-hour plus sixteen minutes, the lowest part of the cloud resembled a swelling cumulus cloud reaching to 9,000 or 10,000 feet. This cloud moved away in the easterly winds at low elevations so that there is no record of it after this time.

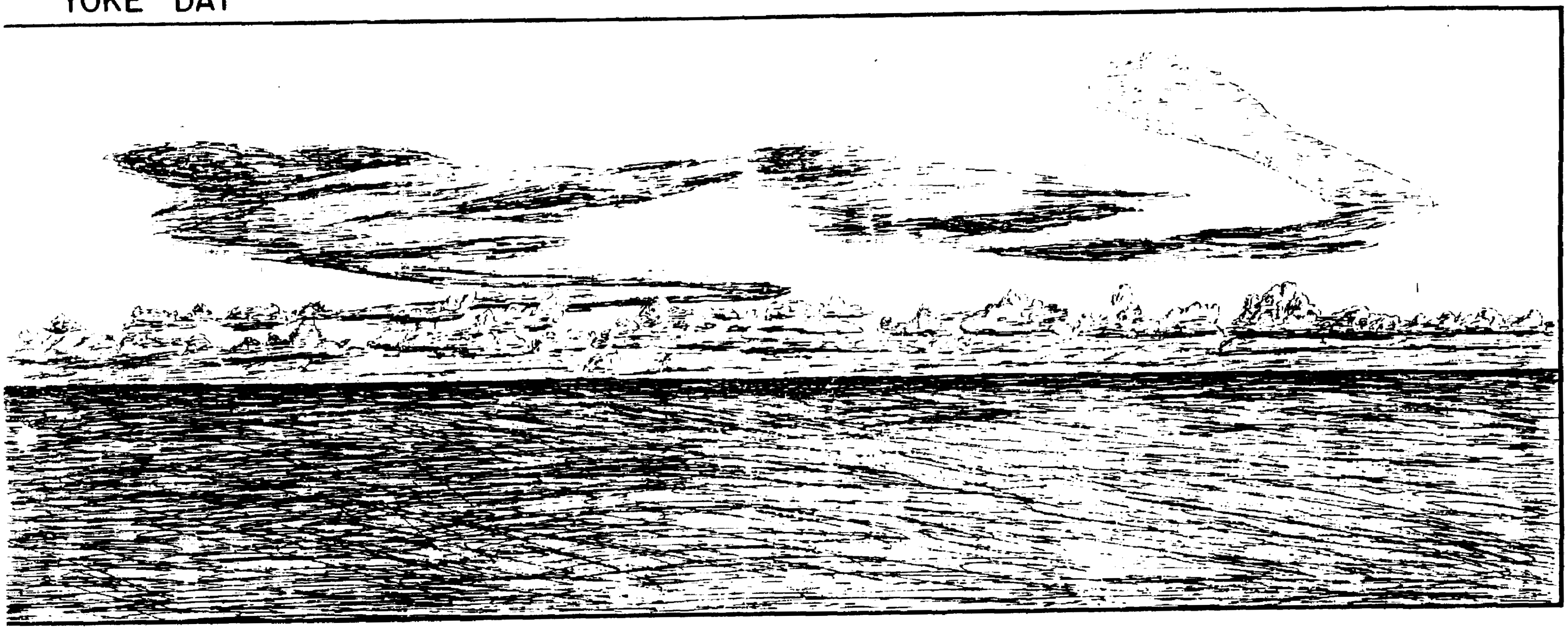
On page 50 is shown a sketch of the YOKE Day cloud at H-hour plus one hour. This sketch has been drawn from a colored photograph which shows the same view as the black-and-white photograph on page 69. Unfortunately, the black-and-white photograph did not print very well, and it is not possible to reproduce colored photographs in this report. Therefore, this sketch is the best available means of showing the shape of the cloud.

ZEBRA DAY-This cloud had the familiar mushroom form, but the cloud did not have a well defined circulation after the second minute. From the third to after the eighth minute, there was little change in the general shape of the cloud; but by the ninth minute, the finger-like projection which rose out of the top of the cloud could be plainly seen. This projection rose an additional 5,000 feet above the top of the atomic cloud and reached maximum elevation at about plus 12 minutes. At about the fifteenth minute, the finger-like part of the cloud broke away, but it never did get far from the main body of the cloud. At about the tenth or eleventh minute, the top and bottom of the cloud had shifted so that the top was east of the broad stem, and observers on the U.S.S. Bairoko were able to look up into the base of what had been the rising mushroom head. These observers stated that the cloud, viewed from the bottom, had a hollow appearance and looked somewhat like a smoke-ring. There was more cloud material in the edges of the cloud than in its center. This cloud also had a cumulus-like formation in its lowest portion. This cumulo-form cloud grew until it reached about 8,000 feet and then disappeared as it moved off to the west.

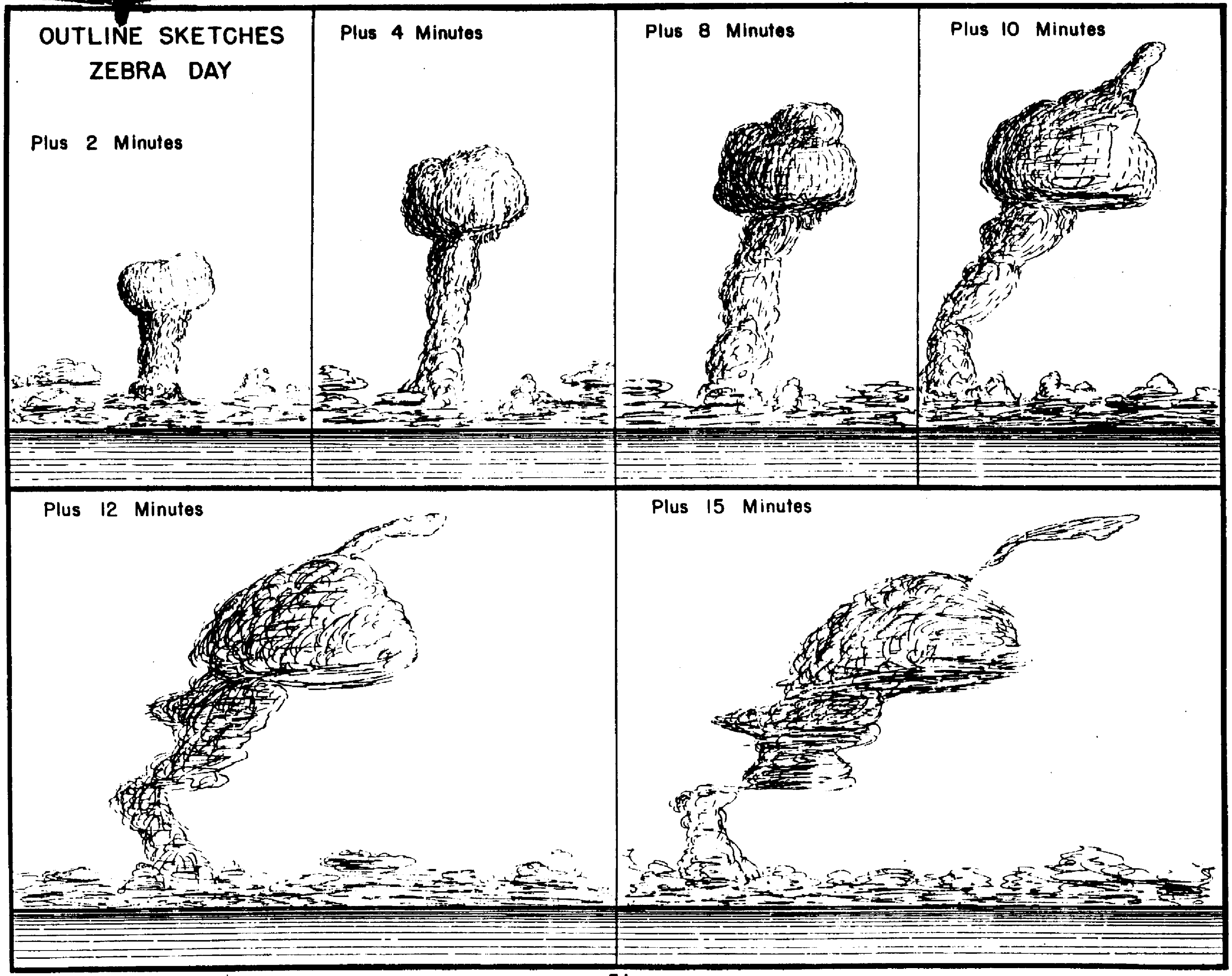

OUTLINE SKETCHES
XRAY DAY
ICE CAP
BREAK
Plus 2 Minutes
Plus 4 Minutes
Plus 5 Minutes
Plus 12 Minutes
OUTLINE SKETCHES
YOKE DAY
Plus 2 Minutes
Plus 4 Minutes
Plus 8 Minutes
Plus 12 Minutes

1-[redacted]

YOKE DAY



H – Hour Plus 1 Hour


OUTLINE SKETCHES
ZEBRA DAY
Plus 2 Minutes
Plus 4 Minutes
Plus 8 Minutes
Plus 10 Minutes
Plus 12 Minutes
Plus 15 Minutes

PHOTOGRAPHS OF THE ATOMIC CLOUDS

Explanation of Photographs

Although many feet of film were used during Operation SANDSTONE to photograph the atomic clouds, very few pictures suitable for a scientific report on the clouds resulted. Since H-hour was before daylight, and because the atomic clouds had become somewhat diffused by the time sufficient light became available, most photographs of the weapon phenomena show only the hemispherical condensation clouds or the fireballs. Most of the film used for the clouds was so completely underexposed that it printed completely black. The results from the XRAY Day cloud were very disappointing to photographers who had hoped to obtain pictures of the spectacular mushroom. Fewer pictures of the YOKE Day cloud were attempted, and almost none were made of the ZEBRA Day cloud. When sunlight for photographs was available, the clouds were being dispersed; and the photographers did not make many pictures of cloud shapes which to them did not seem sufficiently well defined to be of interest. After two or three hours the clouds had many characteristics of natural clouds, so that to an uninformed observer, they did not appear to be particularly significant.

Another feature of the atomic clouds which was discouraging to photographic personnel was that as the clouds dispersed, the cloud material extended over such a large area that it was impossible to frame all of a particular cloud in a single photograph. No camera had a wide-angle lens suitable for such a large coverage, and there was no attempt to adapt a camera for series of panoramic views. In assembling pictures for this report, two photographs have been joined side by side if they give a more complete representation of a cloud even though the two photographs may have been made at slightly different times.

It has not been feasible to make measurements of the clouds directly from the photographs. This is primarily because the distances to the clouds are not sufficiently well determined. It is much easier to make measurements from the theodolite data and the sketches than to use the photographs.

Such data as are available from the calculations on the preceding pages have been added to the photographs. The shape of the top of the XRAY Day cloud was such that the diagram titled Apparent Dispersion of Atomic Cloud on page 35 could be used to obtain a rough idea of its diameter, but the shape of the YOKE Day cloud was such that this type of dispersion analysis was not applicable. No pictures of the ZEBRA Day cloud are available until about H-hour plus 45 minutes, 15 minutes after the time that it became necessary to end the apparent dispersion analysis because of the poor quality of the azimuth angle data. There is no way of adding dimensions to the primary mass to the photographs of the ZEBRA Day cloud except by means of the upper wind vectors, and this does not seem to be worthwhile since the effects of the wind structure on the shape of the cloud are shown on page 42. However, the lengths and widths of the XRAY and YOKE Day clouds have been entered on photographs made one hour past H-hour. These data have been determined from the estimated winds and the diagrams titled Dimensions of Atomic Clouds at End of Three Hours. Where altitude data are given, 5,000 foot intervals are used in most cases because the wind data selected for determining the shapes of the clouds were for 5,000 foot elevations only.

A better understanding of the shapes and sizes of all of the atomic clouds is obtainable by using the photographs in conjunction with the diagrams titled Dimensions of Atomic Clouds at End of Three Hours, beginning on page 39.

The quality of the majority of the cloud photographs included here is poor. Very few of the pictures have contrasts suitable for half-tone reproduction, and many of the details which were evident in the original photographs were lost in printing.

A few colored photographs of different views of each of the atomic clouds exist, but the type of printing facilities available prevented the use of color in this report. However, the colors of the clouds will be described as the photographs of each test are discussed below.

XRAY DAY—Except for not showing the colors of the cloud, these photographs give a reasonably good portrayal of the cloud up to H-hour plus three hours. With this cloud as well as the other two clouds, the coloration was largely determined by the amount of sunlight available. After the blue-violet of the luminescence faded, about three or four minutes after H-hour, the cloud appeared to be a dull white, while the natural cumulus appeared a dirty grey. At about H-hour plus ten minutes, the upper part of the XRAY Day cloud appeared white and the lower portion had a dirty, smoky color. Then at H-hour plus twenty minutes until H-hour plus thirty minutes, the upper portion of the cloud took on the vivid colors of the sunrise. The east side of the mushroom became a brilliant reddish-orange, while the remainder of the cloud remained a dull white. As the sun rose higher, this coloration spread over the cloud and became less brilliant. The cirrus-type plume always appeared much whiter than the primary cloud, and showed up vividly against the background of dark blue sky. In direct sunlight, the globular mass had a cream colored appearance when contrasted to the intense white of the cirrus plume or to natural cirrus. Even when the top had spread until it greatly resembled natural cirrocumulus, the slight coloration was noticeable. The lower portion of the XRAY Day cloud, which appeared to consist of smoke and dust, had a distinct reddish-brown color that persisted as long as it could be seen.

YOKE DAY—Although photographs of this cloud from the surface were not possible until about H-hour plus 35 minutes, cameras in aircraft, where the cloud was silhouetted against the light in the eastern sky, gave usable pictures as early as H-hour plus 15 minutes.

The photograph of this cloud on page 68 does not show the shape of the cloud as well as would be desired, but a color photograph made at the same time shows the details clearly. The color photograph has been used to make a sketch of this cloud. This sketch is presented on page 50.

At about fifteen minutes just after H-hour, the rising sun colored this cloud a dark reddish-orange. After that time, the orange faded into a dirty-yellow and then into a yellowish cream color. The color of the stem of the cloud was the reddish-brown color of the smoke and dust of which it consisted. At about H-hour plus one hour, the time that the photograph on page 68 was made, the stem appeared reddish-brown even in direct sunlight. The top portion of the cloud, between 35,000 and 55,000 feet, appeared as a broad band of cirrocumulus, and was almost white.

ZEBRA DAY—As far as is known, there are no original black and white photographs of the ZEBRA Day cloud. The pictures on pages 69 and 70 have been reproduced from colored prints.

When the sun shown on the ZEBRA Day cloud, the entire cloud was the same reddish-brown that had been seen in the stems of the previous atomic clouds. There seemed to be little or no moisture to give whiteness to any part of this cloud.

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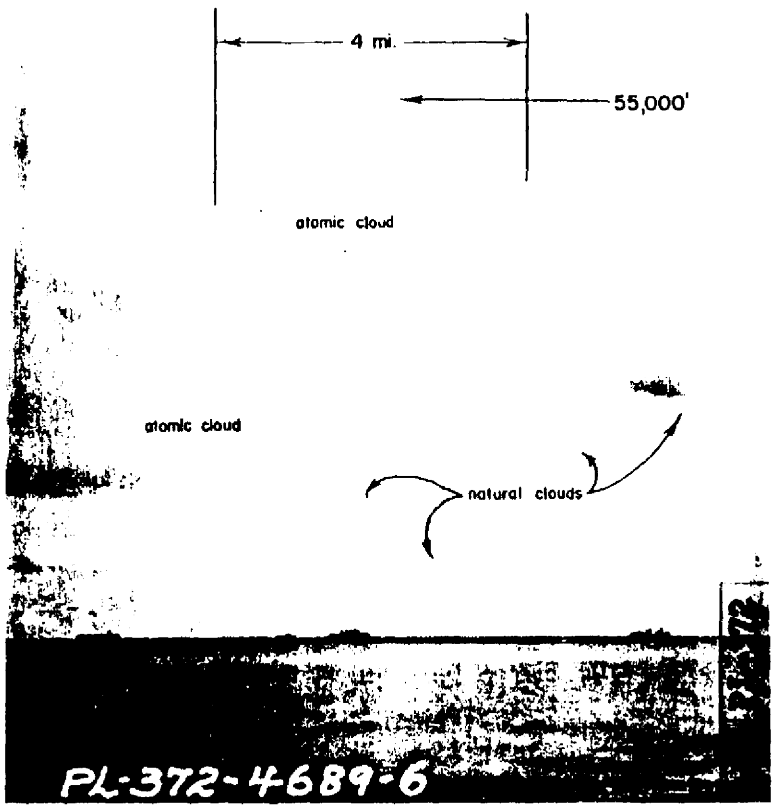
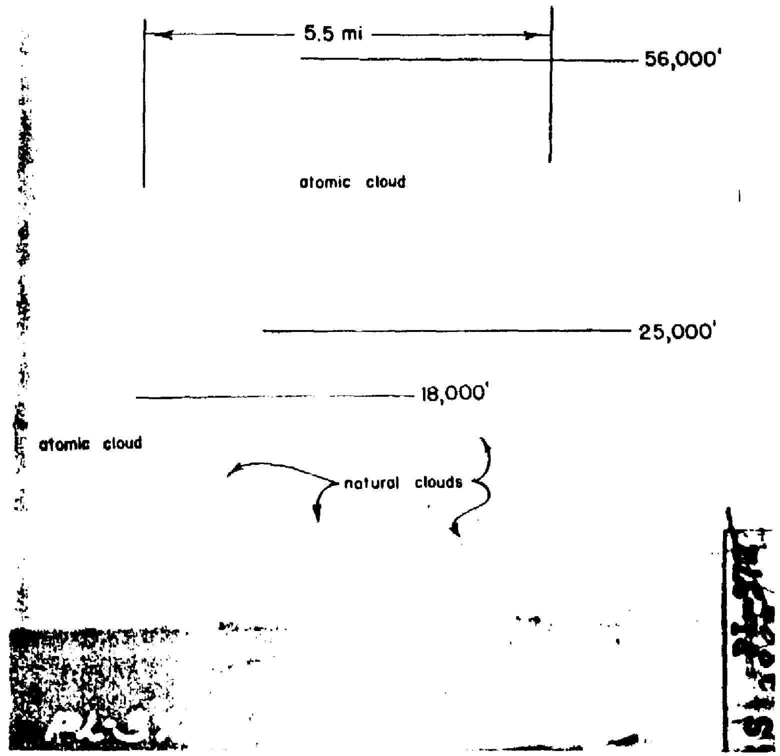
XRAY DAY



Earliest Picture of the Atomic Cloud. Note how the primary portion resembles a swelling cumulus. Natural clouds partially obscure the atomic cloud.

H-hr. plus 11 min.



Separation between primary portion and lower portion may be clearly seen in this photograph. For both pictures the camera was located at Eniwetok.

H-hr. plus 12 min.

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XRAY DAY

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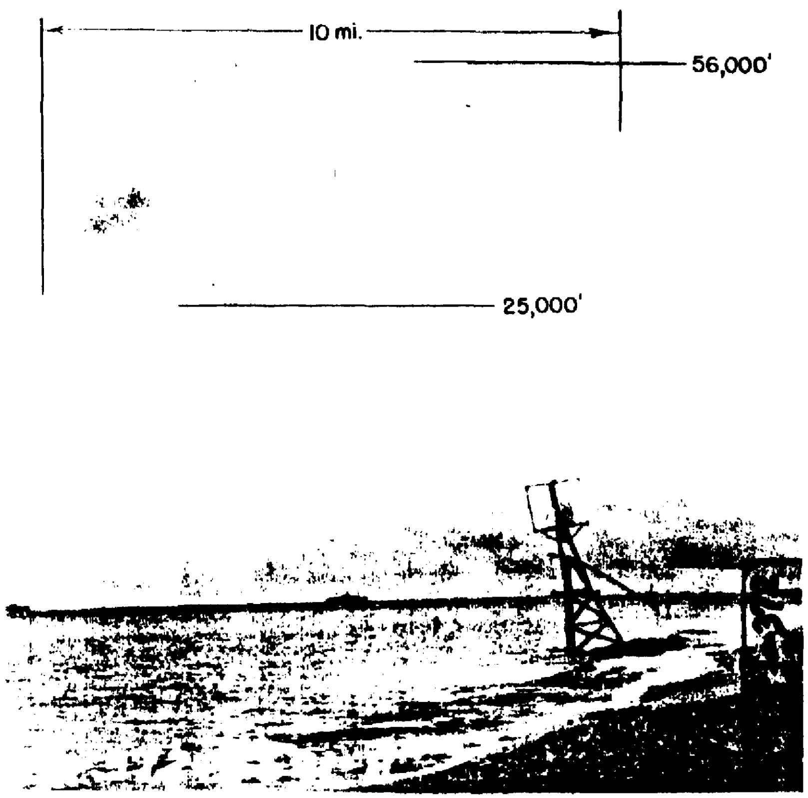
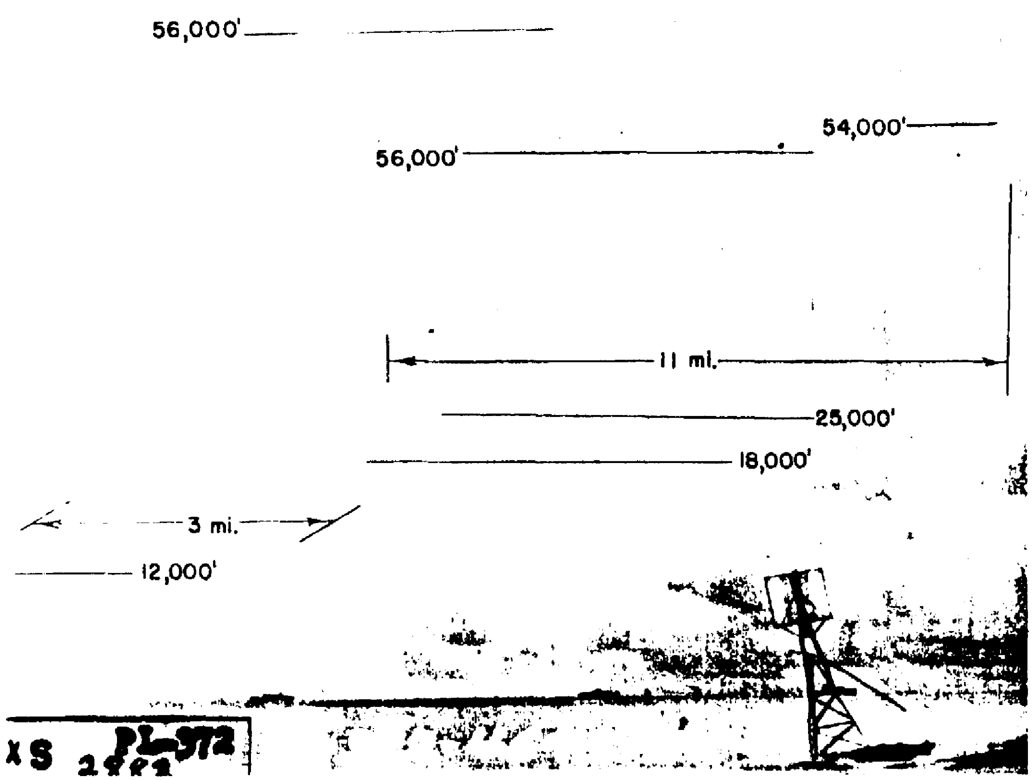


Primary Portion Very Faint Evidence of [illegible] cloud. [illegible] at Eniwetok is shown in both photographs.



Primary Portion, with Plume, and lower Portion. The four large ships are, from left to right, the Bairoko, the Albemarle, the Mt.McKinley, and the Curtiss

H-hr. plus 30 min.

H-hr. plus 33 min.

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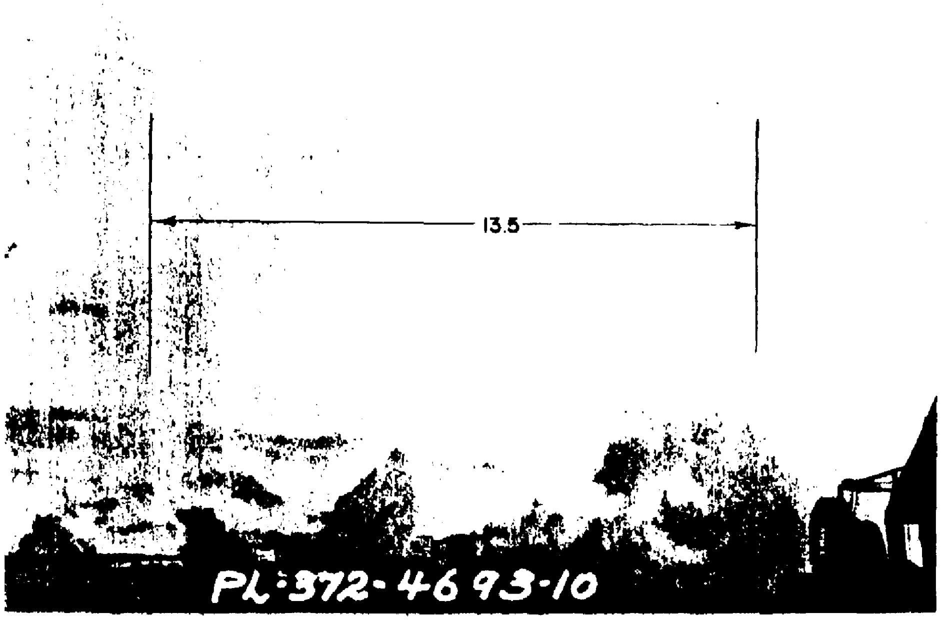

Primary Portion with Plume. The plume is extending out toward the observer and not upward as it appears. The view is from Eniwetok.

H-hr. plus 40 min.

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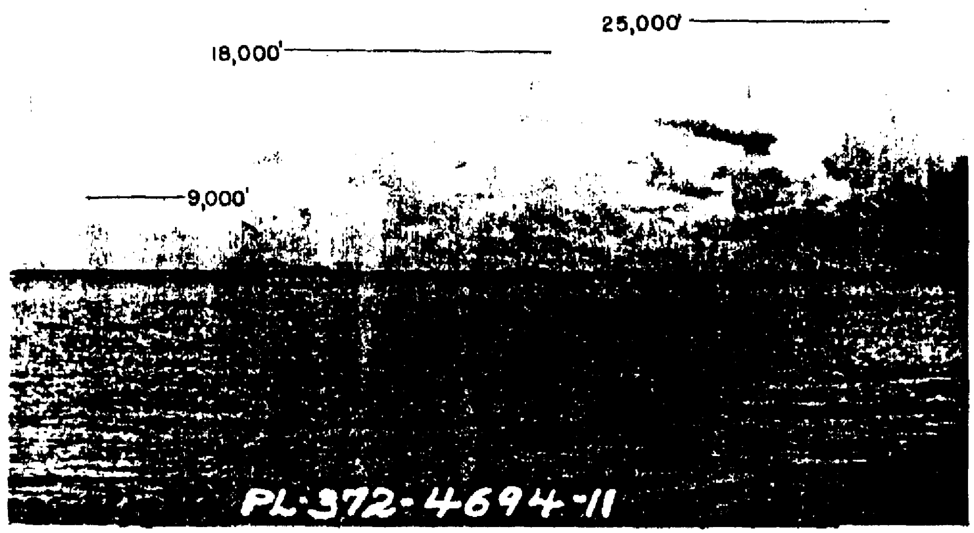
XRAY DAY



Lower Portion of Atomic Cloud. The base of the primary portion is shown in the upper right. The photograph was made from the beach at Eniwetok.

H-hr. plus 40 min.

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XRAY DAY

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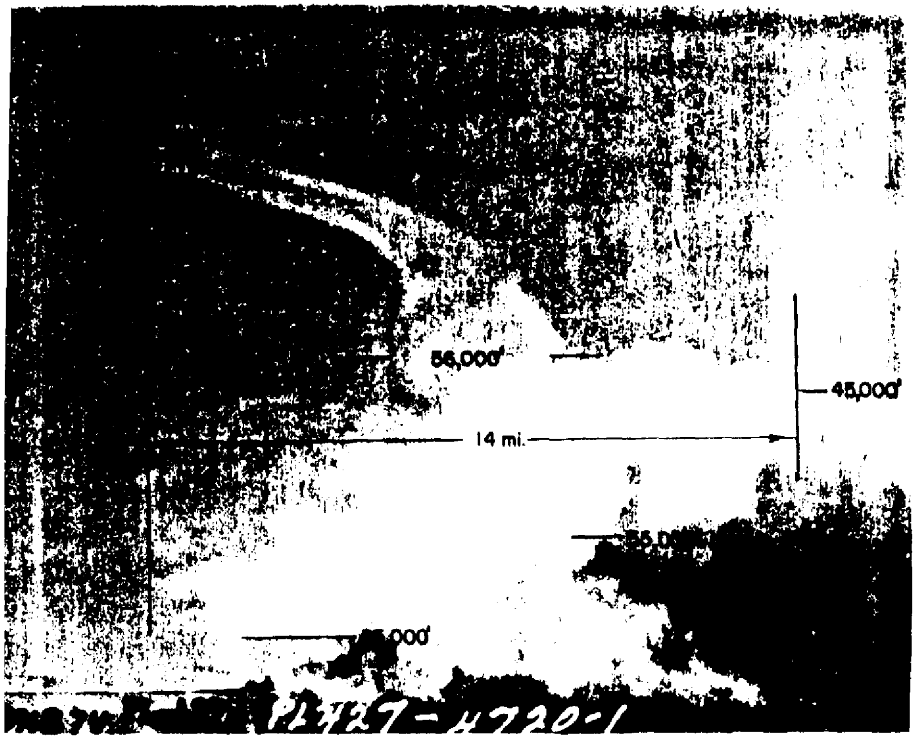

Primary Portion with Plume. Natural clouds in foreground. Note cirrocumulus-like appearance of the plume. The view is from Eniwetok.

H-hr. plus 42 min.

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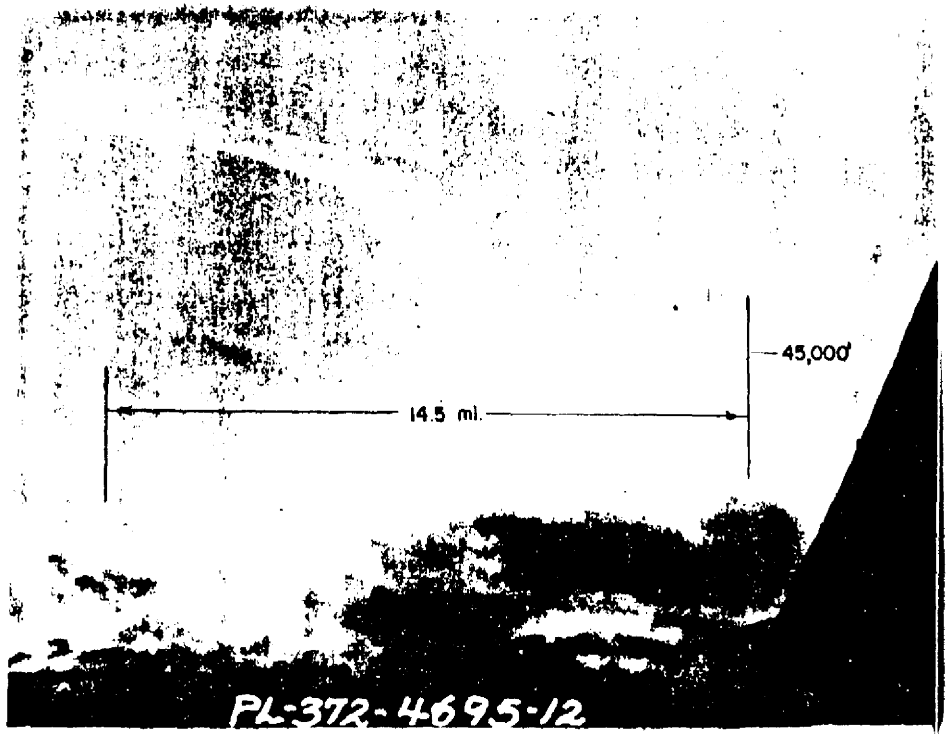
[redacted] SECRET



Primary Portion with Plume. The plume is believed to have extended along the base of the stratosphere in a zone of wind shear. Photographed from Eniwetok.

H-hr. plus 43 min.

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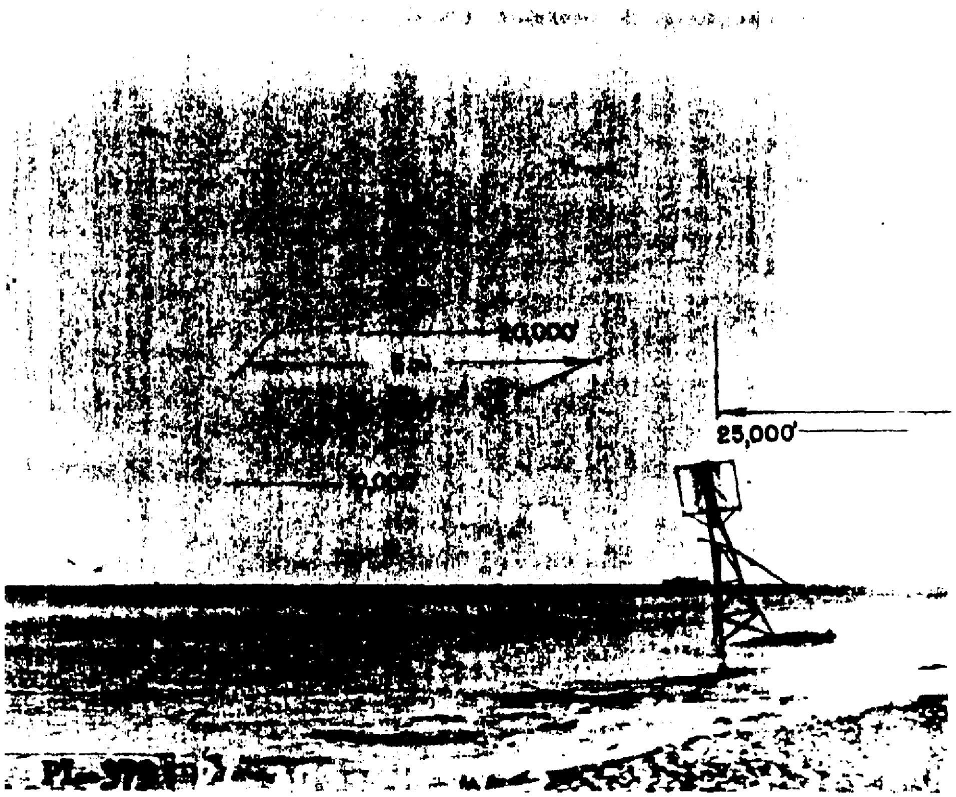
XRAY DAY



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AT[redacted]946

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AT[redacted]46

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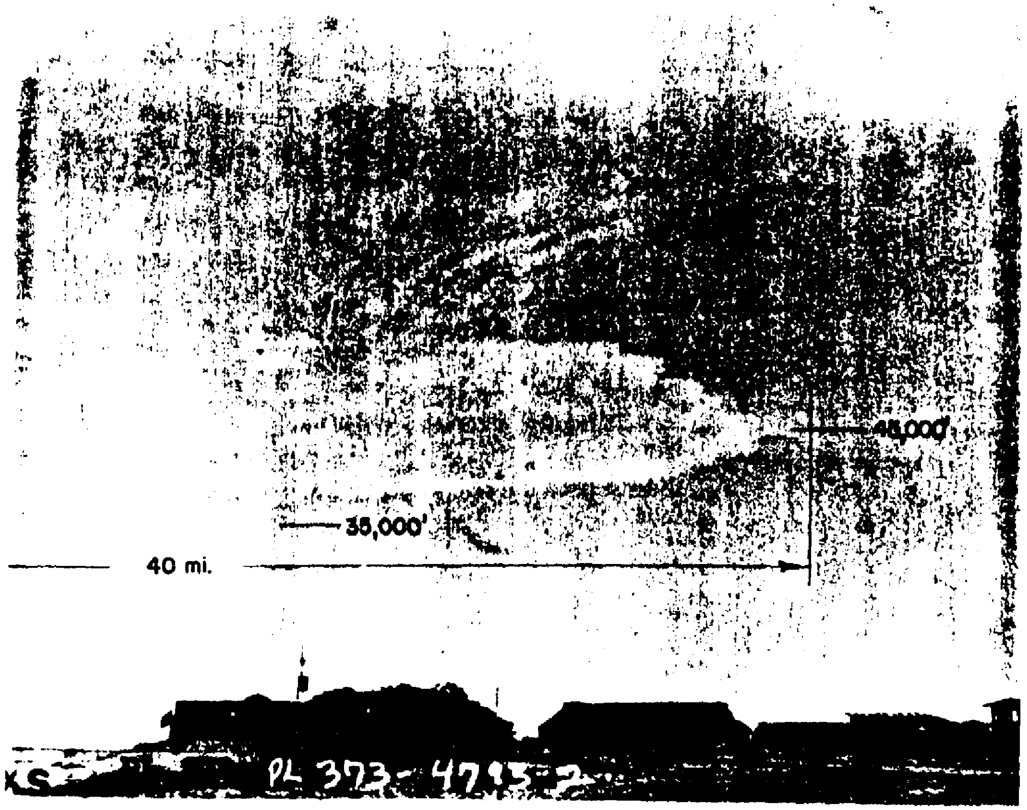

Complete Atomic Cloud. Two photographs made at slightly different times have been placed together to show overall structure of the cloud. It may be seen that even after there was sufficient sunlight the lower portion of the atomic cloud had a smoky appearance in contrast to the whiteness of the upper part. Note that the plume has become very fibrous and seems to sweep around to the right whereas about an hour before it appeared to have swept around to the left. The beach at Eniwetok is in the foreground.

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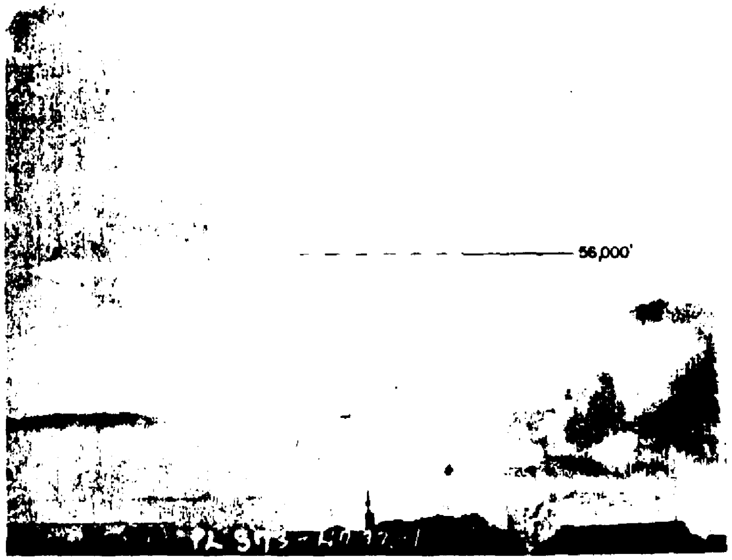
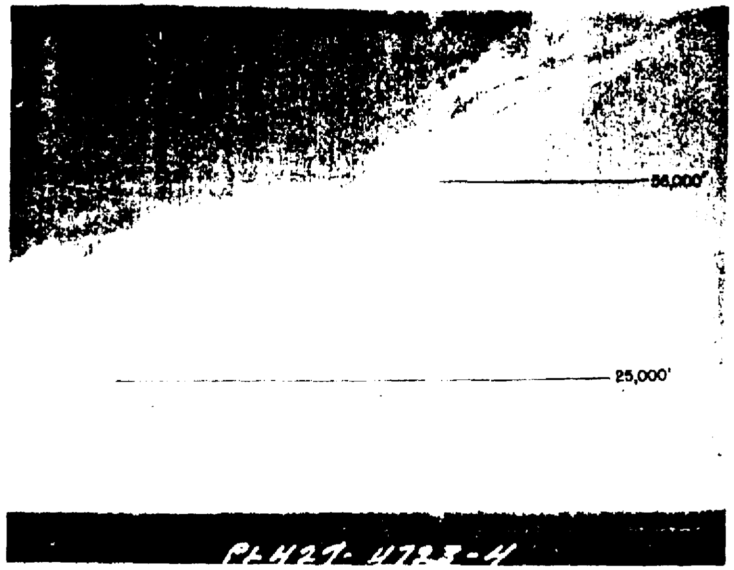
H-hr. plus 1 hr. and 45 min.



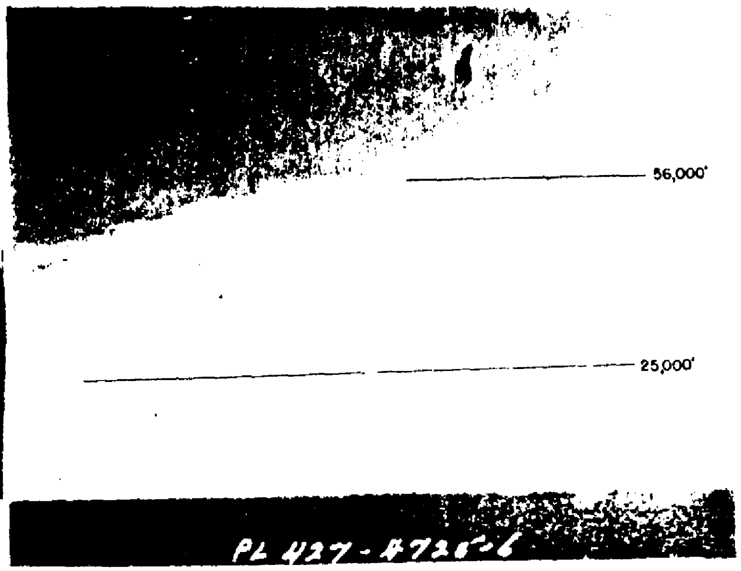
Primary portion with plume. Natural clouds are in foreground.

H-hr. plus 2 hrs.



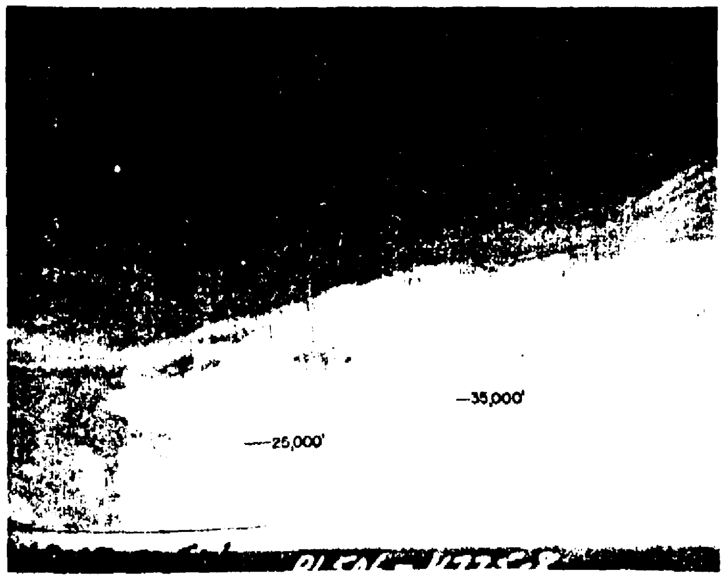
From Mt. McKinley

H-hr. plus 2 hrs. 10 min.

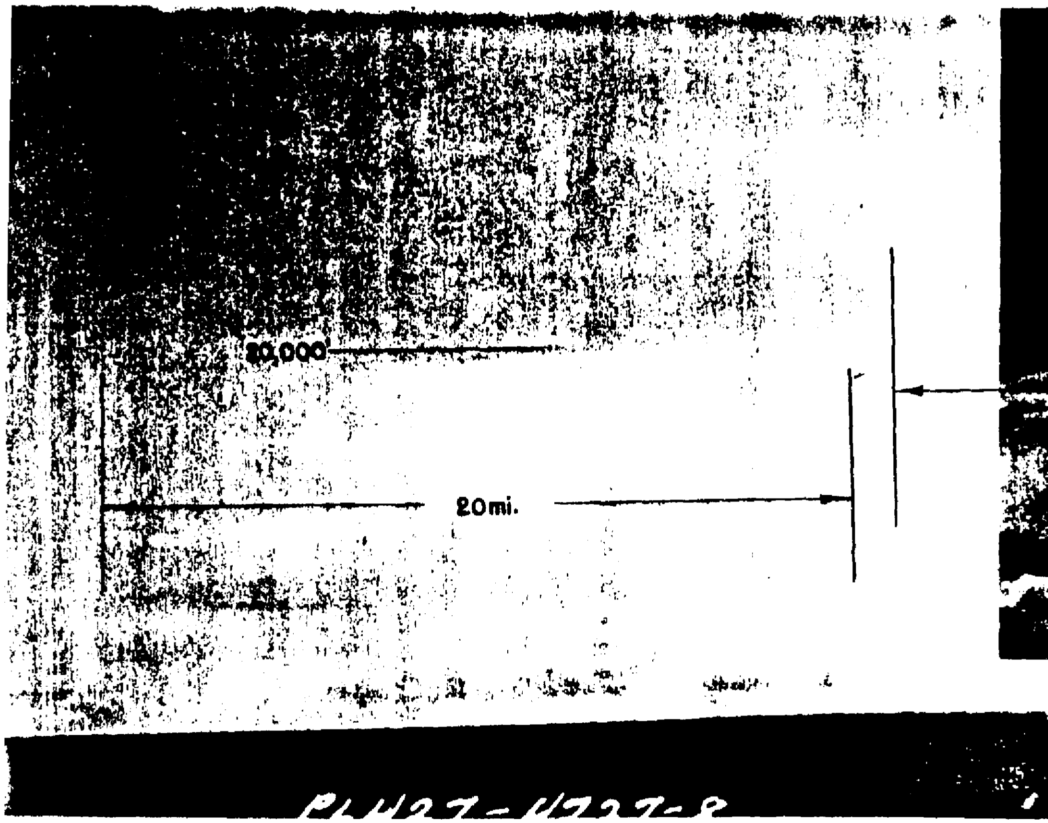


Primary portion with plume. Note how plume continues to be pulled out by the winds.
The photograph was made from the Lt. McKinley.

H-hr. plus 2 hrs. 20 min.



H-hr. plus 2 hrs. 25 min.



Complete Atomic Cloud. Note how the lower portion begins to take on a cirrus-like appearance. Also note how the upper part is separating on the left hand side. Compare this photograph with the diagrams on page 39 which show the dimensions of the cloud at the end of three hours. The pictures were made at slightly different times, but they have been mounted together in order to give a better portrayal of the over-all shape of the cloud.

H-hr. plus 2 hrs. 30 min.

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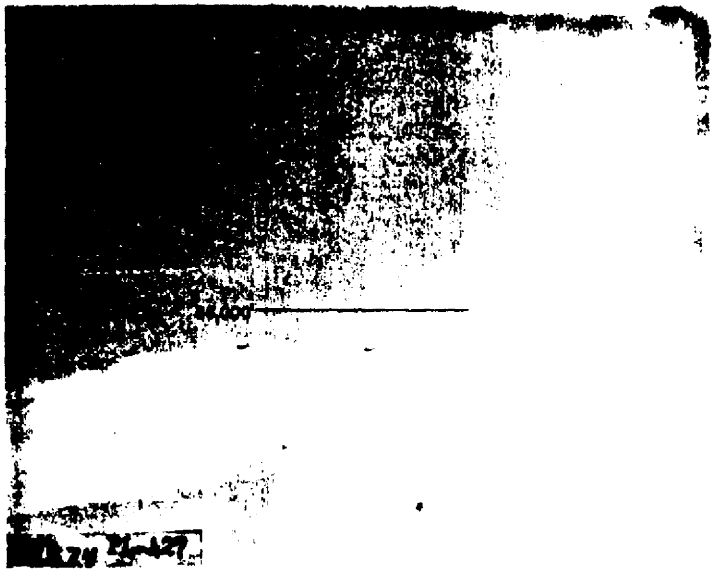
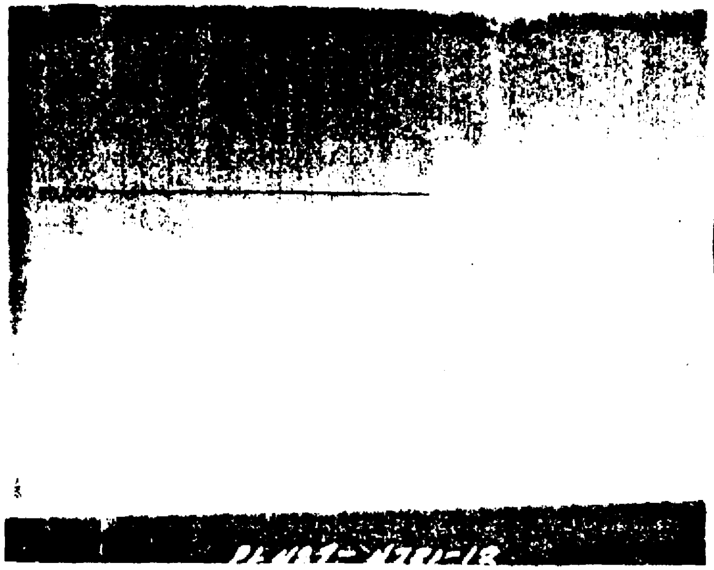
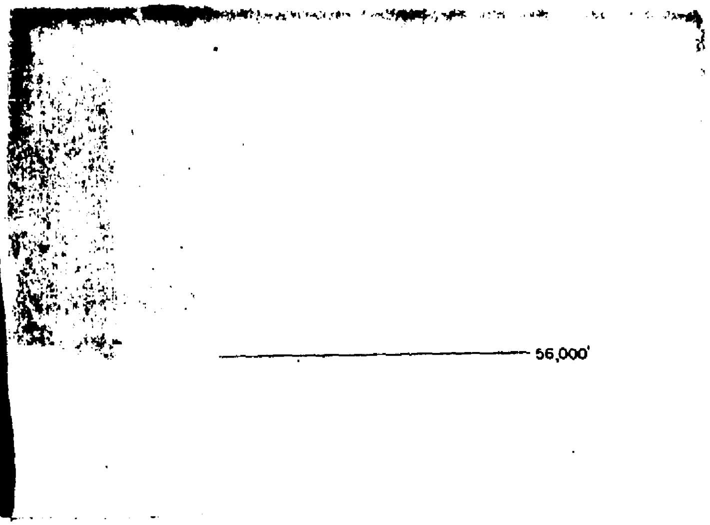


H-hr. plus 2 hrs. 40 min.



H-hr. plus 2 hrs. 40 min.



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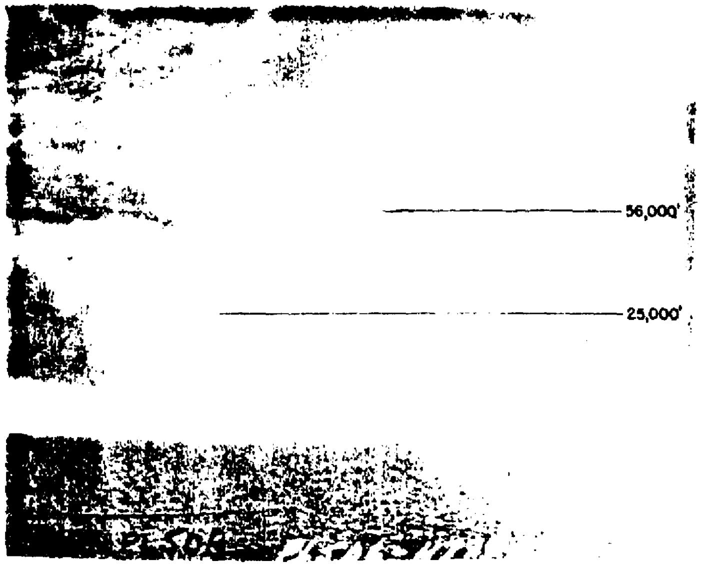
H-hr. plus 2 hrs. 45 min.



H-hr. plus 3 hrs.

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XRAY DAY

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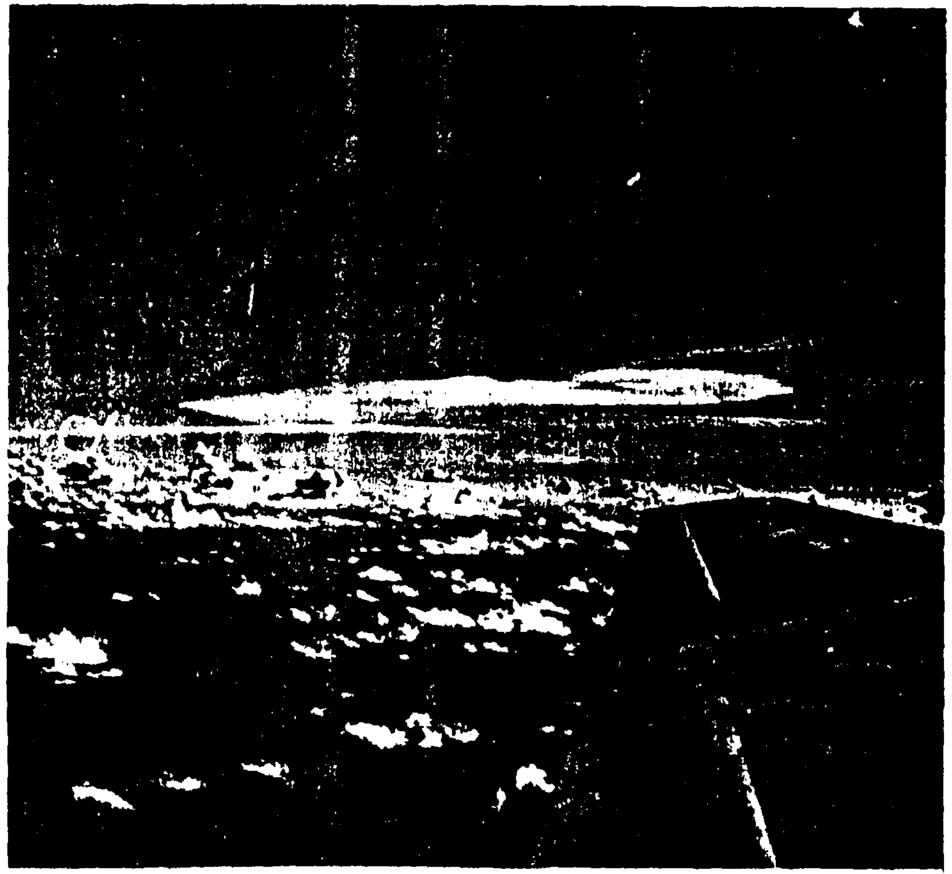
Lower Portion of the Atomic Cloud. This picture was first thought to be the left side of the upper part of the atomic cloud, but close examination showed that the area in the large black circle was the same as the area in the small white circle in the picture on the right hand side of this page. The cirrus-like nature of even the relatively low part of the atomic cloud indirectly shows that the upper part of the cloud did go to stratospheric altitudes, and that the 55,000 foot calculation for the top is not unreasonable. There is some natural cirrus clouds along the horizon. The aircraft from which the photograph is made is over the Eniwetok Lagoon and the island partially covered by clouds is Engebi.

H-hr. plus 2 hrs. 45 min.



A distant view of the Atomic Cloud. The aircraft is flying somewhere to the southeast of Eniwetok. This photograph should be compared with the diagrams on page 39 which show the shape of the cloud at the end of three hours. Note the natural cloudiness. The type of weather which prevailed over Eniwetok Atoll on XRAY DAY can be clearly seen.

H-hr. plus 3 hrs.

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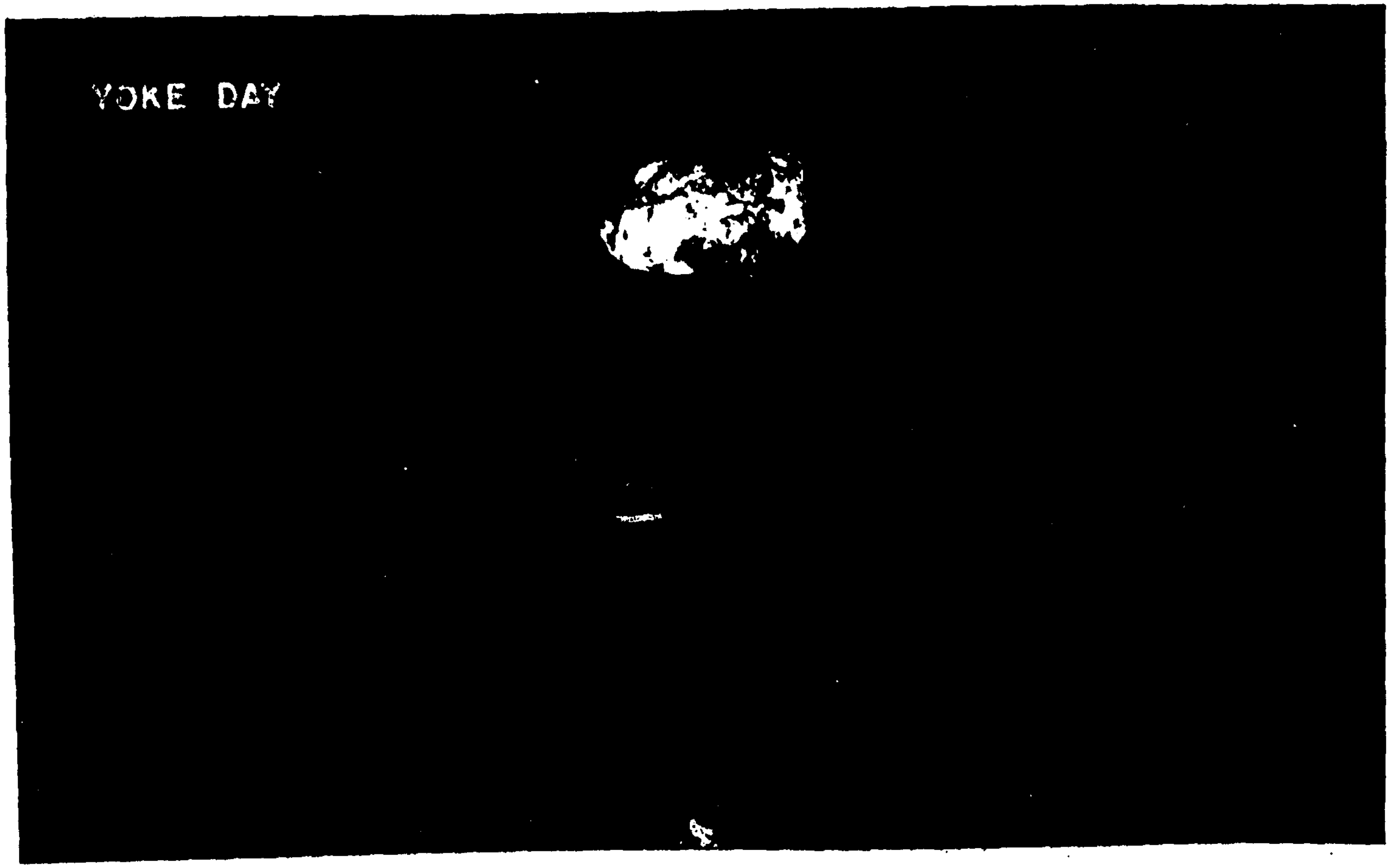


H-hr. plus 10 seconds

[redacted]

YOKE DAY

[redacted]

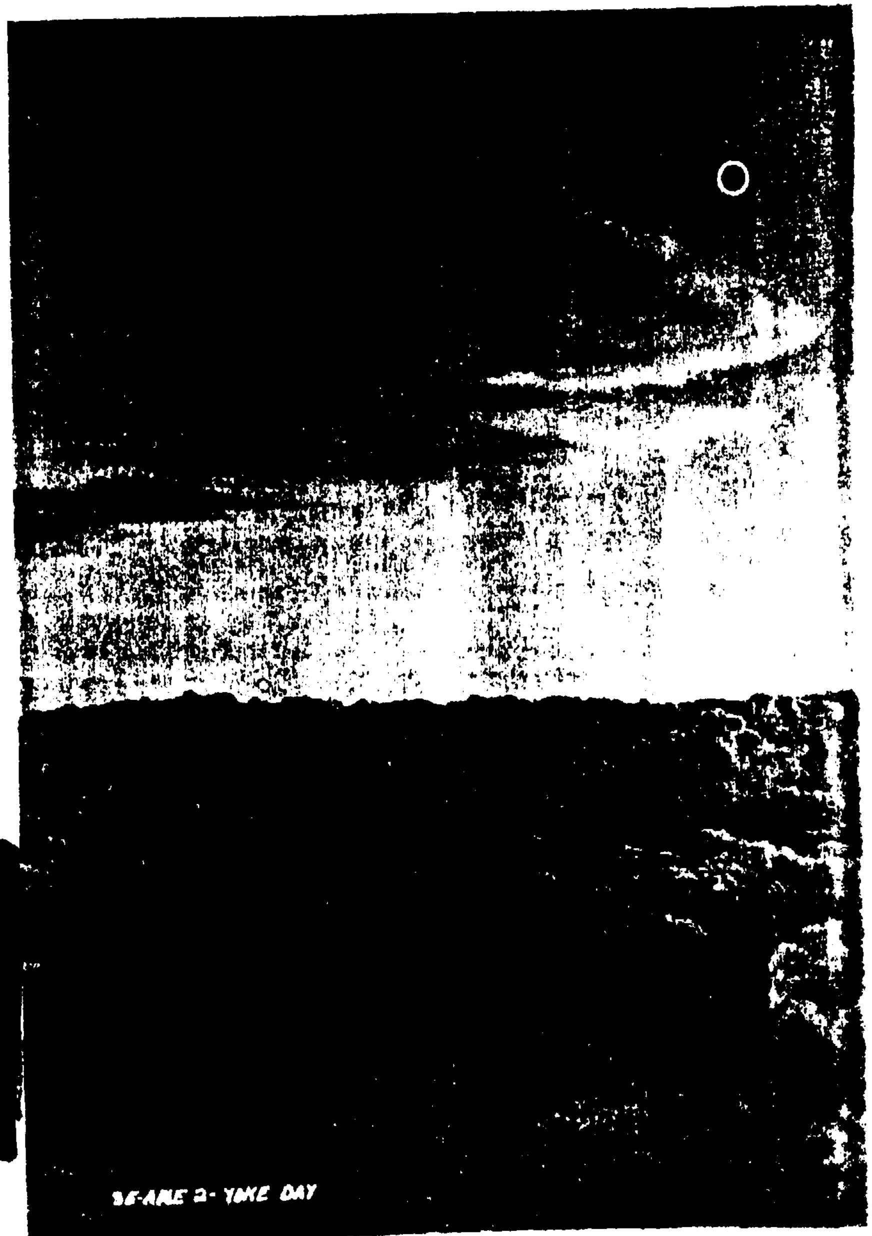
First Pictures of the Atomic Cloud. It is fortunate that the atomic cloud was silhouetted against the light of dawn and that these remarkable pictures were obtained. Note that the cumulus-like cloud which formed at the base of the atomic cloud can be seen at the extreme left.

First Pictures of the Atomic Cloud. Note the dusty, smoky appearance of the atomic cloud. The diameter of the upper part is roughly six miles. In this photograph the anvil-like top of this cloud may be seen. The spreading out of this anvil is thought to have indicated the arrival of the top of the atomic cloud at the stratospheric inversion.

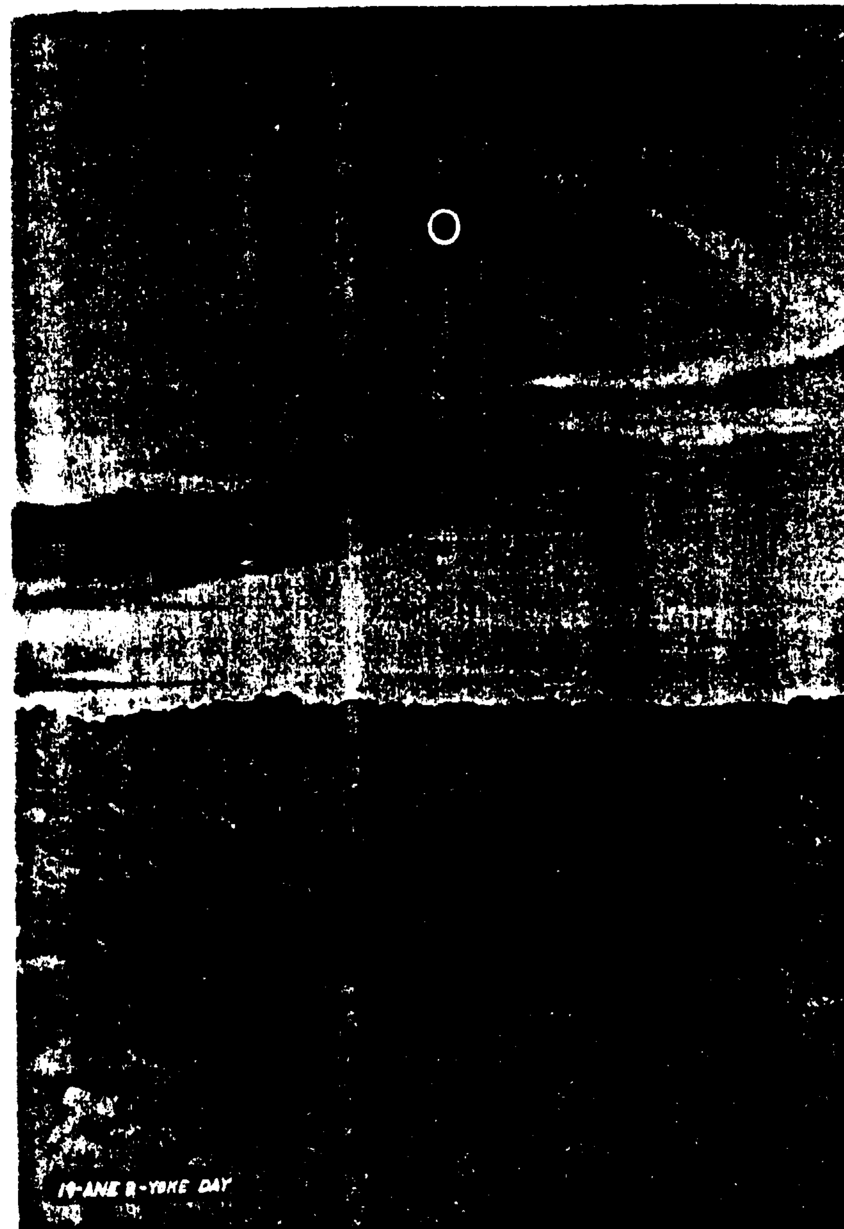
H-hr. plus 15 min.

[redacted]

[redacted]



Upper Part of Atomic Cloud. Note general character of the cloud as compared to the XRAY DAY cloud. The white circles have been drawn around a drone airplane.



Upper Part of Atomic Cloud. Note that the cloud is more or less continuous throughout its entire length. Also note the character of the weather as shown by the natural clouds. The camera is over the western part of the atoll.

H-hr. plus 30 min.

ATOMIC ENERGY [redacted]

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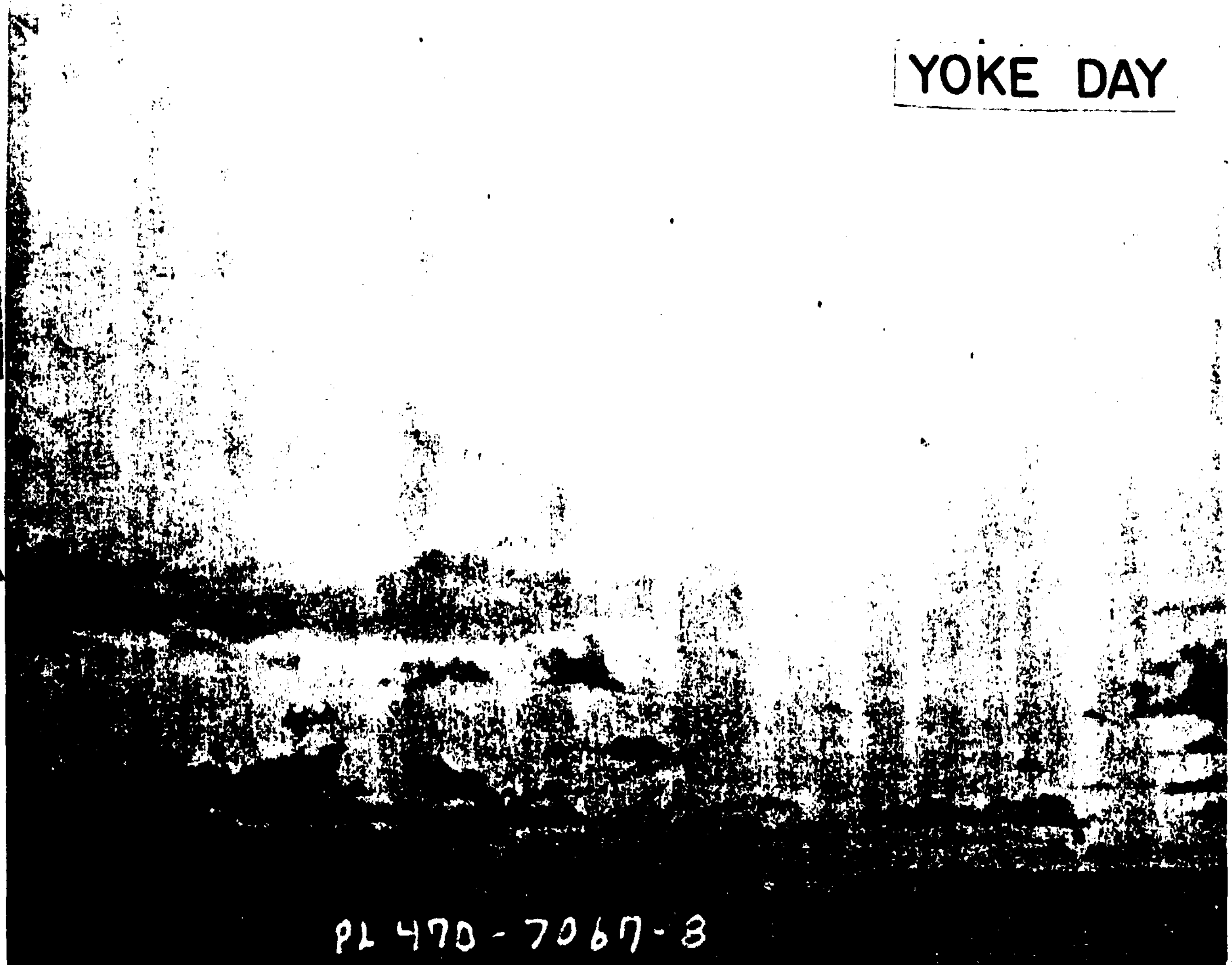

Upper Portion of Atomic Cloud as Viewed from Eniwetok. Darkness prevented better photographs from the surface. Best photographs of the atomic clouds in their early stages were made from aircraft where the cloud was silhouetted against the first light in the eastern sky.

H-hr. plus 35 min.

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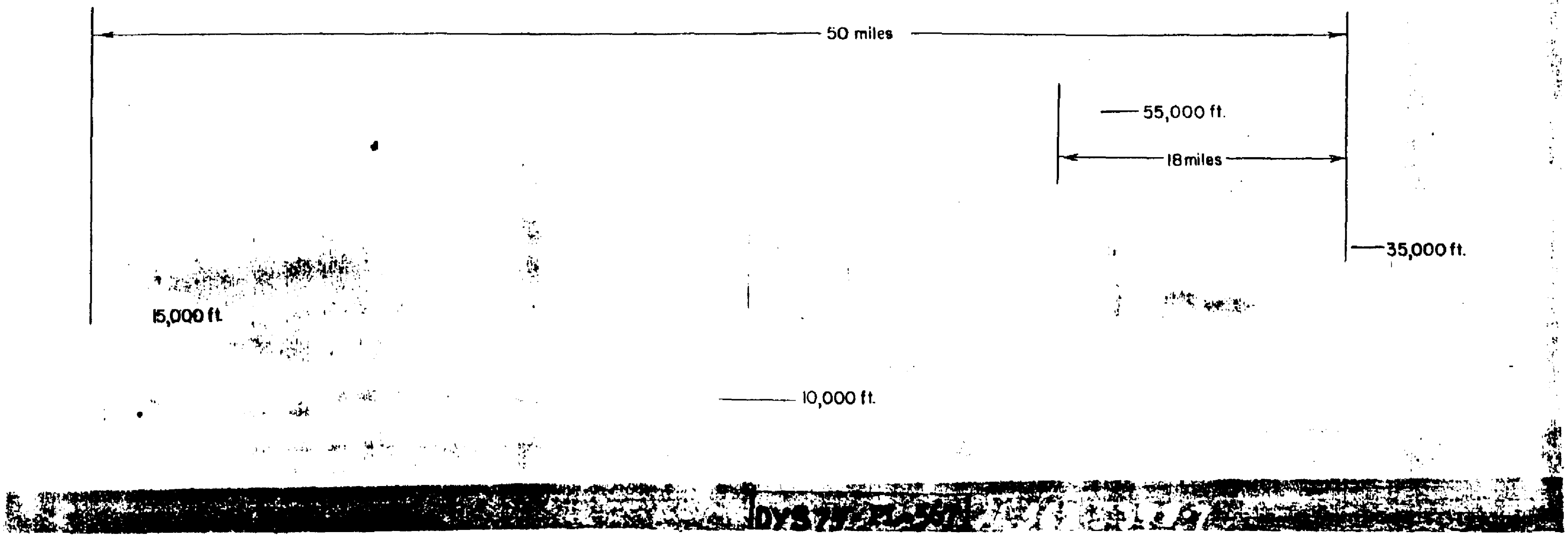
YOKE DAY



View [illegible] Complete at[illegible] Cloud. [illegible] dusty, smoky appearance of cloud in its lower parts. Actually the cl[illegible] [illegible] portion [illegible] is shown in this photograph.

H–hr. plus I hr.

[redacted]

ATOMIC ENERGY ACT - 1946

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Earliest Picture of the Atomic Cloud. The primary mass and the remains of the finger-like projection are shown. [illegible] the projection has separated itself from the primary mass. Both of [illegible] of the ZEBRA Day cloud were made from [illegible].

H-Hr. plus 45 min.

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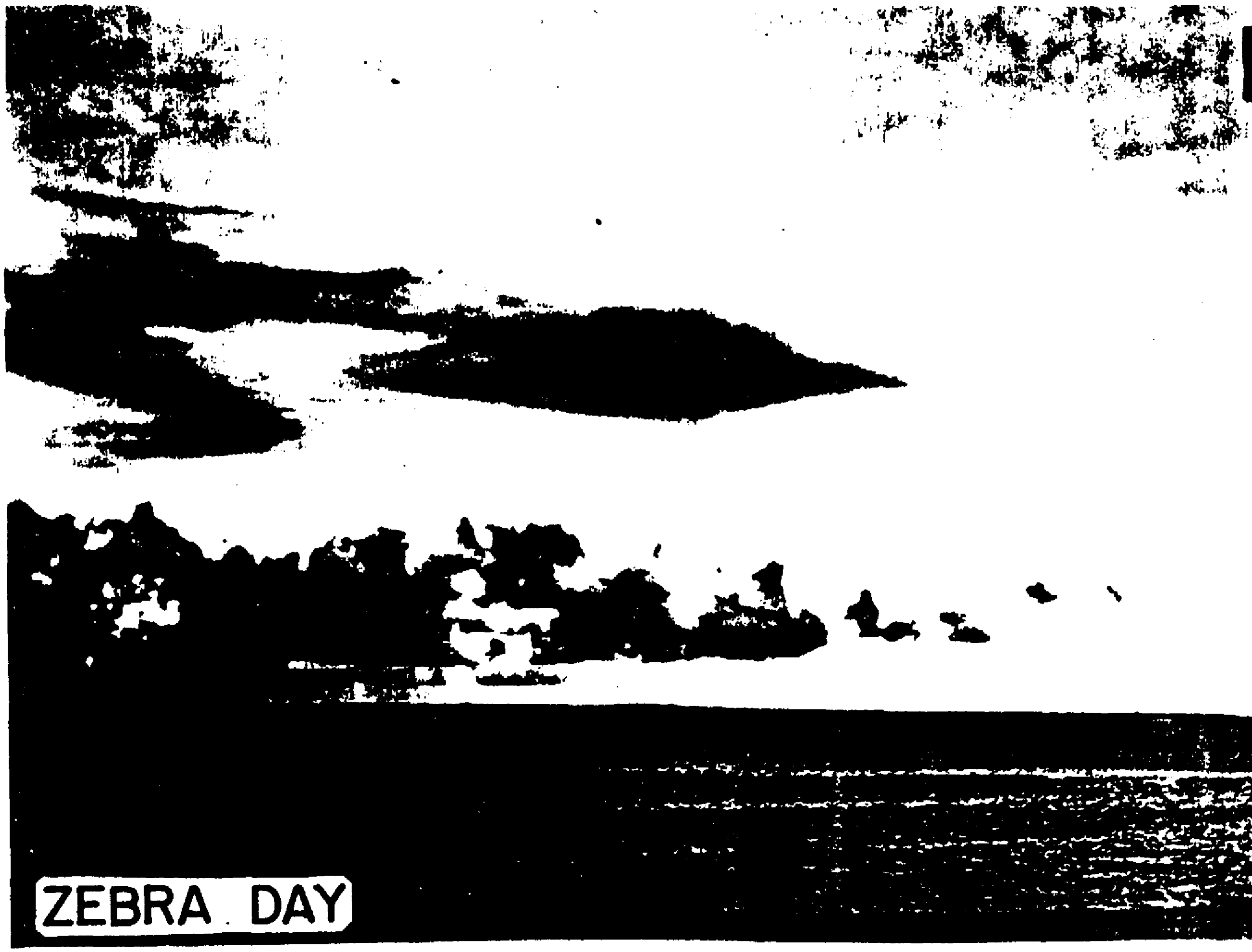
[redacted]

~~Atomic~~ Energy Act — 1946
~~Specific Restricted Data Clearance Required~~



Primary Mass with Zig-Zag Stem. Note how closely the loop in the lower part compares with the diagram showing the dimensions of the cloud at the end of three hours, page [illegible]. The cloud appeared to be entirely composed of smoke and dust when this photograph was made.

H-Hr. plus 1 hr.

Conclusions

The following discussions will be confined to phenomena produced by air bursts.

1. Early Development of an Atomic Cloud:

Important factors affecting early development of an atomic cloud are as follows:

a. Energy of Weapon: The energy of the weapon will be the most important factor in determining the size of the cloud in its initial stages. Also, there is a relationship between the energy of the weapon and the altitude of the burst which affects the shape of the cloud.

b. Temperature of the Air (Lapse Rate): All of the airbursts at Eniwetok and at Bikini were under very similar temperature and lapse rate conditions. Although it is reasonable to assume that differences in atmospheric structure would produce significant changes, little or nothing is known about the effects of lapse rate on the shape of atomic clouds.

c. Moisture Available (Water Vapor or Liquid Water): Judging from the XRAY Day cloud, the fact that the cloud acquired moisture in its early stages by passing up through wet clouds, or by picking up water which had been in the form of droplets on the tower or near the test site, greatly affected the character of the primary mass by the time that it reached maximum altitude. Water content was also important in the dispersion of the visible cloud.

d. Character of the Surface: Where an air burst occurs at an altitude as low as 200 feet, considerable quantities of loose material from the surface follow the fireball as it rises, and some of this material mixes into the mushroom itself. Over a sandy, dusty surface, there is naturally more cloud material. Loose material of this nature contributes to the fall out of radioactive material from the cloud.

e. Altitude of Weapon: The higher a weapon of a given energy, the less material is likely to be swept up from the surface and more perfect the mushroom. It is believed that the break which occurred in the XRAY Day cloud was related to the altitude of the burst, as well as wind structure. It seems that when the burst occurs at a relatively high altitude, the mushroom rises faster than the stem and a break in the cloud is likely to result. It is further believed that the YOKE Day cloud was misshapen because it was at a low altitude with respect to its initial energy.

f. Surface Winds: The winds at low levels do not have much effects on atomic clouds in early stages as at first the clouds seem to rise nearly straight up.

2. Maximum Altitude of an Atomic Cloud:

With respect to the SANDSTONE clouds, the energy of the weapons was the greatest contributing factor to the maximum altitude.

It does not seem that the lower altitude of the ZEBRA cloud can be attributed to meteorological conditions. Where sufficient energy is available, the clouds rise until they reach the base of the stratosphere, at about 55,000 feet in the Eniwetok area.

3. Dispersion of an Atomic Cloud:

The shape of an atomic cloud in its later stages depends on the following factors:

a. Amount of Material at Different Altitudes: The amount of material which is originally distributed at different altitudes largely determines the shape of the cloud throughout its later history. An examination of the three SANDSTONE clouds shows that there is considerable variation in the amounts of material at different altitudes.

Conclusions — (continued from previous page)

b. Wind Direction and Velocity at Particular Altitudes: The most important factor in shaping the cloud as it is dispersed is the transport of the cloud material by the upper winds. In any determination of the shape of an atomic cloud, or the location of atomic cloud material, the wind directions and velocities at particular elevations are of primary importance.

c. Differences in Wind Direction and Velocity which Produce Shearing Action: Where considerable differences in the wind direction or wind velocity occur with respect to altitude, an atomic cloud is spread out as was the top of the XRAY Day cloud or stretched out into a ribbon as was the YOKE Day cloud.

d. Rate of Fall Out of Material: The dropping of material to successively lower altitudes because of the effects of gravity greatly affects the shape of an atomic cloud if periods of time as long as days or weeks are being considered; however, fall out is so slow that it cannot be detected visually. There does not seem to be any need of considering fall out when determining the shape of an atomic cloud three hours old. No definite figures on the rate of fall out are yet available.

e. Condensation of Water Vapor on Cloud Nuclei: It appears that there may have been condensation of water vapor on the cloud nuclei in the upper sections of the XRAY Day cloud which would account for its large area and its resemblance to natural cirrus.

f. Evaporation of Water Droplets: The cumulus-like formations at the lower end of the atomic clouds were lost from sight within 15 minutes and evaporation is thought to be a contributing factor to their disappearance. It is thought that water vapor can both collect on atomic cloud material or evaporate from it depending on the atmospheric conditions.

7. Natural Convection:

The tops of cumulus clouds in the Eniwetok Area averaged 6,000 to 8,000 feet. Occasionally cumulus ranged 10,000 to 20,000, and infrequently they extended to 30,000. Cumulonimbus which range to the base of the stratosphere are a rarity in regions where atomic clouds are likely to be present. Therefore, most of the radioactive material in an atomic cloud is likely to be above the region where it will be affected by natural convection.

8. Washing Action of Precipitation:

The freezing level in the latitude of Eniwetok is from 16,000 to 20,000 feet and it lowers in high latitudes until it reaches the surface. Most of the radioactive material is likely to start out above the level when it can be washed from the atmosphere by rain. Some of it will be trapped into ice crystals, but this effect is thought to be less effective than the washing action of rainfall.

9. Eddy Diffusion:

The circular motions in the atmosphere of every size which range from almost microscopic eddys, through the convective cells that produce cumulus clouds, to the high and low pressure circulations which cover thousands of square miles are the most important factor in determining the volume of the cloud, or the area covered by it.

10. Molecular Diffusion:

The effects of wind and eddy diffusion are thought to be of much greater effect in determining the dimensions of an atomic cloud than molecular diffusion.

11. Radar Observations:

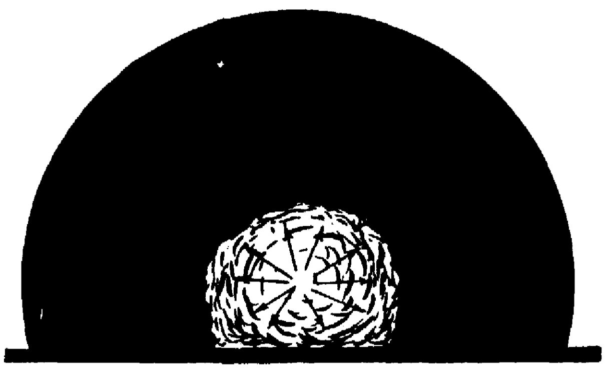
All three of the atomic clouds were observed on the SP radar of the U.S.S. Bairoko. The XRAY Day cloud lasted 4 minutes on the scope, the YOKE Day cloud lasted 12 minutes, and the ZEBRA Day cloud is thought to have lasted 2 hours. Nothing conclusive was learned with regard to radar observations.

Note: The figure on page 71 shows the internal motions within an atomic cloud in its initial stages. It is interesting to note that because of the circular motion within the mushroom, the upward velocity in the center of the mushroom may be approximately twice that of the top of the atomic cloud.

EARLY STAGES OF ATOMIC CLOUDS

IMPORTANT FACTORS AFFECTING EARLY DEVELOPMENT

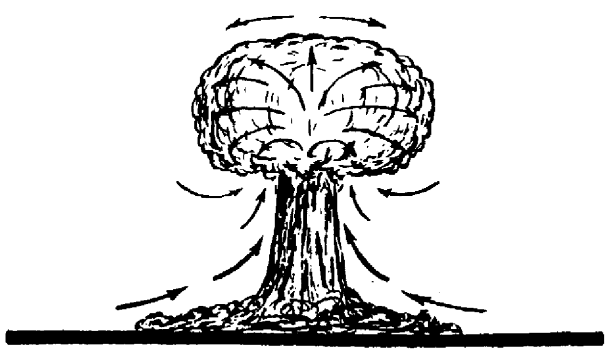
- Energy of Weapon
- Temperature of Air (Lapse Rate)
- Moisture Available (Water Vapor or Liquid Water)
- Character of Surface
- Altitude of Weapon
- Surface Wind (Winds at Lower Levels)



Incandesent Ball

Time: plus 3 seconds

Diameter: 1/2 mile

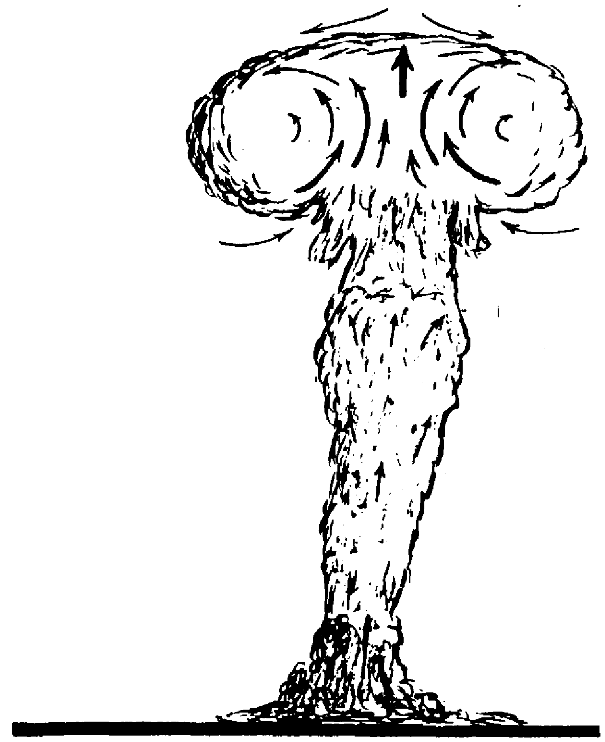


Ball on Pedestal

Time: plus 10 seconds

Diameter: 3/4 miles

Altitude: 6,000 feet



Mushroom Cloud

Time: plus 2 minutes

Diameter: 1 1/2 miles

Altitude: 15,000 feet

The figures given are approximate and apply to atomic clouds in general.

Shape of Visible Cloud in Later Stages Depends on Following Factors:—

1. Amount of material at different altitudes.
2. Wind directions and velocities at particular altitudes.
3. Differences in wind directions and velocities which produce shearing action.
4. Rate of fall out of material.
5. Condensation on cloud nuclei.
6. Evaporation of water droplets.
7. Natural convection.
8. Washing action of precipitation.
9. Eddy diffusion (turbulent diffusion).
10. Molecular diffusion.

Recommendations

1. Scientific Meteorological Program: A scientific meteorological program should be a part of the overall scientific observations made during atomic weapon tests. A desirable scientific program should include the following kinds of activity:

   a. Research and developmental work on observational techniques and instruments.

   b. Coordination of plans with other scientific groups having common interests.

   c. Observational work at the scene of the test.

   d. Analysis of data collected, and the preparation of reports for publication.

2. Upper Wind Observations: Among the first requirements of any study of atomic cloud phenomena are adequate upper wind data. The maximum altitude of the soundings should be at least 10,000 feet above the maximum altitude that the atomic cloud is expected to go. (In the Eniwetok area wind soundings to 65,000 or 70,000 feet are required.) The frequency of the soundings should be such that at least three different sets of data are available for estimating the effects of the winds during the period the cloud will be rising. For three hours before and after the first time, soundings should be at one hour intervals; and for one day before and after, they should be made every three hours. For analysis work, several soundings are preferred to a single sounding. Where it is likely that some soundings will not reach the required maximum altitude, additional soundings should be scheduled. Recorded or coded data should be written in 1,000 foot intervals for all elevations when atomic clouds are under consideration.

3. Upper Air Observations: Dependable upper air observations of temperature and humidity which reach well into the stratosphere are also a requirement for atomic cloud studies. To be of greatest value, there should be at least two soundings which will show the structure of the atmosphere at the time of formation of the atomic cloud.

4. Theodolite Observations: A photo-theodolite capable of making a picture of the cloud, which would include the azimuth angle, the elevation angle, and the time, would be a very useful tool for a study of atomic clouds. However, if the tests are conducted in darkness, visual observations with sketches will continue to be required. Rigidly mounted shore type theodolites are recommended over shipboard theodolites. Also, theodolite observation stations should be connected by telephone or short range radio, so that observations can be better coordinated.

5. Photogrammetry: The task of photographing atomic clouds should be given to experts in photogrammetry. All of the different methods of measurement by photography which could be applied to cloud observations should be tried. In particular, experiments with stereoscopic techniques should be attempted. Also, photographic personnel should be equipped to make panoramic views of the dispersed clouds. Operational orders should specify that the director of photography will work in close conjunction with the scientific meteorological program. The orders should also specify that the director of photography will furnish dimensional data sufficient to construct models of the cloud, should a model be required.

6. Aircraft Observations: Photographs or records of visual observations from aircraft can show many features of the cloud that cannot be recorded in any other way. In the case of the YOKE Day cloud, photographs were possible from aircraft before they were possible from the ships and island bases. Airborne observers can also follow the visual cloud longer than observers on the surface. It is estimated that airborne observers could have followed the SANDSTONE clouds during most of the daylight hours on the test days, whereas observations from the surface were not possible after three hours. Another observation which an aircraft can make which cannot be made safely any other way is visual or photographic coverage of the lowest part of an atomic cloud where fall out occurs to the surface. Anything which could be learned with regard to fall out from the lowest part of the cloud would be very useful for radiological safety studies.

Aircraft should also be used to obtain more information on the cumulus-type formation that occurred over the test sites, and which were a feature of the bottom part of the atomic clouds.

Appendix I

Meteorological Report on the Visible Atomic Clouds

Operation SANDSTONE

DISCUSSION OF OBSERVATIONAL TECHNIQUES, WORKING CHARTS, AND THEODOLITE DATA

[redacted]

Appendix I

Table of Contents

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Discussion of Observational Techniques

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The Official Report of Operation CROSSROADS contains the following statement concerning the atomic cloud formed on ABIE DAY at Bikini, 1 July 1946:

> "The fireball rose initially at the rate of more than one hundred miles per hour. Within twenty seconds it transformed itself into the fireless head of the mushroom, now one mile high. Two minutes later the mushroom's altitude was five miles; five minutes later it was seven miles, one mile higher than Mt. Everest."

The figures stated are rough estimates prepared as an afterthought. Techniques for measuring the cloud were not considered in the CROSSROADS Operation plan. Data on that cloud consist of eye witness accounts from surface and airborne observers, information derived from the operation of the drones, and photographs of the mushroom. Observers on at least one ship used a meteorological theodolite to make altitude determinations, but no considerations were given to movement by the upper winds or to the shape of the cloud. Such data as were obtained have not been useful for scientific work. Therefore, when it was decided that cloud measurements were to be a part of the scientific meteorological program, a technique had to be devised and instructions issued in order that satisfactory data would be obtained.

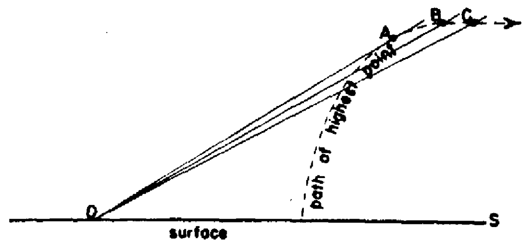
It was not known what kind of phenomena would be produced by the weapons, but since the weapons were to be tested in the air, it was assumed that the clouds would be similar to those observed on ABIE DAY. Also, it was not known at what time of day the tests would be conducted or to what extent photographs could be used. It was not practical to bring additional instruments or personnel into the area for the purpose of making cloud observations, or to establish an observing station separate from the USS Albemarle, the USS Bairoko, the USS Curtiss, the USS Mt. McKinley, or Eniwetok. This meant that observations would have to be made with the ordinary weather instruments at hand and that the base line for observations would be short. The ships were to be grouped together and were to be positioned almost in the line of sight from Eniwetok. The ships were too close together for a base line to be established, but were sufficiently far apart for observers to get significantly different views of the cloud. The weather station at Eniwetok was so located that the XRAY DAY cloud could hardly be seen and little use could be made of the data obtained for YOKE and ZEBRA DAYS. There was no possibility of communicating between the stations and directing stations to sight on the same point at the same time. Therefore, a scheme was devised whereby data would be entered on sketches.

At the time the weather stations were directed to collect data it was not known just how the data would be used to perform the desired operations for measuring the atomic clouds; however, it was decided to collect as much data as practical and then determine how it could be used. After XRAY DAY the sketches and data were examined, and a procedure for processing the data was arrived at by trial and error methods. The data for YOKE and ZEBRA DAYS were processed in somewhat the same manner as those for XRAY DAY, however, there were differences between the behavior of each of the three clouds which made it necessary to interpret the data slightly differently.

In particular, the elevation angles obtained by sighting on the highest part of the clouds gave different shaped curves when plotted, and altitude calculations had to be made in a somewhat different manner each time. At first, an attempt was made to consider each observation station individually and to make completely separate calculations for each station so that final results could be compared. This proved to be impractical, so it was decided that it would be best to consider all of the ships as a single observing station located in the position of the USS Albemarle. The position of the Albemarle was chosen because that ship gave the most consistent data. In the graphs the angles from all of the ships were plotted together, but only one curve is drawn. This curve fits approximately the points of the Albemarle. Where the actual data from the Albemarle does not agree with the other ships, the curve is drawn to what was likely to be the true conditions rather than to the points corresponding to the angles reported by the Albemarle. All of the curves have been fitted by eye, and other liberties have been taken in the interpretation of the theodolite data. This is because of the crude way in which the observations were taken and the uncertainty that all observers were sighting on the same, or corresponding points.

It is very difficult to tell what effect the spreading out of the cloud has on the observed elevation angles. When the cloud is low or at a considerable distance, as in the case of the XRAY DAY cloud, it is possible to see above the edge of the mushroom and sight on the bulging top of the cloud so that a nearly true elevation angle is obtained. In cases where the mushroom rises more nearly overhead, it is not possible to see the top of the mushroom and the observer sights on what appears to be the highest part of the near side. This is likely to produce a recorded elevation angle which is higher than would be obtained by sighting on the highest part of the cloud, assuming that the highest part of the mushroom is somewhere near the center.

When the curve for the elevation angle of the highest point of each of the three clouds is examined, it will be found that the largest elevation angle does not necessarily occur at the time the cloud reaches the highest elevation. Where the cloud moves away from the observer, the rate of increase in distance between the top of the cloud and the observer may be sufficiently great, when compared with the rate of rise, to cause the greatest angle to be observed shortly before the cloud reaches maximum altitude. (See Figure below)



Angle AOS is greater than angle BOS in this example, and angle COS is less than the other two angles when the path of a point is considered. This fact that the highest elevation angle did not necessarily occur at the time that the clouds reached maximum altitude made it very difficult to determine just when the clouds stopped rising. This determination was further complicated by the fact that the clouds were volumes, rather than points, which became larger as they rose and appeared to spread out after reaching the tropopause. In the case of the YOKE DAY cloud, the top appeared to spread back about the time that it reached maximum altitude so that the observed angle corresponding to angle COS in the above figure was larger than the angle BOS for a period of several minutes. The visual appearance of the clouds was one of the best clues to the time when maximum altitude was reached. For example, the time of beginning of the wing-like plume on the XRAY DAY cloud was taken as the approximate time when the cloud reached highest altitude. Another clue to the behavior of the clouds is the rate of rise curve. There are a limited number of

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possible values which will give a reasonable rate of rise curve. By trial and error it was possible to select values which give a reasonable looking curve and also fit the observed behavior of the cloud.

The results contained in this report are based on what are believed to be reasonable assumptions where actual data were not obtainable. Another author could make different assumptions and obtain slightly different answers. However, the difference in answers is not likely to be important for the relatively great size of an atomic cloud makes differences of several thousand feet insignificant. For operational purposes which can be foreseen, estimates which are within 10% of true size or altitude should be exact enough. An atomic cloud is an irregular mass of continuously changing dimensions and density. It does not lend itself to exact measurement.

A better understanding of the data contained herein is possible if some of the limitations of upper wind observations are understood. Upper winds are estimated by observing the behavior of a free balloon rising through the atmosphere. During SANDSTONE the balloons were observed visually, by radar, and by radio direction finding equipment. The results of all three methods are considered together although there may be some differences in reported wind data which are caused by differences in the methods used. Consecutive wind soundings show changes in wind direction and velocity which are greater than would ordinarily be expected for the meteorological conditions which existed. As very little is known about the changes in the upper winds in tropical regions, it is not known how the recorded wind data should be interpreted. Wind soundings were not made exactly at the times the clouds were rising, so the soundings before and after H-hour are used to estimate the winds which affected the rising cloud.

Another difficulty in using upper wind data is caused by the fact that upper wind directions are figured only to the nearest ten degrees. In a vector calculation such as that used to determine the position of the clouds at the time they reached maximum altitude, this coarseness of technique may be of considerable significance, as errors tend to be accumulative.

It would be quite possible for the actual wind which affected the cloud to be quite different from the estimated wind; however, a comparison of the shape of the clouds in sketches and photographs with the shapes which would be expected had the estimated wind prevailed shows that the estimated wind must be a fairly good approximation of the true wind.

Throughout this entire report the times given should be taken to be approximate. It was not possible to exactly synchronize timing between observation stations. Also, human error in reading watches causes any time recorded to be only an approximation of the true time. The times shown for H-hour are given to the nearest minute only. Where data is given for an interval of seconds, the time for that data should be considered to be roughly estimated.

The following are the instructions which were issued to the weather stations which participated in the scientific meteorological program. To these instructions have been added comments which were inserted as this report was made ready for publication. These comments are intended to be of assistance in the preparation of instructions for future scientific observational programs.

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HEAD[redacted] JOINT TASK FORCE SEVEN
[redacted] 187, c/o Postmaster
San Francisco, California

000.93 — 6 April 1948

SUBJECT: Participation of Weather Stations in the Scientific Meteorological Program.

TO : Commander, Air Forces, Joint Task Force Seven
Commander, Task Group 7.3

1. Paragraphs 3b(4) and 3c(2) of Annex K, METEOROLOGICAL PLAN, to Field Order No. 1, Headquarters, Joint Task Force Seven, dated 14 November 1947, delineate the responsibilities of the meteorological units of the Task Force with regard to the scientific meteorological program.

2. Detailed instructions for making scientific observations by aerological and weather personnel are contained in the inclosure to this letter, titled Participation of Weather Stations in the Scientific Meteorological Program. These instructions apply only to weather activities within visual range of a proof test, and are primarily concerned with the adequate documentation of any meteorological phenomena, including an atomic cloud, which may be associated with a test. It is very desirable that the Navy Aerology units aboard the USS MT McKINLEY, the USS ALBEMARLE, the USS CURTISS and the USS BAIROKO, and the Air Weather Service station at Eniwetok cooperate in making these special observations; and it is requested that copies of the inclosure be distributed to all aerological and weather officers concerned.

3. It is also desired that the above mentioned meteorological activities operate high speed micro-barographs as part of the scientific meteorological program. The instructions for these instruments will be issued separately.

4. Meteorological data collected on atomic phenomena will be treated as (but not necessarily classified as) "TOP SECRET - AEA Restricted Data" for all purposes. Such data will be submitted as soon as practicable to the Staff Meteorologist, this Headquarters, and the Staff Meteorologist will submit all data to the Test Director for review for classification.

BY COMMAND OF LIEUTENANT GENERAL HULL:

GARLEN R. BRYANT
Lt Col AGD
Adjutant General

1 Inclosure

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ENCLOSURE (A)

PARTICIPATION OF WEATHER STATIONS IN THE SCIENTIFIC METEOROLOGICAL PROGRAM

Weather stations within sight of the atomic phenomena should give first priority to the tasks assigned by the operational plan; but where time and personnel are available, the following contributions should be made to the scientific meteorological program. The meteorological units which are expected to contribute to the collection of data are the weather station at Eniwetok and the aerological units aboard the Curtiss, the Mt. McKinley, the Albemarle, and the Bairoko.

1. Special Weather Observations: One hour prior to the time of the test (or tests) and throughout the period that any atomic cloud is visible, weather conditions should be constantly observed. Add to the regular hourly or special observations any other observational data or plain language descriptions necessary to give a true picture of the meteorological conditions associated with the atomic phenomena. Strive for great accuracy and detail in recording observations. Well written eyewitness accounts, backed up by instrumental data, from meteorological units will be included in the published scientific report. Attempt to document dimensions, distances, times, rates of formation, or other scientific data, if available, or if such information can be readily estimated.

a. Observations of Natural Cloudiness: Give the best possible description of natural cloudiness from a period one hour prior to the test until the atomic cloud and its effects have completely disappeared. Record amounts, heights of bases, and tops of all clouds. If numerical data is not available for middle or high clouds, describe them using such words as "very thin" or "thick,shape of sun disk not discernable, but clouds show no shadows on undersides." Use balloon and aircraft data if possible, or make best possible estimates. If cloud data is obtained by measurement, that fact should be stated. Also, give orientation of cloud masses or sheets with respect to the weather station and the test area. Record cloud movements, dissipation, or development. Should natural clouds be mixed or associated with the atomic clouds, describe the extent of the mixing.

b. Observations of Showers: If rain showers or thunderstorms are observed while the atomic cloud is present, describe them and show their development and movement relative to the target area and the atomic cloud. If radar views of the rain area are available, describe their development and movement, and state if photographs were made. Should rain occur at the station while the atomic cloud is in the area, state the exact time rain began and ended and tell the intensity of the rainfall throughout the period that it occurred. If no rain guage is available, state how much the ground or decks were wet and to what extent objects were soaked, and state to what extent visibility was reduced by the rain.

(Comment: The rain showers in the test area showed plainly on the radar scopes aboard the U.S.S. Mt. McKinley and could have been easily photographed. If photographs had been made shortly after the tests and during the period that the atomic clouds were in range, it would have been possible to estimate whether or not a shower resulting from natural causes occurred within the diffusing atomic cloud. A study of radar photographs of shower areas associated with different meteorological situations would permit an estimate of the extent of the shower activity affecting the cloud in areas where observations are not possible. For example, it might be determined that the lowest portion of the atomic cloud was carried in an air mass in which there were only widely scattered cumulus with tops below 12,000 feet and with bases from one-half to one mile in diameter. It might be estimated that such showers would occupy only 5% of the total horizontal area and would therefore, not greatly affect the atomic cloud.)

c. Observations of Surface Wind: Stations near the test area should note carefully any changes in wind direction or velocity associated with the atomic phenomena. Consecutive aerial photographs of the sea surface around the test area during the rise of an atomic cloud would be most useful in determining the circulation pattern produced.

(Comment: Surface winds are not affected by atomic phenomena at the distances at which weather observation stations have been located. Beyond three miles from the test site there is little reason to give attention to possible changes in the surface wind as result of an atomic blast.)

d. Observations of Unusual Phenomena: Observers should be on the alert to record any weather occurrence, however improbable. Small whirlwinds might form over a heated surface after the main cloud has moved clear, a small tornado or waterspout might form at the base of the atomic cloud, lightning might be observed in the atomic cloud, etc.

(Comment: Because of distance and dust, it is unlikely that a weather observer could see occurrences beneath an atomic cloud.)

e. Observations from Recording Instruments: Submit records of all recording meteorological instruments. Indicate dates, times, instrument corrections, and point out changes produced by atomic phenomena. Give positions of instruments in longitude and latitude and in distance from atomic test site. For particular instruments, the following instructions apply:

(1) Barographs or Micro-barographs: State location in building or ship and describe the route of the pressure wave to the barograph. A drawing showing location of the building or ship and the openings through which the pressure wave passed would be most helpful. Show by means of an arrow the direction that the pressure wave came in its route to the barographs. Be sure to state the height of the instrument above mean sea level. Tell whether or not the barograph was on a sponge rubber mat; and if there is evidence that the instrument was shaken by vibration from the building or ground, point that out on the trace.

(2) Thermographs and Hydrothermographs: State the location of the thermoscreen. State whether or not it was in direct line of heat radiation from atomic phenomena. Also state how it was affected by direct sunlight. If a drawing will give more complete information, include one. Accurate measurements of temperature and humidity are very desirable. If it is suspected that the temperature in the thermoscreen may be higher because the sun has been shining directly against the side of the ship on which the thermoscreen is mounted, several readings from a hand psychrometer should be obtained in shaded, but exposed areas. State where such observations were made. Be sure to use clean, fresh water and new muslin on wet-bulb thermometers. Hairs on hydrographs should be cleaned with distilled water applied with a soft brush.

(3) Radiosondes: If a radiosonde trace shows evidence of heating or unusual inversions which may be the result of atomic phenomena, submit the trace and a copy of the adiabatic chart showing the change produced.

(Comment: Ordinary meteorological instruments give disappointing results when exposed to the instantaneous radiant heat of an atomic weapon and microbarographs in similar locations give widely differing measurements of the same pressure wave. No further measurements with ordinary instruments are recommended.)

2. Observations of Atomic Phenomena:

a. Heat: Note any effects of heating such as the production of natural clouds by convection or the dissipation of clouds by evaporation.

(Comment: Natural clouds are greatly affected in the vicinity of the condensation cloud but not perceptibly outside of it. (See photographs of Able Day at Bikini.)

b. Pressure Wave: A blast wave traveling through the atmosphere may produce effects which might not be easily photographed, therefore visual observations may prove to be very useful in the study of the pressure wave phenomena.

(1) Diffraction of Light: There may be a diffraction of ordinary daylight through a blast wave which could be seen but not easily photographed. Should this occur, the wave would appear as a rapidly expanding transparent bubble and would likely be seen against the clear, blue sky at some distance to either side of the test point.

(2) Effect on Natural Clouds: The bursting of atomic bombs has produced a fog bubble around the bursting point. That bubble can be easily studied from photographs, but other cloud phenomena may occur which might not be caught by the cameras. The pressure wave may appear to cause movement in existing clouds, particularly as it moves along the base of a uniform cloud layer. Also, the passage of the pressure through any area of high relative humidity may produce visible vapor formation outside of the main fog bubble. It should be noted that the size of the fog bubble depends upon the pressure drop necessary to produce 100% relative humidity. Accurate radiosonde data for about the first 5,000 feet of altitude will help in the study of the fog bubble phenomena.

(3) Water Waves: If the pressure wave is noted to produce any effect as it travels over the water surface, describe what happens.

(Comment: No pressure wave phenomena, such as suggested above, was visible.)

c. Air Circulation: Look for any disturbance of the local winds and signs of any convective pattern which might be produced. Notice if clouds form, or dissipate, as air is pulled into, or subsides from, a rising atomic cloud.

(Comment: Such phenomena was not reported. However, studies of aerial motion pictures may show some evidence of a convective pattern.)

d. Atomic Cloud:

(1) Size and Shape: Data on an atomic cloud which can be obtained with the theodolite will be of considerable value. Rough outline sketches of the cloud showing outstanding features and giving distances, heights, angles, etc., will aid in checking photographic measurements. In particular, visual data will be of greatest value as the cloud become very diffuse and invisible to the camera. Also, after several hours, the cloud may become too widespread in area for its shape to be shown by a photograph. Two sample sketches are included. Notice that some plain language data is included in the sketches. At first, when the cloud is rising and changing rapidly, make readings first on the top of the highest portion. Then as it slows down, make readings on the top of the two or three major cloud masses. As the cloud becomes more stable, make as many measurements as possible. Make readings continuously. No set of readings should exceed 5 minutes duration, so that there is no longer than 5 minutes lapsed time between readings on any one portion of the cloud. On practice days, the men who will make these observations on the atomic cloud will submit data on a large cumulus cloud (if one occurs) for a period of one-half hour.

(Comment: The results of these instructions make up the most important part of this report. No observing station followed exactly the method shown in the examples. Best results were obtained by the use of two or more theodolites at a station. One theodolite was used for the left and right hand edge of the primary portion and the other theodolite concentrated on the highest part of the cloud. At the same time, sketches were made by a separate observer who marked on the sketches the points at which the theodolites were aimed. There was no difficulty in making observations on the highest point at 30 second intervals and on each side of the cloud at one minute intervals. At first, sketches were made at the rate of one each minute for about the first 15 minutes. Then they were made at 5 minute intervals for the first hour. After that, sketches were made at 10 or 15 minute intervals. The color and characteristics of the atomic clouds were entered on the sketches. Rigidly mounted shore type theodolites are greatly preferred to shipboard theodolites for this type of work. Magnification of the cloud by a lens system is not required and may be objectionable. Any instrument which will measure azimuth and elevation angles simultaneously can be used instead of a theodolite.)

(2) Ice Veil: The atomic cloud on Able Day at Bikini was topped by a smooth veil cloud which was thought to be composed of cirrus-like ice crystals. Should such a cloud occur again, as much data as possible should be collected. Show the veil structure in sketches and give theodolite data with exact times of formation, changing, and disappearance.

(3) Color of Sun: If the sun should be seen to be shining through the atomic cloud, record the color of the sun. Also, record the times of the observations and the angles of the sun above the horizon. If the sun disk can be shown in the cloud sketches, show through which portion of the cloud it shows.

(Comment: The sun was not seen to shine through the atomic clouds except possibly on XRAY Day when the upper part of the cloud mingled with cirrus through which the sun was shining. There was no coloration. This observation was requested by radiologists who thought that color would give some indication of the size of the particles in the cloud.)

(4) Radar Views: Should the atomic cloud show on a radar screen, report in detail what happened.

(Comment: In early stages the atomic clouds were observed on radar; however, the observational data obtained is inconclusive.)

(5) Movement: The movement of the cloud relative to the upper winds (and the dispersion of the cloud) should be studied and made the subject of a special report if any information is available and is not otherwise covered.

(Comment: Observers submitted sketches and data but did not submit separate reports of cloud movement.)

SECRET

Examples of Sketches Distributed to Observers Before Tests:—

SECRET Sample

Date: 30 Feb, '48

Local Time (a): 1214

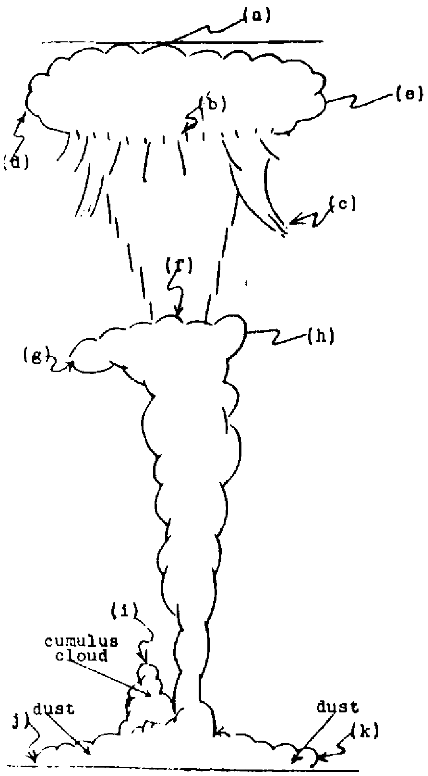
Local Time (k): 1218

Position:

Long. 180 ° 35 ' 15 "

Lat. 10 ° 43 ' 30 "

Height of Theodolite: 15 feet.



	Azimuth	Elevation
a.	270.0	12.0
b.	270.0	11.2
c.	273.2	11.0
d.	266.8	11.3
e.	273.4	11.3
f.	270.0	9.7
g.	270.8	9.5
h.	270.0	9.5
i.	269.9	2.5
j.	267.0	0.8
k.	273.2	0.8
l.		
m.		

Observer: J. Smith, CAerm

Recorder: T. Jones, Aerm 1

Unit: USS Neversail

Sample SECRET

- 5 -

SECRET Sample

Date: 30 Feb. '48

Local Time (a): 1305

Local Time (h): 1309

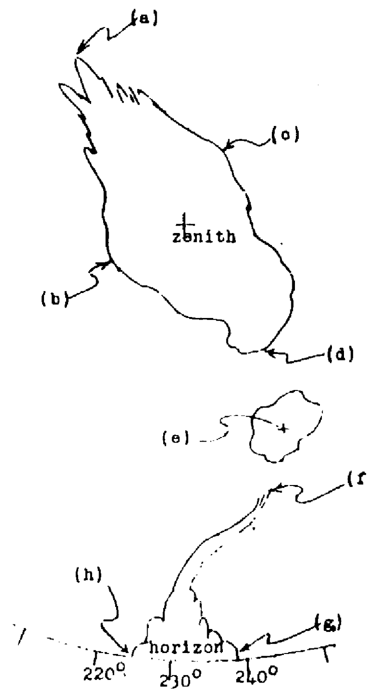
Position:

Long. 180 ° 49 ' 45 "

Lat. 10 ° 41 ' 00 "

Height of Theodolite: 15 feet.

Portion of Cloud Overhead



	Azimuth	Elevation
a.	82.0	75.0
b.	180.0	84.0
c.	20.0	82.0
d.	278.0	70.0
e.	260.0	63.0
f.	248.0	47.0
g.	238.0	0.5
h.	225.0	0.5
i.		
j.		
k.		
l.		
m.		

Observer: J. Smith, CAerm

Recorder: T. Jones, Aerm 1

Unit: USS Neversail

Sample SECRET

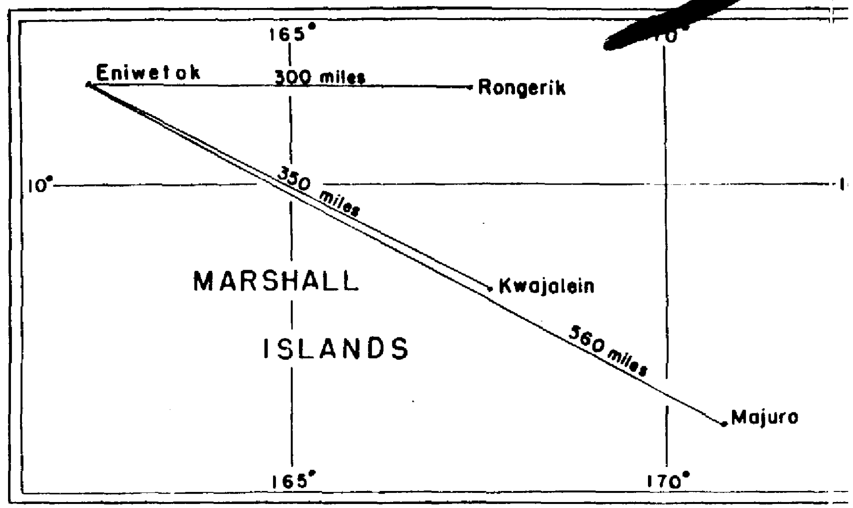
- 6 -

SECRET

Visual Observations at Long Distances

When it was discovered that H-hour for YOKE DAY would be in darkness, it was anticipated that a brilliant display would be produced similar to that of XRAY DAY, and that the light would be seen at a considerable distance. With due regard to security, observers on Kwajalein, Rongerik, and Majuro were asked to watch the horizon in the direction of Eniwetok at approximately H-hour. They were not told what they should expect to see, and they were not prepared to time any phenomena which they saw. Apparently, they saw both the initial flash of the weapon and the intense light of the fireball within the condensation cloud. As far as is known, this is the greatest distance which any object or occurrence on the surface has been seen. In future tests which may be conducted in darkness, it is hoped that color photographs can be made of this light transmitted to long distances. Such photographs would be of general interest and might be useful in studies of the atmosphere.

SECRET



S E C R E T

I observed the flash of the Atomic Weapon explosion from Kwajalein on "Y" Day. A very bright flash occurred first which gave a reflected light to clouds almost vertically overhead. I could not estimate the horizontal extent of the reflected light from the flash, it seemed to show everywhere in my field of vision. The instant appearance and disappearance of the reflected light from the flash made it very difficult to evaluate its extent and intensity realistically. The flash was followed by a very rapidly increasing, nearly instantaneous, red glow on the horizon which gave a pronounced pink reflection from the clouds to about 60 degrees both vertically and horizontally. This after-glow receded steadily and perceptably within 15-20 seconds (estimated) to a small spot on the horizon which remained faintly visibly for perhaps another 10-15 seconds.

Murray O. Jones
MURRAY O. JONES
1st Lt., USAF
Task Unit 7.4.4 (Mobile)

SECRET

STATEMENT CONCERNING "Y" day flash as seen from islands indicated:

Rongerik: Latoback Isle, Rongerik Atoll, Marshall Islands
The flash covered approximately 60 degrees in a horizontal plane and 20 degrees in a vertical plane. The color was a blend of pink and orange. It's intensity was comparable to that of the rising sun. Duration was about 3 seconds. It started suddenly and gradually diminished. It was bright enough to cast a shadow.

Majuro: Rosalie Isle, Majuro Atoll, Marshall Islands
It presented a faint pinkish glow along the horizon, extending horizontally 25 to 40 degrees and vertically it extended 10 degrees It appeared to be just a narrow band ofcolor along the horizon. It was stated that they saw a glow, not an instantaneous flash. It became instantly visible and died slowly, lasting about 20 seconds.

Personnel at Wake Island stated that no one had paid any particular attention to noting the southsouthwest horizon.

Louis A. Gazzaniga
LOUIS A. GAZZANIGA
Major, USAF

Discussion of Working Charts and Theodolite Data

The following pages contain the theodolite data which were used in the studies of the three atomic clouds produced on XRAY, YOKE, and ZEBRA DAYS at Eniwetok. The figures given have been copied from the original records submitted by the observers on the U.S.S. Albemarle, the U.S.S. Bairoko, the U.S.S. Curtiss, and the U.S.S. Mt. McKinley.

The observers on the Albemarle submitted their original theodolite data in columns similar to the way that the figures are presented in this appendix. Two theodolites were used and angles were recorded for almost every minute. Sketches were made independently of the theodolite observations. In the cases of the other ships, theodolite data were taken in conjunction with the sketching; and theodolite angles were entered directly on the sketches. This latter procedure resulted in less data for a particular point, but gave more specific information about the entire cloud. Where data were entered directly on the sketches there was less doubt about the point in question. For example, it would have been easy for an observer to sight on the near part of the plume which extended from the XRAY DAY cloud and record data on the edge of the plume instead of the highest part of the primary part of the cloud. With the aiming point clearly marked on the sketch, it was easy to select the correct angles for the top of, and for each side of the primary mass. Angles for other parts of the clouds have been omitted from these lists except the elevation and azimuth angles of the cloud projection which formed on the ZEBRA DAY cloud. By means of the sketches it was possible to determine which angles were for the top of the primary mass and which were for the top of the cloud projection. Where the sketches show that the clouds were being dispersed so that it was difficult to sight on the top of the cloud, or determine the left or right side of the primary mass, data are omitted. In the case of the XRAY DAY cloud, the primary mass was more compact and significant points could be sighted on for a longer time than in the case of the YOKE and ZEBRA DAY clouds.

The curves have been drawn for the data submitted by the Albemarle with consideration being given to data from the other ships. Considerable smoothing of the curves was done as the large size of the clouds and their changing shape made it difficult to keep the theodolites aimed at a particular significant point. Also, observers on different ships sighted on different, although corresponding, points.

The shapes of the curves for the elevation angles are determined by the rates of rise of the clouds, the upper winds, and the shape of the cloud. Irregularities in the curves after the clouds reached maximum altitude are believed to be the result of changes in the shape of the clouds. There is no indication that the maximum altitude of the clouds fluctuated after the greatest height was attained. However, it is likely that some evaporation of the tops of the YOKE and ZEBRA DAY clouds was taking place at about the end of the first hour.

Azimuth angle data are significant while the primary mass was of regular shape, but mean very little after the cloud becomes sheared apart by winds from different directions at different altitudes.

Examination of the points for azimuth angles of the YOKE and ZEBRA clouds show that separate curves can be drawn for each observing ship because of the spacing of the ships relative to the cloud. It may be seen that the points of the different ships give similar curves; however, the curve for the Albemarle is the only one for which calculations have been prepared. The position of the test site relative to the Albemarle has been marked on these graphs. This offers a check on the orientation of the theodolite.

In the following collection of numerical data and graphs, the numerical values are presented just before the graph to which they pertain.

Elevation angle data and graphs are given first and these are followed by azimuth angle data and graphs. The order of presentation and the page numbers are shown in the Table of Contents on Page I-2.

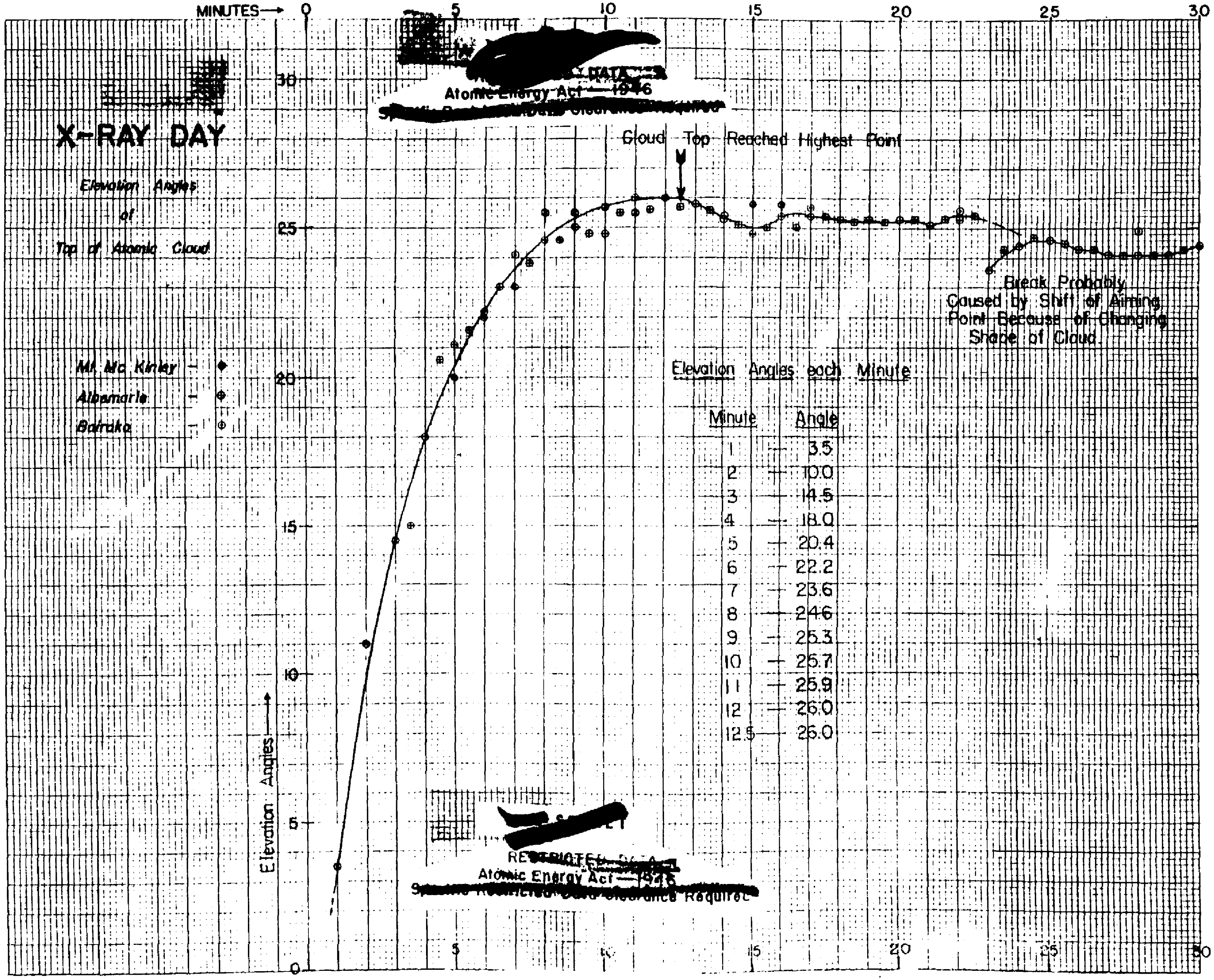
XRAY DAY

[redacted] SEC[redacted]T
[redacted]
A[redacted]Energy Act—1946
~~Specific[redacted] Data Clearance Requi~~

Highest Point — Elevation Angle

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:00	061700	-	-	-	-
0:30	1730	-	-	-	-
1:00	1800	-	-	-	3.5
1:30	1830	-	-	-	-
2:00	1900	-	-	-	11.0
2:30	1930	-	-	-	-
3:00	062000	-	-	-	14.5
3:30	2030	15.0	-	-	-
4:00	2100	18.0	18.0	-	-
4:30	2130	20.6	-	-	-
5:00	2200	21.1	-	-	20.0
5:30	2230	21.6	-	-	-
6:00	2300	22.2	-	-	22.0
6:30	2330	23.0	-	-	-
7:00	2400	23.0	24.1	-	23.0
7:30	2430	23.8	-	-	-
8:00	062500	24.6	-	-	25.5
8:30	2530	24.6	-	-	-
9:00	2600	25.0	-	-	25.5
9:30	2630	24.8	-	-	-
10:00	062700	24.8	-	-	25.7
10:30	2730	25.5	-	-	-
11:00	2800	26.0	-	-	25.5
11:30	2830	25.6	-	-	-
12:00	2900	25.9	25.9	-	26.0
12:30	2930	25.7	-	-	-
13:00	063000	25.8	-	-	-
13:30	3030	25.6	-	-	-
14:00	3100	25.3	-	-	25.4
14:30	3130	25.1	-	-	-
15:00	3200	24.8	-	-	25.8
15:30	3230	25.0	-	-	-
16:00	3300	25.4	-	-	25.8
16:30	3330	25.0	-	-	-
17:00	3400	25.4	25.7	-	-
17:30	3430	25.4	-	-	-
18:00	063500	25.3	-	-	-
18:30	3530	25.2	-	-	-
19:00	3600	25.3	-	-	-
19:30	3630	25.2	-	-	-
20:00	063700	25.3	-		
20:30	3730	25.3	-		
21:00	3800	25.1	-		
21:30	3830	25.3	-		
22:00	3900	25.3	25.6		
22:30	3930	25.4	-		
23:00	064000	23.6	-		
23:30	4030	24.2	-		
24:00	4100	24.4	-		
24:30	4130	24.7	-		
25:00	4200	24.6	-		
25:30	4230	24.5	-		
26:00	4300	24.3	-		
26:30	4330	24.3	-		
27:00	4400	24.1	-		
27:30	4430	24.1	-		
28:00	064500	24.1	24.9		
28:30	4530	24.1	-		
29:00	4600	24.1	-		
29:30	4630	24.3	-		
30:00	064700	24.4			
30:30	064730	24.1			
31:00	4800	23.9			
31:30	4830	23.7			
32:00	4900	23.4			
32:30	4930	23.0			
33:00	065000	23.5			
33:30	5030	24.8			
34:00	5100	24.4	23.1		
34:30	5130	23.9			
35:00	5200	23.6			
35:30	5230	23.5			
36:00	5300	23.4			
36:30	5330	23.5			
37:00	5400	23.5			
37:30	5430	23.5			
38:00	065500	23.5			
38:30	5530	23.5	22.6		
39:00	5600	23.4			
39:30	5630	23.3			
40:00	065700	23.3			
40:30	5730	23.2			
41:00	5800	23.2			
41:30	5830	22.2			
42:00	5900	22.1			
42:30	5930	22.8			
43:00	070000	23.1			
43:30	0030	22.9			
44:00	0100	22.5			
44:30	0130	22.1			
45:00	0200	22.1	22.2		
45:30	0230	22.1			
46:00	0300	22.1			
46:30	0330	22.0			
47:00	0400	22.0			
47:30	0430	22.0			
48:00	070500	22.1			
48:30	0530	22.1			
49:00	0600	22.1			
49:30	0630	22.1			
50:00	070700	22.1			
50:30	0730	22.1			
51:00	0800	22.1			
51:30	0830	22.1			
52:00	0900	22.4			
52:30	0930	22.1			
53:00	071000	21.8			
53:30	1030	21.5			
54:00	1100	21.6			
54:30	1130				
55:00	1200				
55:30	1230				
56:00	1300				
56:30	1330				
57:00	1400				
57:30	1430				
58:00	071500				
58:30	1530				
59:00	1600				
59:30	[illegible]				
60:00	1700				

[redacted] SE[redacted]RET
[redacted]
A[redacted]Energy Act—[redacted]46
~~Specific[redacted]~~



[redacted]
Atomic Energy Act — 1946
[redacted]
X-RAY DAY
Elevation Angles of Top of Atomic Cloud
Mt. Mc Kinley
Albemarle
Bairoko
MINUTES→
Elevation Angles→
Cloud Top Reached Highest Point
Break Probably Caused by Shift of Aiming Point Because of Changing Shape of Cloud
Elevation Angles each Minute
Minute — Angle
1 — 3.5
2 — 10.0
3 — 14.5
4 — 18.0
5 — 20.4
6 — 22.2
7 — 23.6
8 — 24.6
9 — 25.3
10 — 25.7
11 — 25.9
12 — 26.0
12.5 — 26.0
[redacted]
RESTRICTED DATA
Atomic Energy Act — 1946
[redacted]

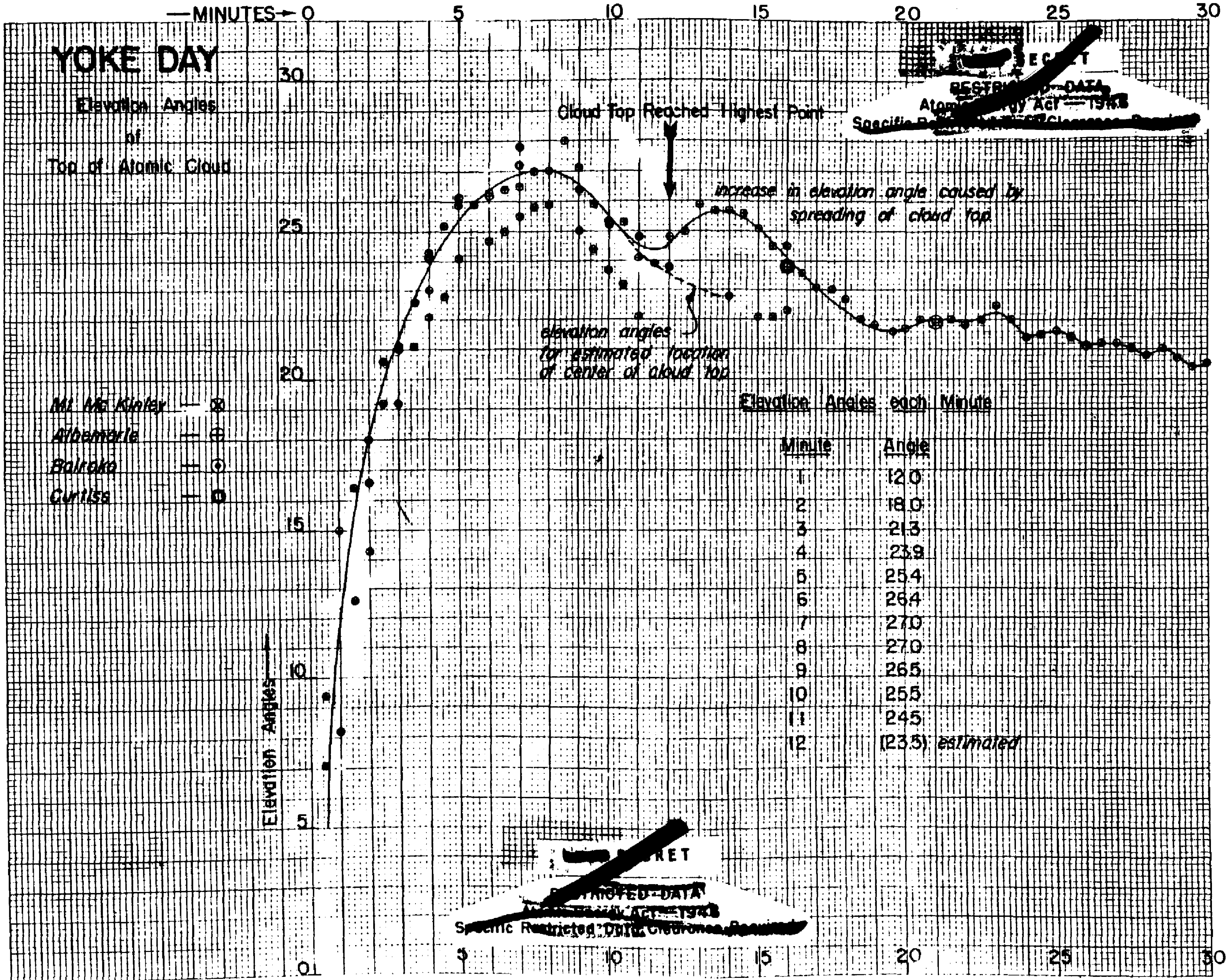
YOKE DAY

Highest Point — Elevation Angle

[redacted] SECRET
RESTRICTED DATA
Atomic Energy Act — 1946
Specific Restricted Data Clearance Required

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:00	060900	-	-	-	-
0:30	0930	09.4	07.1	-	-
1:00	061000	15.0	-	-	08.2
1:30	1030	16.4	-	-	12.6
2:00	1100	18.0	16.6	17.2	14.3
2:30	1130	20.6	-	-	19.2
3:00	1200	21.1	20.95	-	19.2
3:30	1230	22.6	-	-	21.1
4:00	1300	23.0	24.33	24.1	22.1
4:30	1330	25.2	-	-	22.8
5:00	1400	25.9	26.12	-	24.1
5:30	1430	25.9	-	-	-
6:00	061500	26.3	-	26.[illegible]	24.7
6:30	1530	26.4	-	-	25.0
7:00	1600	26.5	27.82	-	25.5
7:30	1630	27.0	-	-	25.8
8:00	1700	27.0	-	27.[illegible]	25.9
8:30	1730	28.0	-	-	-
9:00	1800	27.1	26.42	-	25.0
9:30	1830	25.9	-	-	24.4
10:00	1900	25.2	-	25.[illegible]	23.7
10:30	1930	25.3	-	-	23.2
11:00	062000	24.1	24.82	-	22.1
11:30	2030	23.9	-	-	-
12:00	062100	24.8	-	23.8	-
12:30	2130	25.0	-	-	-
13:00	062200	25.9	-	-	-
13:30	2230	25.7	-	-	-
14:00	062300	25.7	-	22.8	-
14:30	2330	25.6	-	-	-
15:00	062400	25.1	-	-	22.1
15:30	2430	24.5	-	-	22.1
16:00	062500	23.8	24.53	23.8	21.3
16:30	2530	23.6	-	-	-
17:00	2600	23.1	-	-	-
17:30	2630	23.0	-	-	-
18:00	2700	22.7	-	-	-
18:30	2730	22.0	-	-	-
19:00	2800	21.8	-	-	-
19:30	2830	21.6	-	-	-
20:00	2900	21.7	-	-	-
20:30	2930	22.0	-	-	-
21:00	063000	21.9	21.9	-	-
21:30	3030	22.0	-	-	-
22:00	063100	21.8	-	-	-
22:30	3130	22.0	-	-	-
23:00	3200	22.5	-	-	-
23:30	3230	22.0	-	-	-
24:00	3300	21.4	-	-	-
24:30	3330	21.5	-	-	-
25:00	3400	21.6	-	-	-
25:30	3430	21.4	-	-	-
26:00	063500	21.1	-	-	-
26:30	3530	21.2	-	-	-
27:00	3600	21.2	-	-	-
27:30	3630	21.0	-	-	-
28:00	3700	20.8	-	-	-
28:30	3730	21.0	-	-	-
29:00	3800	20.7	-	-	-
29:30	3830	20.4	-	-	-
30:00	3900	20.5	-	-	-

[redacted] SECRET
RESTRICTED DATA
Atomic Energy Act — 1946
Specific Restricted Data Clearance Required


YOKE DAY
Elevation Angles
of
Top of Atomic Cloud
—MINUTES→
Elevation Angles
Mt. Mc Kinley
Albemarle
Bairoko
Curtiss
Cloud Top Reached Highest Point
increase in elevation angle caused by spreading of cloud top
elevation angles for estimated location of center of cloud top
Elevation Angles each Minute
Minute Angle
1 12.0
2 18.0
3 21.3
4 23.9
5 25.4
6 26.4
7 27.0
8 27.0
9 26.5
10 25.5
11 24.5
12 (23.5) estimated

ZEBRA DAY

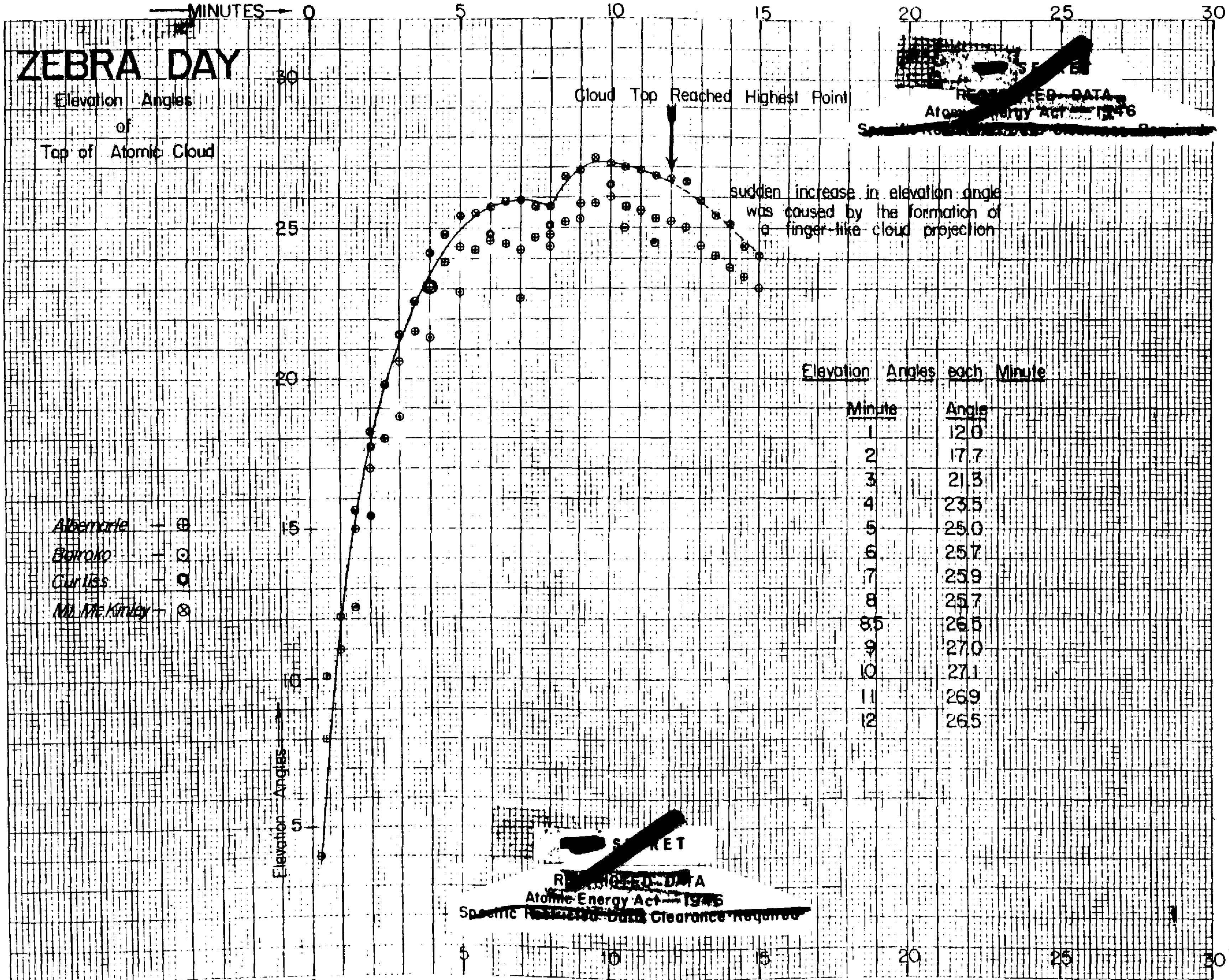
[redacted] SECRET
~~RESTRICTED DATA~~
~~Atomic Energy Act~~
[redacted]

Highest Point — Elevation Angle

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:15	060415	4	-	-	-
0:30	0430	8	10.1	-	-
1:00	060500	11	-	-	12.1
1:30	0530	15	12.4	-	15.6
2:00	0600	17	15.4	17.7	18.2
2:30	0630	18	-	-	19.8
3:00	0700	20.6	18.7	-	21.5
3:30	0730	21.6	-	-	22.6
4:00	0800	23.1	21.4	23.1	24.2
4:30	0830	23.9	-	-	24.8
5:00	0900	24.4	22.9	-	25.4
5:30	0930	24.3	-	-	25.5
6:00	061000	24.6	-	24.8	25.7
6:30	1030	24.5	-	-	25.9
7:00	1100	24.3	22.7	-	25.9
7:30	1130	24.7	-	-	25.7
8:00	1200	24.8	24.4	25.1	25.7
8:30	1230	25.2	-	-	26.7
9:00	1300	25.8	25.3	-	26.9
9:30	1330	25.8	-	-	27.3
10:00	1400	26.0	-	26.4	27.1
10:30	1430	25.7	25.0	-	27.0
11:00	061500	25.6	-	-	26.9
11:30	1530	25.3	24.5	-	26.7
12:00	1600	25.2	-	-	26.6
12:30	1630	25.0	-	-	26.5
13:00	1700	24.4	-	-	25.9
13:30	1730	24.1	-	-	25.4
14:00	1800	23.7	-	-	25.1
14:30	1830	23.4	-	-	24.4
15:00	1900	23.0	-	-	24.1

[redacted] SECRET
~~RESTRICTED DATA~~
~~Atomic Energy Act — 1954~~
[redacted]

ZEBRA DAY



Elevation Angles each Minute

Minute	Angle
1	12.0
2	17.7
3	21.3
4	23.5
5	25.0
6	25.7
7	25.9
8	25.7
8.5	26.5
9	27.0
10	27.1
11	26.9
12	26.5

[redacted] SECRET
~~RESTRICTED DATA~~
~~Atomic Energy Act — 1946~~
~~Specific Restricted Data Clearance Required~~

XRAY DAY

Highest Point — Azimuth Angle

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:00	061700	-	-	-	-
0:30	1730	-	-	-	-
1:00	1800	-	338.5	-	342.0
1:30	1830	-	-	No	-
2:00	1900	-	-	Data	343.0
2:30	1930	-	-	"	-
3:00	062000	-	-	-	344.0
3:30	2030	-	-	-	-
4:00	2100	-	330.7	-	-
4:30	2130	-	-	-	-
5:00	2200	-	-	-	345.0
5:30	2230	343.0	-	-	-
6:00	2300	345.0	-	-	346.0
6:30	2330	345.0	-	-	-
7:00	2400	346.0	339.5	-	[illegible]
7:30	2430	346.0	-	-	-
8:00	2500	344.0	-	-	352.0
8:30	2530	346.0	-	-	-
9:00	2600	348.0	-	-	353.0
9:30	2630	349.0	-	-	-
10:00	062700	350.0	-	-	353.8
10:30	2730	351.0	-	-	-
11:00	2800	351.0	-	-	354.4
11:30	2830	353.0	-	-	-
12:00	2900	354.0	346.6	-	356.4
12:30	2930	356.0	-	-	-
13:00	063000	357.0	-	-	-
13:30	3030	355.0	-	-	-
14:00	3100	355.0	-	-	002.0
14:30	3130	358.0	-	-	-
15:00	3200	358.0	-	-	002.2
15:30	3230	355.0	-	-	-
16:00	3300	357.0	-	-	-
16:30	3330	359.0	-	-	-
17:00	3400	359.0	356.7	-	-
17:30	3430	360.0	-	-	-
18:00	063500	357.0	-	-	-
18:30	3530	360.0	-	-	-
19:00	3600	360.0	-	-	-
19:30	3630	003.0	-	-	-
20:00	063700	003.0	-	-	-
20:30	3730	005.0	-	-	-
21:00	3800	007.0	-	-	-
21:30	3830	007.0	-	-	-
22:00	3900	008.0	357.4	-	-
22:30	3930	008.0	-	-	-
23:00	064000	009.0	-	-	-
23:30	4030	009.0	-	-	-
24:00	4100	009.0	-	-	-
24:30	4130	009.0	-	-	-
25:00	4200	010.0	-	-	-
25:30	4230	011.0	-	-	-
26:00	4300	012.0	-	-	-
26:30	4330	013.0	-	-	-

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
27:00	4400	014.0	-	-	-
27:30	4430	014.0	-	-	-
28:00	064500	014.0	005.9	-	-
28:30	4530	014.0	-	-	-
29:00	4600	015.0	-	-	-
29:30	4630	015.0	-	-	-
30:00	064700	015.0	-	-	-
30:30	4730	015.0	-	-	-
31:00	4800	014.0	-	-	-
31:30	4830	016.0	-	-	-
32:00	4900	016.0	-	-	-
32:30	4930	017.0	-	-	-
33:00	5000	017.0	-	-	-
33:30	5030	018.0	-	-	-
34:00	5100	018.0	011.1	-	-
34:30	5130	018.0	-	-	-
35:00	5200	018.0	-	-	-
35:30	5230	019.0	-	-	-
36:00	5300	021.0	-	-	-
36:30	5330	021.0	-	-	-
37:00	5400	021.0	-	-	-
37:30	5430	021.0	-	-	-
38:00	5500	021.0	-	-	-
38:30	5530	021.0	009.0	-	-
39:00	5600	021.0	-	-	-
39:30	5630	021.0	-	-	-
40:00	065700	024.0	-	-	-
40:30	5730	024.0	-	-	-
41:00	5800	023.0	-	-	-
41:30	5830	024.0	-	-	-
42:00	5900	024.0	-	-	-
42:30	5930	025.0	-	-	-
43:00	070000	025.0	-	-	-
43:30	0030	027.0	-	-	-
44:00	0100	027.0	-	-	-
44:30	0130	026.0	-	-	-
45:00	0200	026.0	033.0	-	-
45:30	0230	027.0	-	-	-
46:00	0300	027.0	-	-	-
46:30	0330	027.0	-	-	-
47:00	0400	028.0	-	-	-
47:30	0430	028.0	-	-	-
48:00	070500	029.0	-	-	-
48:30	0530	029.0	-	-	-
49:00	0600	029.0	-	-	-
49:30	0630	029.0	-	-	-
50:00	070700	030.0	-	-	-
50:30	0730	031.0	-	-	-
51:00	0800	031.0	-	-	-
51:30	0830	030.0	-	-	-
52:00	0900	030.0	-	-	-
52:30	0930	031.0	-	-	-
53:00	071000	031.0	-	-	-
53:30	1030	031.0	-	-	-
54:00	1100	029.0	-	-	-

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Highest Point — Azimuth Angle

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:00	060900	-	-	-	-
0:30	0930	350.0	359.5	-	-
1:00	061000	352.0	-	-	-
1:30	1030	354.0	-	-	-
2:00	1100	355.0	358.0	356.0	-
2:30	1130	355.0	-	-	-
3:00	1200	356.0	356.7	-	-
3:30	1230	357.0	-	-	-
4:00	1300	357.0	-	357.0	-
4:30	1330	358.0	-	-	-
5:00	1400	359.0	-	-	-
5:30	1430	360.0	-	-	-
6:00	061500	360.0	-	007.0	-
6:30	1530	003.0	-	-	-
7:00	1600	004.0	-	-	-
7:30	1630	004.0	-	-	-
8:00	1700	007.0	-	014.0	-
8:30	1730	006.0	-	-	-
9:00	1800	007.0	006.9	-	-
9:30	1830	010.0	-	-	-
10:00	1900	009.0	-	015.0	-
10:30	1930	012.0	-	-	-
11:00	062000	012.0	006.2	-	-
11:30	2030	013.0	-	-	-
12:30	2130	008.0	-	-	-
13:00	062200	007.0	-	-	-
13:30	2230	008.0	-	-	-
14:00	062300	010.0	-	022.0	-
14:30	2330	012.0	-	-	-
15:00	062400	013.0	-	-	-
15:30	2430	012.0	-	-	-
16:00	062500	011.0	011.4	011.0	-
16:30	2530	011.0	-	-	-
17:00	2600	011.0	-	-	-
17:30	2630	010.0	-	-	-
18:00	2700	011.0	-	008.0	-
18:30	2730	010.0	-	-	-
19:00	2800	011.0	-	-	-
19:30	2830	010.0	-	-	-
20:00	2900	010.0	-	019.0	-
20:30	2930	011.0	-	-	-
21:00	063000	012.0	016.5	-	-
21:30	3030	010.0	-	-	-
22:00	063100	012.0	-	012.0	-
22:30	3130	011.0	-	-	-
23:00	3200	012.0	-	-	-
23:30	3230	012.0	-	-	-
24:00	3300	010.0	017.0	018.0	-
24:30	3330	012.0	-	-	-
25:00	3400	014.0	-	-	-
25:30	3430	013.0	-	-	-
26:00	063500	014.0	-	010.0	-
26:30	3530	013.0	-	-	-
27:00	3600	014.0	019.2	-	-
27:30	3630	014.0	-	-	-
28:00	3700	014.0	-	011.0	-
28:30	3730	014.0	-	-	-
29:00	3800	014.0	-	-	-
29:30	3830	016.0	-	-	-
30:00	3900	015.0	027.0	012.0	-

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ecific Re[redacted] Clearance Required

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At [redacted]
S[redacted]

ZEBRA DAY

Highest Point — Azimuth Angle

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:15	060415	005	-	-	-
0:30	0430	006	010.7	-	-
1:00	060500	004	-	-	-
1:30	0530	003	011.5	-	-
2:00	0600	004	011.9	004.0	-
2:30	0630	005	-	-	-
3:00	0700	006	-	-	-
3:30	0730	005	-	-	-
4:00	0800	006	013.0	009.0	-
4:30	0830	006	-	-	-
5:00	0900	006	015.0	-	-
5:30	0930	010	-	-	-
6:00	061000	011	-	007.0	-
6:30	1030	011	018.9	-	-
7:00	1100	010	017.0	-	-
7:30	1130	010	-	-	-
8:00	1200	-	016.7	011.0	-
8:30	1230	-	-	-	-
9:00	1300	-	018.6	-	-
9:30	1330	-	-	-	-
10:00	1400	-	-	014.0	-
10:30	1430	-	022.0	-	-
11:00	061500	-	-	-	-
11:30	1530	-	026.6	-	-

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Left Side of Primary Portion — Azimuth Angle

Minutes	Time	Albemarle	Beiroko	Curtiss	McKinley
0:00	061700	-	-	-	-
0:30	1730	-	-	-	-
1:00	1800	-	-	-	-
1:30	1830	-	-	-	-
2:00	1900	-	-	-	-
2:30	1930	334.5	-	-	-
3:00	062000	-	-	-	-
3:30	2030	-	-	-	-
4:00	2100	-	-	-	-
4:30	2130	-	-	-	-
5:00	2200	-	-	-	-
5:30	2230	335.5	-	-	-
6:00	2300	336.0	-	-	-
6:30	2330	-	-	-	-
7:00	2400	339.5	-	-	-
7:30	2430	-	-	-	344.0
8:00	2500	335.5	-	-	-
8:30	2530	-	-	-	346.0
9:00	2600	342.0	-	-	-
9:30	2630	-	-	-	345.0
10:00	062700	336.5	-	-	-
10:30	2730	341.2	-	-	345.4
11:00	2800	339.5	-	-	-
11:30	2830	339.7	-	-	346.5
12:00	2900	339.5	-	-	-
12:30	2930	338.5	-	-	346.9
13:00	063000	340.7	-	-	-
13:30	3030	339.2	-	-	346.1
14:00	3100	339.0	-	-	-
14:30	3130	339.8	-	-	347.3
15:00	3200	340.5	-	-	-
15:30	3230	342.0	-	-	-
16:00	3300	341.3	-	-	-
16:30	3330	339.8	-	-	-
17:00	3400	344.0	340.5	-	-
17:30	3430	348.8	-	-	-
18:00	063500	-	-	-	-
18:30	3530	-	-	-	-
19:00	3600	344.0	-	-	-
19:30	3630	347.5	-	343.0	-
20:00	063700	346.0	-	-	-
20:30	3730	347.0	-	-	-
21:00	3800	347.3	-	-	-
21:30	3830	347.7	-	-	-
22:00	3900	349.4	341.1	-	-
22:30	3930	350.3	-	-	-
23:00	064000	348.0	-	-	-
23:30	4030	349.4	-	357.0	-
24:00	4100	351.8	-	-	-
24:30	4130	351.0	-	-	-
25:00	4200	348.2	-	-	-
25:30	4230	348.8	-	-	-
26:00	4300	351.3	-	-	-
26:30	4330	352.8	-	-	-
27:00	4400	354.5	-	-	-

Minutes	Time	Albemarle	Beirko	Curtiss	McKinley
27:30	4430	350.0	-	-	-
28:00	064500	348.5	343.3	-	-
28:30	4530	349.6	-	-	-
29:00	4600	348.0	-	-	-
29:30	4630	350.4	-	-	-
30:00	064700	351.5	-	-	-
30:30	4730	351.6	-	-	-
31:00	4800	349.0	-	-	-
31:30	4830	351.3	-	-	-
32:00	4900	351.5	-	-	-
32:30	4930	350.5	-	-	-
33:00	5000	351.4	-	-	343.2
33:30	5030	351.0	-	-	-
34:00	5100	351.9	348.1	-	-
34:30	5130	352.5	-	-	-
35:00	5200	352.0	-	-	-
35:30	5230	352.8	-	-	-
36:00	5300	354.0	-	-	-
36:30	5330	353.5	-	-	-
37:00	5400	354.0	-	-	-
37:30	5430	354.1	-	-	-
38:00	5500	354.5	-	-	-
38:30	5530	354.3	349.3	-	-
39:00	5600	354.2	-	-	-
39:30	5630	355.1	-	-	-
40:00	065700	356.3	-	-	-
40:30	5730	356.6	-	-	-
41:00	5800	355.8	-	-	-
41:30	5830	356.0	-	-	-
42:00	5900	355.9	-	-	-
42:30	5930	356.8	-	-	-
43:00	070000	356.8	-	-	-
43:30	0030	358.2	-	-	-
44:00	0100	359.7	-	-	-
44:30	0130	000.6	-	-	-
45:00	0200	359.5	-	-	-
45:30	0230	002.7	-	-	-
46:00	0300	001.8	-	-	-
46:30	0330	000.3	-	-	-
47:00	0400	001.2	-	-	-
47:30	0430	001.5	-	-	-
48:00	070500	000.4	-	-	-
48:30	0530	359.3	-	-	-
49:00	0600	001.8	-	-	-
49:30	0630	002.8	-	-	-
50:00	070700	002.6	-	-	-
50:30	0730	003.8	-	-	-
51:00	0800	004.3	-	-	-
51:30	0830	007.7	-	-	-
52:00	0900	010.6	-	-	-
52:30	0930	011.0	-	-	-
53:00	071000	007.8	-	-	-
53:30	1030	007.0	-	-	-
54:00	1100	005.8	-	-	-

XRAY DAY

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~~Atomic Energy Act — 1946~~
~~Specific Re[redacted] Data Clearance~~ [redacted]

Right Side of Primary Portion — Azimuth Angle

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:00	061700	-	-	-	-
0:30	1730	-	-	-	-
1:00	1800	-	-	-	-
1:30	1830	-	-	-	-
2:00	1900	-	-	-	-
2:30	1930	341.0	-	-	-
3:00	062000	-	-	-	-
3:30	2030	-	-	-	-
4:00	2100	-	-	-	-
4:30	2130	-	-	-	-
5:00	2200	-	-	-	-
5:30	2230	343.2	-	-	-
6:00	2300	345.5	-	-	-
6:30	2330	-	-	-	-
7:00	2400	346.3	-	-	-
7:30	2430	-	-	-	-
8:00	2500	347.0	-	-	352.0
8:30	2530	-	-	-	-
9:00	2600	348.2	-	-	353.0
9:30	2630	-	-	-	-
10:00	062700	349.7	-	-	353.8
10:30	2730	351.8	-	-	-
11:00	2800	351.0	-	-	354.4
11:30	2830	352.8	-	-	-
12:00	2900	354.5	-	-	356.4
12:30	2930	356.5	-	-	-
13:00	063000	358.0	-	-	-
13:30	3030	357.3	-	-	-
14:00	3100	356.8	-	-	002.0
14:30	3130	357.8	-	-	-
15:00	3200	358.4	-	-	002.2
15:30	3230	000.5	-	-	-
16:00	3300	359.7	-	-	-
16:30	3330	001.0	-	-	-
17:00	3400	002.5	002.1	-	-
17:30	3430	002.5	-	-	-
18:00	063500	-	-	-	-
18:30	3530	-	-	-	-
19:00	3600	004.0	-	-	-
19:30	3630	005.0	-	-	-
20:00	063700	003.5	-	-	-
20:30	3730	008.5	-	-	-
21:00	3800	009.5	-	-	-
21:30	3830	008.5	-	-	-
22:00	3900	007.5	003.4	-	-
22:30	3930	009.7	-	-	-
23:00	064000	009.3	-	-	-
23:30	4030	011.5	-	-	-
24:00	4100	011.0	-	-	-
24:30	4130	010.8	-	-	-
25:00	4200	011.5	-	-	-
25:30	[illegible]230	011.8	-	-	-
26:00	4300	012.7	-	-	-
26:30	4330	013.1	-	-	-
27:00	4400	013.8	-	-	-
27:30	4430	014.0	-	-	-
28:00	064500	013.3	009.6	010.3	-
28:30	4530	014.5	-	-	-
29:00	4600	015.0	-	-	-
29:30	4630	015.2	-	-	-
30:00	064700	014.7	-	-	-
30:30	4730	015.2	-	-	-
31:00	4800	015.0	-	-	-
31:30	4830	016.5	-	-	-
32:00	4900	016.8	-	-	-
32:30	4930	016.7	-	-	-
33:00	5000	018.2	-	-	016.0
33:30	5030	018.4	-	-	-
34:00	5100	018.6	-	-	018.1
34:30	5130	018.4	-	-	-
35:00	5200	019.6	-	-	-
35:30	5230	020.2	-	-	-
36:00	5300	021.7	-	-	-
36:30	5330	021.3	-	-	-
37:10	5400	022.5	-	-	-
37:30	5430	023.2	-	-	-
38:00	5500	022.4	-	-	-
38:30	5530	022.5	019.7	-	-
39:00	5600	021.9	-	-	-
39:30	5630	023.3	-	-	-
40:00	065700	024.1	-	-	-
40:30	5730	025.8	-	-	-
41:00	5800	026.5	-	-	-
41:30	5830	027.2	-	-	-
42:00	5900	027.0	-	-	-
42:30	5930	027.4	-	-	-
43:00	070000	028.0	-	-	-
43:30	0030	028.1	-	-	-
44:00	0100	028.2	-	-	-
44:30	0130	028.3	-	-	-
45:00	0200	028.8	-	-	-
45:30	0230	029.3	-	-	-
46:00	0300	030.9	-	-	-
46:30	0330	031.7	-	-	-
47:00	0400	031.4	-	-	-
47:30	0430	032.8	-	-	-
48:00	070500	033.0	-	-	-
48:30	0530	033.5	-	-	-
49:00	0600	033.0	-	-	-
49:30	0630	033.0	-	-	-
50:00	070700	033.9	-	-	-
50:30	0730	034.4	-	-	-
51:00	0800	034.4	-	-	-
51:30	0830	035.5	-	-	-
52:00	0900	036.0	-	-	-
52:30	0930	035.7	-	-	-
53:00	071000	036.3	-	-	-
53:30	1030	035.2	-	-	-
54:00	1100	033.8	-	-	-

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~~Atomic Energy Act — 1946~~
~~Specific [redacted] Clearance Required~~

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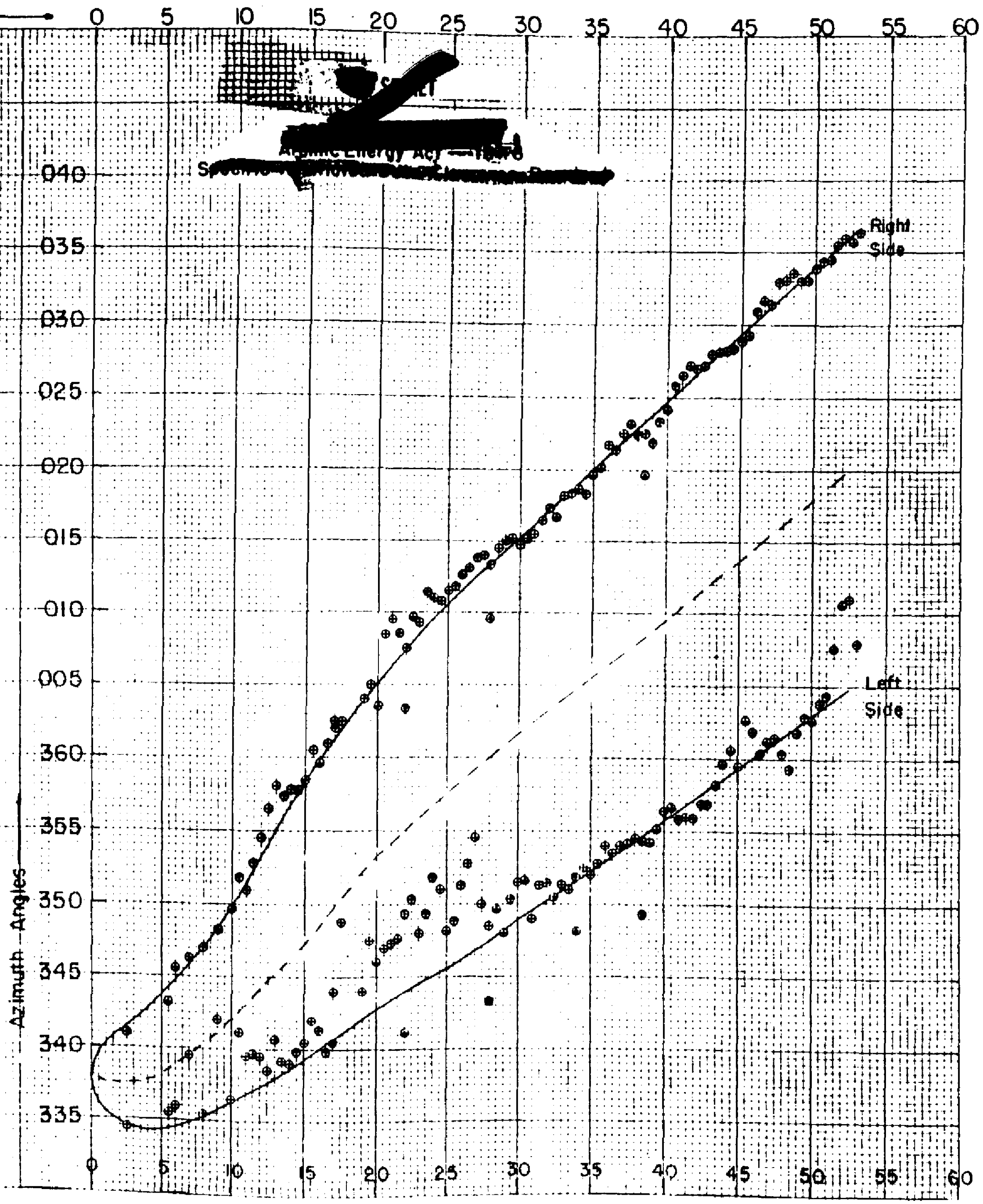
X-RAY DAY

Azimuth Angles of Primary Cloud Mass

Min.	Right Side	Left Side	Center
13	355	338	346
15	358	339	347
20	005	343	353
25	011	345	358
30	016	349	002
35	020	352	006
40	025	356	010
45	030	359	014
50	034	003	018

Albemarle — ⊕

Bairoko — ⊗



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YOKE DAY

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[redacted]—~~Atomic Energy Act of 1946—Specific Restricted Data Clearance Required~~

Left Side of Primary Portion — Azimuth Angle

Minutes	Time	Albemarle	Beiroko	Curtiss	McKinley
0:00	060900	-	-	-	-
0:30	0130	349.0	354.0	-	350.0
1:00	061000	349.0	-	-	349.0
1:30	1030	351.0	-	-	-
2:00	1100	352.0	353.5	352.0	351.0
2:30	1130	351.0	-	-	-
3:00	1200	349.0	353.5	-	350.0
3:30	1230	353.0	-	-	-
4:00	1300	351.0	352.6	346.0	350.0
4:30	1330	351.0	-	-	-
5:00	1400	357.5	354.0	-	350.0
5:30	1430	355.5	-	-	-
6:00	061500	353.4	-	340.0	350.0
6:30	1530	359.5	-	-	-
7:00	1600	356.2	358.4	-	350.0
7:30	1630	353.0	-	-	-
8:00	1700	355.0	-	349.0	352.0
8:30	1730	354.4	-	-	-
9:00	1800	356.0	358.8	-	352.0
9:30	1830	357.3	-	-	-
10:00	1900	356.2	-	-	353.5
10:30	1930	358.0	-	-	-
11:00	082000	358.3	360.0	-	356.0
11:30	2030	359.2	-	-	-
12:00	2100	005.5	-	346.0	H.
12:30	2130	006.5	-	-	-
13:00	062200	006.9	359.5	-	357.0
13:30	2230	007.1	-	-	-
14:00	062300	006.3	-	-	354.0
14:30	2320	008.0	-	-	-
15:00	2400	007.7	-	-	-
15:30	2430	008.0	-	-	-
16:00	062500	008.2	002.0	352.0	-
16:30	2530	007.9	-	-	-
17:00	2600	010.5	-	-	352.0
17:30	2630	009.5	-	-	-
18:00	2700	009.0	-	-	353.0
18:30	2730	009.0	-	-	-
19:00	2800	010.0	-	-	-
19:30	2830	008.3	-	-	-
20:00	2900	010.0	-	356.0	357.0
20:30	2930	010.2	-	-	-
21:00	063000	008.8	357.0	-	357.0
21:30	3030	010.3	-	-	-
22:00	063100	010.2	-	358.0	359.0
22:30	3130	010.2	-	-	-
23:00	3200	010.5	-	-	359.0
23:30	3230	011.0	-	-	-
24:00	3300	009.5	359.0	-	358.0
25:00	3400	011.6	-	-	358.0
25:30	3430	012.8	-	-	-
26:00	063500	012.0	-	014.0	358.0
26:30	3530	013.0	-	-	-
27:00	3600	013.5	009.6	-	357.0
27:30	3630	013.4	-	-	-
28:00	3700	012.3	-	-	355.0
28:30	3730	011.5	-	-	-
29:00	3800	012.5	-	-	357.0
29:30	3830	013.0	-	-	-
30:00	3900	013.1	013.0	-	-

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Right Side of Primary Portion — Azimuth Angle

[redacted] RET
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Atomic Energy Act — 1946
~~Specific Restricted Data Clearance Required~~

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:00	060900	-	-	-	-
0:30	0130	351.0	358.2	-	352.0
1:00	061000	354.0	-	-	353.0
1:30	1030	357.0	-	-	-
2:00	1100	357.0	000.5	360.0	354.0
2:30	1130	357.0	-	-	-
3:00	1200	358.0	002.0	-	356.0
3:30	1230	359.0	-	-	-
4:00	1300	359.0	002.4	-	358.0
4:30	1330	360.0	-	-	-
5:00	1400	003.4	004.0	-	360.0
5:30	1430	005.0	-	-	-
6:00	061500	006.0	-	002.0	002.0
6:30	1530	007.3	-	-	-
7:00	1600	010.3	010.0	-	004.0
7:30	1630	007.8	-	-	-
8:00	1700	011.5	-	004.0	006.0
8:30	1730	010.5	-	-	-
9:00	1800	013.0	012.2	-	007.5
9:30	1830	014.0	-	-	-
10:00	1900	013.7	-	006.0	009.0
10:30	1930	014.5	-	-	-
11:00	062000	015.4	014.0	-	010.0
11:30	2030	020.0	-	-	-
12:00	062100	018.7	-	006.0	012.5
12:30	2130	018.5	-	-	-
13:00	062200	018.1	017.5	-	013.0
13:30	2230	018.3	-	-	-
14:00	062300	019.3	-	012.0	014.0
14:30	2330	020.0	-	-	-
15:00	062400	019.0	-	-	015.0
15:30	2430	020.4	-	-	-
16:00	062500	019.9	020.5	010.0	016.0
16:30	2530	017.5	-	-	-
17:00	2600	021.4	-	-	016.5
17:30	2630	019.9	-	-	-
18:00	2700	020.5	-	018.0	017.5
18:30	2730	019.0	-	-	-
19:00	2800	020.5	-	-	018.0
19:30	2830	019.0	-	-	-
20:00	2900	020.5	-	020.0	019.0
20:30	2930	020.5	-	-	-
21:00	063000	021.4	020.3	-	019.0
21:30	3030	025.9	-	-	-
22:00	063100	022.5	-	021.0	019.5
22:30	3130	022.2	-	-	-
23:00	3200	023.4	-	-	020.0
23:30	3230	023.0	-	-	-
24:00	3300	022.3	023.4	-	021.0
24:30	3330	023.5	-	023.0	-
25:00	3400	024.2	-	-	021.2
25:30	3430	024.5	-	-	-
26:00	063500	023.7	-	024.0	022.0
26:30	3530	025.0	-	-	-
27:00	3600	025.3	024.5	-	022.3
27:30	3630	026.0	-	-	-
28:00	3700	031.0	-	025.0	022.0
28:30	3730	029.2	-	-	-
29:00	3800	026.5	-		024.0
29:30	3830	028.2	-	-	-
30:00	3900	027.8	025.7	032.0	-

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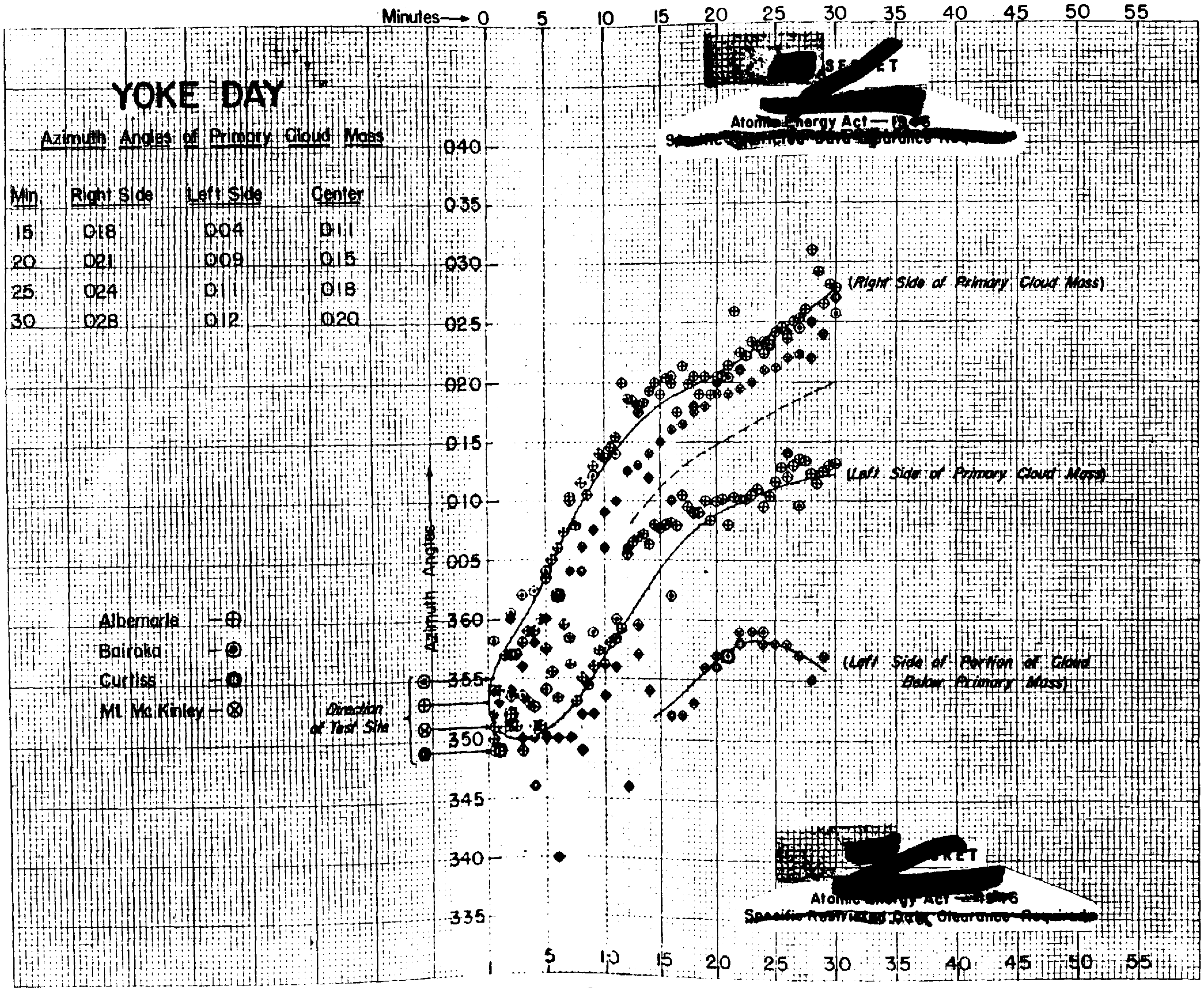
Atomic Energy Act — 1946
~~Specific Restricted Data Clearance Required~~

YOKE DAY

Azimuth Angles of Primary Cloud Mass

Min.	Right Side	Left Side	Center
15	018	004	011
20	021	009	015
25	024	011	018
30	028	012	020



ZEBRA DAY

Left Side of Primary Portion — Azimuth Angle

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:30	060430	002.5	-	-	359.0
1:00	060500	001.3	-	-	358.0
1:30	0530	360.5	006.5	-	358.0
2:00	0600	359.8	006.5	009.0	357.0
2:30	0630	359.9	-	-	-
3:00	0700	359.7	004.5	-	357.0
3:30	0730	359.8	-	-	-
4:00	0800	359.8	004.0	352.0	357.2
4:30	0830	001.8	-	-	-
5:00	060900	000.5	005.5	-	358.0
5:30	0930	001.8	-	-	-
6:00	1000	001.1	-	-	359.2
6:30	1030	002.0	006.0	-	-
7:00	1100	002.9	007.0	-	000.5
7:30	1130	002.9	-	-	-
8:00	1200	005.7	008.0	-	003.2
8:30	1230	006.3	-	-	-
9:00	1300	007.8	005.0	-	004.0
9:30	1330	008.2	-	-	-
10:00	061400	008.5	-	-	006.0
10:30	1430	010.5	-	-	-
11:00	1500	011.0	-	-	008.0
11:30	1530	011.0	008.0	-	-
12:00	1600	013.8	-	-	008.0
12:30	1630	012.4	-	-	-
13:00	1700	013.2	009.0	-	-
13:30	1730	015.9	-	-	-
14:00	1800	016.2	-	-	-
14:30	1830	016.3	-	-	-
15:00	061900	016.5	-	-	-
15:30	1930	016.5	-	-	-
16:00	2000	017.4	006.5	-	-
16:30	2030	017.7	-	-	-
17:00	2100	017.3	-	-	-
17:30	2130	018.0	-	-	-
18:00	2200	018.0	-	-	-
18:30	2230	019.0	-	-	-
19:00	2300	019.5	-	-	-
19:30	2330	020.0	-	-	-
20:00	062400	020.4	-	-	-
20:30	2430	021.0	-	-	-
21:00	2500	021.0	-	-	-
21:30	2530	020.8	-	-	-
22:00	2600	021.9	-	-	-
22:30	2630	020.2	-	-	-
23:00	2700	021.5	-	-	-
23:30	2730	021.5	-	-	-
24:00	2800	022.0	-	-	-
24:30	2830	022.4	-	-	-
25:00	062900	023.2	-	-	-
25:30	2930	024.0	-	-	-
26:00	3000	023.8	-	-	-
26:30	3030	023.8	-	-	-
27:00	3100	024.2	-	-	-
27:30	3130	024.0	-	-	-
28:00	3200	025.4	-	-	-
28:30	3230	-	-	-	-
29:00	3300	025.3	-	-	-
29:30	3330	-	-	-	-
30:00	3400	025.8	-	-	-

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Atomic Energy Act — 1946

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ZEBRA DAY

Right Side of Primary Portion – Azimuth Angle

Minutes	Time	Albemarle	Bairoko	Curtiss	McKinley
0:30	060430	009.2	-	-	001.0
1:00	060500	007.8	-	-	001.0
1:30	0530	007.4	009.0	-	004.0
2:00	0600	008.4	009.5	017.0	-
2:30	0630	008.8	-	-	-
3:00	0700	010.2	013.5	-	005.0
3:30	0730	010.3	-	-	-
4:00	0800	012.0	-	004.0	006.8
4:30	0830	013.1	-	-	-
5:00	0900	015.8	017.0	-	008.0
5:30	0930	015.3	-	-	-
6:00	061000	014.5	-	010.0	010.0
6:30	1030	015.0	018.0	-	-
7:00	1100	015.7	020.0	-	012.5
7:30	1130	016.2	-	-	-
8:00	1200	017.6	021.0	014.0	012.6
8:30	1230	019.0	-	-	-
9:00	1300	020.0	-	-	015.2
9:30	1330	021.0	-	-	-
10:00	1400	021.0	-	-	017.0
10:30	1430	021.3	024.0	-	-
11:00	061500	023.0	-	-	019.0
11:30	1530	024.2	-	-	-
12:00	1600	025.8	-	-	020.0
12:30	1630	026.8	-	-	-
13:00	1700	028.4	029.0	-	021.5
13:30	1730	029.2	-	-	-
14:00	1800	029.8	-	-	022.5
14:30	1830	028.2	-	-	-
15:00	1900	028.9	-	-	023.2
15:30	1930	029.0	-	-	-
16:00	062000	029.8	034.0	-	025.0
16:30	2030	031.1	-	-	-
17:00	2100	029.7	-	-	027.5
17:30	2130	031.4	036.0	-	-
18:00	2200	032.3	-	-	028.5
18:30	2230	032.3	-	-	-
19:00	2300	033.8	-	-	030.0
19:30	2330	034.2	039.5	-	-
20:00	2400	034.5	-	-	030.0
20:30	2430	035.1	-	-	-
21:00	062500	035.3	040.5	-	-
21:30	2530	035.8	-	-	-
22:00	2600	036.0	-	-	-
22:30	2630	036.0	-	-	-
23:00	2700	036.9	045.0	-	-
23:30	2730	037.0	-	-	-
24:00	2800	039.0	-	-	-
24:30	2830	040.0	-	-	-
25:00	2900	038.8	043.0	-	-
25:30	2930	040.5	-	-	-
26:00	3000	038.9	-	-	-
26:30	3030	039.6	046.0	-	-
27:00	3100	039.7	-	-	-
27:30	3130	040.5	-	-	-
28:00	3200	041.3	-	-	-
28:30	3230	-	-	-	-
29:00	3300	040.6	048.0	-	-
29:30	3330	-	-	-	-
30:00	3400	041.5	-	-	-

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A[redacted]ergy Act — 19[redacted]

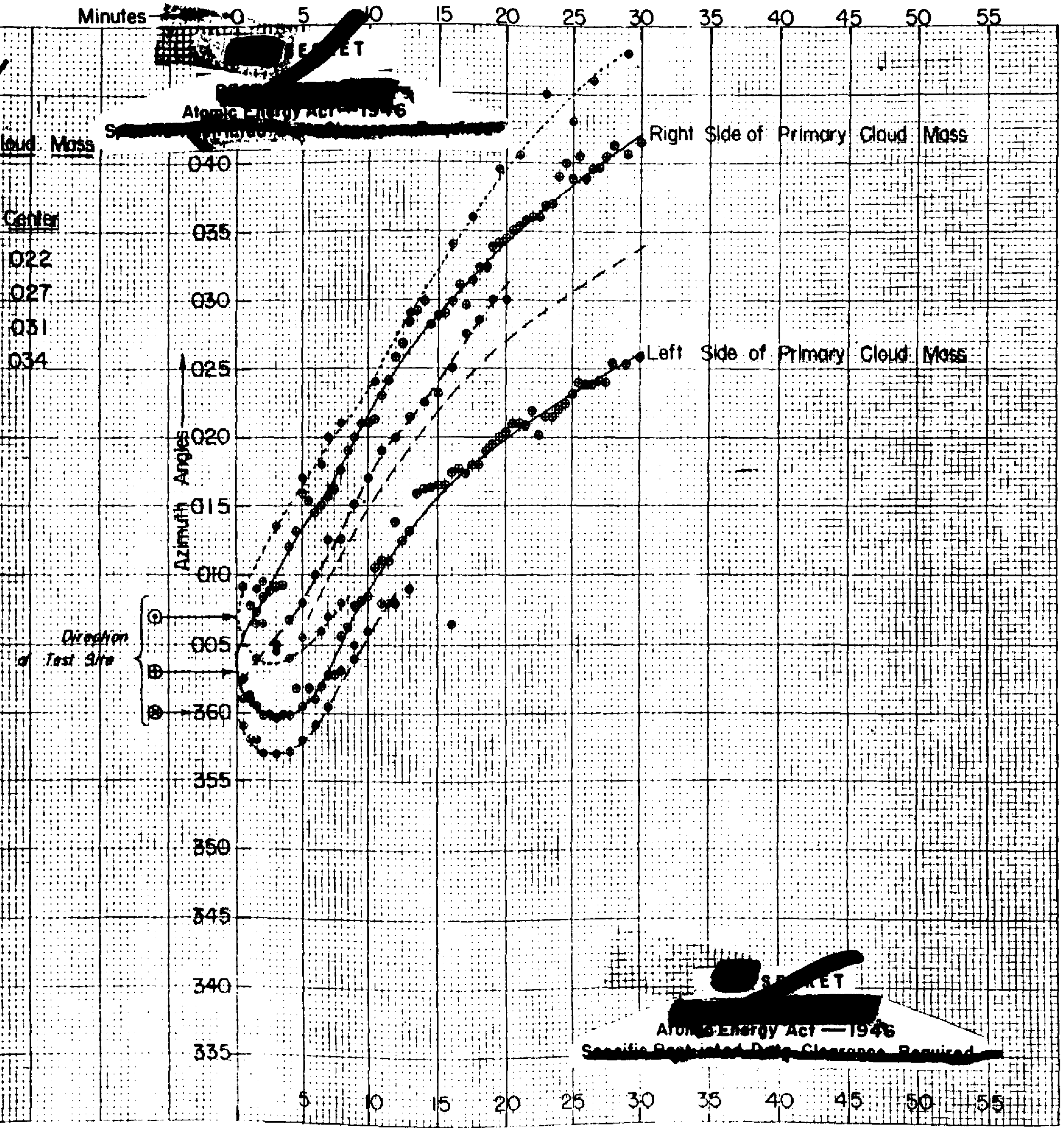
Sp[redacted]Data Clearance Required

ZEBRA DAY

Azimuth Angles of Primary Cloud Mass

Min.	Right Side	Left Side	Center
15	029	016	022
20	034	020	027
25	038	023	031
30	042	026	034

Albemarle — ⊕
Bairoko — ⊙
Mt. Mc Kinley — ⊗



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Atomic Energy Act — 1946
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Atomic Energy Act — 1946
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Appendix II

Meteorological Report on the Visible Atomic Clouds
Operation SANDSTONE

WEATHER OBSERVATIONS FOR TEST PERIODS

SECRET

Table of Contents

Note

Locations of the Observing Stations:

From midnight until H-hour, on all three tests, the four observing ships were anchored in the southeastern part of the Eniwetok Atoll, just west of Parry Island and about three and one half miles north of Eniwetok. After H-hour the movements of the ships were as follows: The U.S.S. Bairoko was charged with responsibility of monitoring for radiological safety purposes and for landing the helicopters. That ship began to move slowly toward the test island at approximately H-hour plus one hour and by mid morning was anchored within a mile or two of the test site. The other three ships departed the observational anchorages on XRAY and YOKE DAYS and one by one proceeded to the new anchorage just off the island where the next weapon would be fired. On XRAY DAY the three ships moved to Aomon, on YOKE DAY they moved to Runit, and on ZEBRA DAY they remained at their anchorages. Therefore, the observations for H-hour are at the locations of the ships and the weather station at Eniwetok rather than at the test sites. Shower areas were widely scattered and small so that on XRAY DAY showers occurred on some ships while not on others; however, other meteorological elements observed are believed to be representative of the entire atoll.

Types and Amounts of Clouds:

Some observers have included the atomic cloud in their observations of natural clouds when the atomic cloud added more than one tenth to the total sky cover. The cirrus and cirrostratus reported on XRAY DAY were to a large extent the remains of the atomic cloud.

Times of Upper Wind and Upper Air Soundings:

The times of the upper wind and upper air soundings are the times the balloons were released. The balloons rise at approximately 1000 feet per minute. Therefore, the average sounding to 60,000 feet should be considered to be representative of the wind at lower levels during the first part of the hour following the time of release and representative of the winds at highest levels at a period of time approximately one hour after the time of release.

SECRET

HOURLY SURFACE WEATHER OBSERVATIONS

XRAY, YOKE, and ZEBRA DAYS

USS Albemarle
USS Bairoko
USS Curtiss
USS Mt. Mc Kinley
USAF Weather Station Eniwetok

ALSO, WEATHER OBSERVATIONS FOR FIVE MINUTE INTERVALS FOR XRAY AND YOKE DAYS AND FOR FIFTEEN MINUTE INTERVALS FOR ZEBRA DAY.

SECRET

ABBREVIATIONS

1. Ceiling (Hnds. of Feet):

"E" means estimated.

Example - "E-20" means ceiling estimated to be 2000 feet.

2. Sky:

"C" means clear
"S" means scattered, 15S means scattered at 1500 feet.
"B" means broken
"O" means overcast

These letters replace the common teletype sumbols ○, ⦶, ⦷, and ⊕, respectively.

"/" signifies that the word high should be used with the symbol that it follows.

Examples - O/, B/, and S/ mean high overcast, high broken, and high scattered, respectively.

"+" means thick or dark.
"-" means thin.

Symbols in combination are read as follows:

-O/S means thin high overcast, lower scattered.
BB means broken, lower broken.
O/+B means high overcast, lower dark broken.
-S/15S means thin high scattered, lower scattered at 1500 feet.

3. Weather:

RW means rain shower
RW- means light rain shower

4. Sea Level Pressure:

"083" means that the sea level pressure was 1008.3 millibars.
"000" means that the sea level pressure was 1000.0 millibars.

5. Wind Velocity:

Wind velocity is in knots unless otherwise stated.

6. Pressure Tendency:

This figure is derived from the trace of the barograph and describes the behavior of the barograph pen during the past three (3) hours. The figures have the following meaning:

(Pressure higher than, or the same as three (3) hours ago.)

0 - Rising, then falling.
1 - Rising, then steady; or rising, then rising more slowly.
2 - Unsteadily rising, or unsteady.
3 - Rising steadily, or steady.
4 - Falling or steady, then rising; or rising, then rising more rapidly.
(Pressure lower than three (3) hours ago)
5 - Falling, then rising.
6 - Falling, then steady; or falling, then falling more slowly.
7 - Falling unsteadily.
8 - Falling steadily.
9 - Steady, or rising, then falling; or falling, then falling more rapidly.

7. Net 3 Hour Pressure Change:

This figure is in millibars and tenths of millibars. Whether this value is plus or minus must be determined from the pressure tendency figure.

8. Amount Low Cloud:

Amount in tenths of low cloud entered in following column. Additional amounts of other low cloud are entered in remarks. (Amounts of middle and high clouds are also in tenths.)

9. Type Low Cloud:

Cu - cumulus

10. Type of Middle Cloud:

Ac - altocumulus
As - altostratus

11. Type of High Cloud:

Ci - cirrus
Cs - cirrostratus

12. Remarks:

PCPN IN SGT means precipitation in sight.

QUADS means quadrants.

20S, 80S, mean scattered clouds at 2000 and 8000 feet, respectively.

SECRET

SECRET

XRAY DAY

SURFACE OBSERVATIONS

Ship or Station USS ALBEMARLE (AV5) Date 15 April 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0100				C		122	79	75	E	7											
0200				C		118	79	75	ESE	7											
0300				C		111	80	74	E	9	9	1.6									
0400				S		109	79	75	E	10			1	Cu	E08						
0500				S		115	79	75	E	8			1	Cu	E08						
0600				S	RW	119	78	77	ENE	12	3	0.8	5	Cu	E06						
0700				S		123	79	74	E	9			5	Cu	E10						
0800				S/S		127	83	75	ENE	11			5	Cu	E10				2	Ci	
0900			E20	S/B		136	87	79	ENE	11	3	1.7	6	Cu	E20				2	Ci	
1000				S/S		136	87	79	E	9			4	Cu	E15				3	Ci	
1100			E10	S/B	RW	136	87	78	E	9			8	Cu	E10				2	Ci	
1200			E15	S/B	RW	136	87	78	E	11	1	0.0	8	Cu	E15				1	Ci	
1300				S/S		127	85	75	ESE	15			3	Cu	E20				2	Ci	
1400				S/S		121	87	75	ESE	12			3	Cu	E25				3	Ci	
1500				S/S		118	83	73	ESE	14	8	1.8	3	Cu	E25				3	Ci	
1600				S/S		110	92	71	E	13			4	Cu	E25				2	Ci	
1700				S/S		112	93	74	E	11			3	Cu	E25				1	Ci	
1800				S/S		114	90	73	ESE	11	5	0.4	2	Cu	E15				2	Ci	
1900				S/S		115	86	72	ESE	15			2	Cu	E25				2	Ci	
2000				S/S		122	87	72	E	14			2	Cu	E25				3	Ci	
2100				S/S		130	81	73	ESE	16	3	1.6	2	Cu	E25				2	Ci	
2200				S/S		133	80	72	ESE	15			4	Cu	E25				1	Ci	
2300				S/S		135	80	72	ESE	14			4	Cu	E25				2	Ci	
2400				S/S		136	80	74	E	16	3	0.6	3	Cu	E25				1	Ci	

SECRET

SECRET

XRAY DAY

SURFACE OBSERVATIONS

Ship or Station USS BAIROKO (VE-115) Date 15 April 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (III)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0000				S/20S		131	80	74	E	6	3	1.0	1	Cu		0			1	Ci	
0100				S/20S		127	80	74	E	7			1	Cu		0			1	Ci	
0200				S/20S		122	80	74	ENE	5			2	Cu		0			2	Ci	
0300				S/20S		118	80	75	E	3	8	1.2	3	Cu		0			2	Ci	
0400				S/20S		115	79	75	E	7			2	Sc		0			3	Ci	
0500				S/20S		117	80	74	ENE	6			1	Sc		0			3	Ci	
0600				S/15S	RW-	122	79	76	NE	9	2	0.4	3	Cu		0			2	Ci	
0700				B/15S		128	80	76	NE	6			3	Cu		1	Ac		3	Ci	
0800				B/15S		130	81	75	NE	5			3	Cu		1	Ac		3	Ci	
0900				B/20S		138	81	76	ENE	7	3	1.6	3	Cu		1	Ac		4	Ci	
1000			E20	B/B		139	81	76	ENE	8			6	Cu		0			2	Ci	
1100				B/20S		139	82	77	ENE	10			5	Cu		0			2	Ci	PCPN IN SGT
1200				O/20S		135	82	77	ENE	10	1	0.2	3	Cu		0			7	Ci	
1300				O/20S		134	83	76	E	14			4	Cu		0			6	Ci	
1400				O/20S		127	83	76	E	13			4	Cu		0			6	Ci	
1500				B/20S		123	83	76	E	12	8	1.2	3	Cu		0			5	Ci	
1600				B/20S		119	82	75	E	12			3	Cu		0			4	Ci	
1700				S/20S		116	81	75	E	9			2	Cu		0			3	Ci	
1800				S/20S		116	81	75	E	12	8	0.4	2	Cu		0			2	Ci	
1900				S/20S		125	81	75	E	12			2	Cu		0			2	Ci	
2000				S/20S		127	81	75	E	15			2	Cu		0			1	Ci	
2100				S/20S		135	81	74	E	15	3	1.8	2	Cu		0			2	Ci	
2200				S/20S		138	81	74	E	15			1	Cu		0			1	Ci	
2300				S/20S		140	80	74	E	15			1	Cu		0			1	Ci	

SECRET

SECRET

XRAY DAY

SURFACE OBSERVATIONS

Ship or Station USS CURTISS (AV 4) Date 15 April 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS. (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0100				S		127	82	74	E	9	0	0.2	2	Cu	E20	0			0		
0200				S		120	80	74	E	8	9	1.0	2	Cu	E20	0			0		
0300				S		117	80	74	ENE	9	8	1.8	2	Cu	E20	0			0		
0400				S		113	80	74	ENE	9	8	1.4	2	Cu	E20	0			0		
0500				S		117	80	75	E	8	5	0.3	2	Cu	E20	0			0		
0600				S		120	80	75	ENE	11	4	0.4	2	Cu	E20	0			0		
0608			E20	B	RW-	120	80	76	ENE	12			8	Cu	E20	0			0		
0613			E15	B		123	80	75	ENE	9			7	Cu	E15	0			0		
0700				S		123	80	75	ENE	9	3	1.0	4	Cu	E15	0			0		
0713			E15	B	RW-				E	12											
0725				S					ENE	11											
0800				S/S		132	81	77	E	9	3	1.5	1	Cu	E15	1	As	E100	1	Ci Cc	
0900				S/S		137	82	75	ESE	12	3	1.7	5	Cu	E15	1	As	E100	2	Ci	
1000				S/S		139	82	76	E	10	3	1.6	3	Cu	E20	0			3	Ci	
1100				B/S		139	84	76	E	11	1	0.7	4	Cu	E20	0			2	Ci	
1200			E20	B/B	RW-	137	82	76	ESE	14	3	0.0	6	Cu	E20	0			6	Ci	
1210				B/S					E	14											
1300				B/S		135	83	75	E	15	9	0.4	1	Cu	E20	0			5	Ci	
1400				B/S		125	84	76	ESE	14	8	1.4	3	Cu	E20	0			3	Ci	
1500				S/S		122	83	75	E	15	8	1.5	2	Cu	E20	0			3	Ci	
1600				S/S		117	83	75	E	13	8	1.8	3	Cu	E20	0			2	Ci	
1700				S		116	82	77	E	13	8	0.9	3	Cu	E20	0			0		
1800				S		114	82	74	E	12	8	0.8	3	Cu	E20	0			0		
1900				S		118	81	74	E	14	4	0.1	2	Cu	E20	0			0		
2000				S		126	81	74	ESE	12	4	1.0	2	Cu	E20	0			0		
2100				S		130	81	74	E	15	3	1.6	2	Cu	E20	0			0		
2200				S		135	81	74	E	14	3	1.7	2	Cu	E20	0			0		
2300				S		137	81	75	E	16	3	1.1	3	Cu	E20	0			0		
2400				S		138	80	74	E	16	3	0.8	2	Cu	E20	0			0		

SECRET

SECRET

XRAY DAY

SURFACE OBSERVATIONS

Ship or Station: USS MT McKINLEY (AGC-7) Date: 15 April 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0030				S/20S		122	81	77	E	1	0	0.7	1	Cu	20				3	Ci	
0130				20S		124	82	75	E	3			3	Cu	20						
0230				20S		118	82	75	E	3			3	Cu	20						
0330				20S		114	80	77	ENE	3	8	0.8	3	Cu	20						
0430				20S		110	81	77	E	4			3	Cu	20						
0530			E20	B		117	81	77	ENE	7			9	Cu	20						RW Began 0541 Ended 0547
0630			E20	S/B		118	81	76	ENE	7	4	0.4	7	Cu	20				2	Ci	
0730				S/20S		123	80	76	E	6			4	Cu	20	1	Ac	80	1	Ci	
0830				S/20S		132	81	75	ESE	8			4	Cu	20				2	Ci	
0930				S/20S		130	83	76	ESE	4	0	1.2	3	Cu	20				2	Ci	
1030			E20	S/B		133	84	79	ENE	4			6	Cu	20				1	Ci	
1130			E15	B		128	84	79	ENE	7			7	Cu Sc	15						RW Began 1120 Ended 1128
1230				S/18S		131	84	77	E	9	4	0.1	5	Cu	18				2	Cs	
1330				S/20S		120	84	76	E	9			2	Cu	20				4	Ci	
1430				S/20S		114	84	76	E	10			4	Cu	20				1	Ci	
1530				S/20S		109	84	75	E	9	8	3.0	3	Cu	20				1	Ci	
1630				S/20S		114	84	75	E	10			3	Cu	20				2	Cs	
1730				S/20S		114	84	75	E	9			2	Cu	20				1	Cs	
1830				S/20S		117	83	75	E	9	4	1.5	2	Cu	20				2	Ci	
1930				S/20S		118	82	75	E	11			2	Cu	20						
2030				C		121	82	75	E	10											
2130				20S		127	82	75	E	12	3	1.0	2	Cu	20						
2230				20S		135	81	75	E	10			1	Cu	20						
2330				20S		134	82	75	E	14			1	Cu	20						

SECRET

XRAY DAY

SURFACE OBSERVATIONS

Ship or Station Eniwetok   Latitude ______   Longitude ______   Date 15 April 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (III)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS. (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY (MPH)	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0000	-	-	-	C	-	132	80	67	ESE	8	3	045	-	-	-	-	-	-	-	-	
0300	-	-	-	C	-	119	80	75	E	8	3	040	-	-	-	-	-	-	-	-	
0600	-	-	E15	0	-	119	75	71	ESE	9	5	005	10	Cu	E15	-	-	-	-	-	
0900	-	-	-	S	-	139	84	75	E	9	3	055	4	Cu	E20	-	-	-	-	-	
1200	-	-	-	S	-	139	83	76	ESE	10E	7	005	5	Cu	E20	-	-	-	-	-	
1500	-	-	-	S	-	122	84	66	E	10	9	050	2	Cu	E20	-	-	-	-	-	
1800	-	-	-	S	-	122	82	68	E	12	3	005	4	Cu	E20	-	-	-	-	-	
2100	-	-	-	S/S	-	135	80	74	E	10	3	040	2	Cu	E20	-	-	-	1	Ci	

SECRET

YOKE DAY

SURFACE OBSERVATIONS

Ship or Station USS Albemarle AV-5

Date 1 May 1948

TIME (LOCAL)	LATITUDE (OLLL)	LONGITUDE (III)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0100				S		104	80	73	ENE	17			2	Cu	E15						
0200				S		098	80	73	E	17			2	Cu	E15						Precip. in sight
0300				S		094	79	73	E	18	7	1.3	1	Cu	E15						
0400				S		085	79	73	E	17			1	Cu	E15						
0500				S		084	79	73	ENE	17			1	Cu	E15						
0600				S		088	79	73	E	17	5	0.6	1	Cu	E15						
0700				S/S		092	80	73	E	17			2	Cu	E15				2	Cs	
0800				S/S		094	81	72	E	17			3	Cu	E20				2	Cs	
0900				S/S		102	81	73	E	18	3	1.4	3	Cu	E20				2	Cs	
1000				S/S		102	83	72	E	17			3	Cu	E20				2	Cs	
1100				S/S		103	84	72	E	18			3	Cu	E25				2	Cs	
1200				S/S		102	85	72	E	17	0	0.0	3	Cu	E25				1	Cs	
1300				S/S		097	87	75	E	15			[illegible]	Cu	E20				1	Cs	
1400				S/S		091	83	72	E	14			4	Cu	E20				1	Cs	
1500				S/S		083	86	73	E	14	8	1.9	3	Cu	E20				2	Cs	
1600				S/S		076	83	72	ENE	16			2	Cu	E20				2	Cs	
1700				S/S		080	86	71	NE	13			3	Cu	E25				1	cc	
1800				S/S		079	85	72	NE	13	[illegible]	[illegible]	3	cu	E25				1	cc	
1900				S/S		083	83	73	ENE	13			4	cu	E25				2	cc	
2000				S/S		089	80	73	ENE	13			3	cu	E15				3	cl	
2100				/S		094	80	73	ENE	13	5	1.5	3	cu	E15						
2200				/S		100	80	74	ENE	14			3	cu	E15						
2215				/S		100	80	74	ENE	16			4	cu	E15						
2300				/S		098	79	73	E	[illegible]			5	cu	E15						RW
2400				/B		097	79	73	E	[illegible]	[illegible]	0.3	7	cu	E12						

SECRET

SECRET

YOKE DAY

SURFACE OBSERVATIONS

Ship or Station USS BAIROKO CVE-115

Date 1 MAY 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (III)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0000				20S		112	80	76	ENE	16	1	0.4	3	Cu							
0100				20S		106	80	73	E	17			2	Cu							
0200				20S		100	80	73	E	16			4	Cu							
0300				20S		096	80	73	ENE	15	3	1.6	3	Cu							
0400				S/20S		091	80	73	ENE	15			2	Cu					1	Cs	
0500				20S		095	80	72	ENE	16			4	Cu							
0600				20S		098	80	73	ENE	17	4	0.6	2	Cu							
0700				B/20S		100	80	70	ENE	14			2	Cu					5	Cs	
0800				S/20S		104	81	71	ENE	17			2	Cu					3	Cs	
0900				S/20S		110	81	71	E	15	3	1.2	2	Cu					2	Cs	
1000				S/20S		112	81	73	ENE	15			3	Cu					1	Cs	
1100				S/20S		112	81	73	ENE	15			3	Cu					1	Cs	
1200				S/20S		105	81	73	ENE	14	3	0.4	3	Cu					1	Cs	
1300				S/20S		105	83	75	ENE	10			3	Cu					1	Cs	
1400				20S		095	83	75	ENE	13			3	Cu							
1500				20S		093	83	75	ENE	14	8	1.2	3	Cu							
1600				20S		090	83	75	ENE	13			3	Cu		1	As				
1700				S/20S		088	83	76	NE	12			3	Cu		1	As				
1800				S/20S		087	83	76	NE	11	8	0.6	3	Cu					1	Cs	
1900				S/20S		090	83	77	NE	11			3	Cu		1	As		1	Cs	
2000				B/20S		097	80	76	NE	11			3	Cu					2	Cs	
2100				S/20S		102	81	73	ENE	11	3	1.4	4	Cu					1	Cs	
2200				20S		104	80	72	NE	11			2	Cu							
2300				20S		104	80	72	ENE	14			2	Cu							

SECRET

SECRET

YOKE DAY

SURFACE OBSERVATIONS

Ship or Station: USS CURTISS AV-4

Date: 1 May 19 48

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0100				S		110	80	74	E	16	9	0.0	3	Cu	E20						
0200				S		100	80	74	E	[illegible]	8	1.1	3	Cu	E20						
0300				S		095	80	72	ENE	16	9	1.5	2	Cu	E20						
0400				S		091	80	73	ENE	17	[illegible]	1.9	3	Cu	E20						
0500				S		091	80	73	E	[illegible]	6	1.0	2	Cu	E20						
0600				S		091	80	72	ENE	17	6	0.4	1	Cu	E20						
0700				S/S		096	80	72	E	[illegible]	4	0.5	2	Cu	E20				4	Ci	
0800				S/s		102	81	73	E	[illegible]	4	1.1	3	Cu	E20				2	Cs	
0900				S		106	81	74	E	19	[illegible]	1.5	4	Cu	E20						
1000				S/S		111	82	73	E	18	[illegible]	1.5	2	Cu	E20				1	Cs	
1100				S/S		107	83	73	E	18	[illegible]	0.5	2	Cu	E20				2	Cs	
1200				S		106	84	74	ENE	15	[illegible]	0.0	3	Cu	E20						
1300				S		103	82	73	NE	[illegible]	8	0.8	3	Cu	E20						
1400				S/S		093	83	73	ENE	[illegible]	8	1.4	2	Cu	E20				2	Cc	
1500				S/S		087	84	74	ENE	15	8	1.9	2	Cu	E20				2	Cc	
1600				S/S		083	84	74	NE	[illegible]	[illegible]	2.0	3	Cu	E20	2	Ac	E150			
1700				S/S		083	85	74	NE	13	[illegible]	1.0	2	Cu	E20	1	Ac	E150			
1800				S/S		083	84	73	NE	[illegible]	[illegible]	0.4	2	Cu	E20	1	Ac	E150	2	Cs	
1900				S/S		085	81	74	NE	[illegible]	[illegible]	0.3	2	Cu	E20				5	Cs	
2000				S/S		093	81	74	NE	13	[illegible]	1.0	3	Cu	E20				5	Cs	
2100				S/S		098	80	74	NE	[illegible]	[illegible]	1.5	2	Cu	E20				3	Cs	
2200				S/S		100	80	74	E	18	[illegible]	1.5	2	Cu	E20				3	Cs	
2300				S/S		102	80	73	NE	16	[illegible]	0.9	2	Cu	E20				2	Cs	
2400				S/S		098	80	75	ENE	19	[illegible]	0.0	3	Cu	E20				3	Cs	

SECRET

SECRET

YOKE DAY

SURFACE OBSERVATIONS

Ship or Station USS MOUNT McKINLEY AGC-7

Date 1 May 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (III)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0030				S/20S		104	80	76	ENE	13	3	0.4	2	Cu	E20				3	Ci	
0130				S/20S		095	80	76	ENE	10			3	Cu	E20				4	Ci	
0230				S/20S		088	80	74	ENE	12			3	Cu	E20				4	Ci	
0330				S/20S		088	80	74	ENE	10	6	1.6	3	Cu	E20				4	Ci	
0430				S/20S		080	80	74	ENE	10			3	Cu	E20				4	Ci	
0530				S/20S		081	80	76	ENE	7			3	Cu	E20				4	Ci	
0630				S/20S		086	80	76	NE	13	5	0.2	5	Cu	E20				4	Ci	
0730				S/20S		089	81	74	ENE	9			3	Cu	E20				4	Ci	
0830				S/20S		096	81	74	ENE	6			3	Cu	E20				3	Ci	
0930				S/20S		102	81	75	ENE	12	3	1.2	3	Cu	E20				3	Ci	
1030				S/20S		101	81	74	ENE	14			2	Cu	E20				4	Ci	
1130				S/20S		098	82	74	ENE	10			2	Cu	E20				3	Ci	
1230				S/20S		091	83	75	ENE	7	9	1.2	1	Cu	E20				3	Ci	
1330				S/20S		085	83	75	ENE	10			2	Cu	E20				3	Ci	
1430				S/20S		081	83	75	ENE	7			2	Cu	E20	2	Ac	E170	3	Ci	
1530				S/20S		077	83	75	NE	9	8	1.4	2	Cu	E20	1	Ac	E100	4	Ci/Cs	
1630				S/20S		071	82	75	ENE	9			2	Cu	E20	2	Ac	E100	2	Ci	
1730				S/20S		072	81	75	NE	10			3	Cu	E20	1	Ac	E100	2	Ci	
1830				20S		074	81	74	NE	10	6	0.3	3	Cu	E20						
1930				S/20S		083	81	75	ENE	7			3	Cu	E20				3	Ci	
2030				20S		087	81	75	NE	10			2	Cu	E20						
2130				18S		092	81	75	NE	9	3	1.8	2	Cu	E18						
2230				18S		091	81	75	ENE	10			2	Cu	E18						
2330				18S		086	81	75	ENE	15			2	Cu	E18						

SECRET

SECRET

YOKE DAY

SURFACE OBSERVATIONS

Ship or Station ENIWETOK

Date 1 May 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY (MPH)	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0000				S		115	80	73	ENE	20	0	020	1	Cu	E20						
0300				S		102	79	73	ENE	10	8	015	3	Cu	E20						
0600				S/S		105	79	72	E	10	8	005	2	Cu	E20						
0900				S		108	82	72	ENE	14	2	005	4	Cu	E20						
1200				S/S		105	85	71	ENE	7	9	005	3	Cu	E20	2	Ac	Ello			
1500				S/S .		085	86	73	ENE	15	8	060	3	Cu	E20						
1800			E20	B/S		081	82	73	ENE	13	6	010	6	Cu	E20						
2100				S/S		098	80	72	ENE	12	3	050	2	Cu	E20						

SECRET

SECRET

ZEBRA DAY

SURFACE OBSERVATIONS

Ship or Station: USS ALBEMARLE AV-5 — Date: 15 May 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0100				S		083	80	75	E	9			1	Cu	E10						
0200				S		076	30	75	E	10			1	Cu	E10						
0300				S		070	80	76	ESE	10	8	1.8	1	Cu	E10						
0400				S		069	80	76	ESE	10			1	Cu	E10						
0500				S		071	80	76	E	10			1	Cu	E10						
0600				B/S		073	80	75	E	10	4	0.3	2	Cu	E10	2	As	E150	9	Cs	
0700				B/S		081	80	73	ESE	12			3	Cu	E20				8	Cs	
0800				O/S		086	82	75	ESE	12			3	Cu	E20				10	Cs	
0900			E20	B/B		093	83	76	E	16	3	2.0	8	Cu	E20				6	Cs	
1000				B/S		095	85	76	SE	13			4	Cu	E20				8	Cs	
1100				B/S		079	85	76	ESE	13			3	Cu	E20				8	Cs	
1200				B/S		095	84	73	ESE	12	0	0.2	3	Cu	E20				7	Cs	
1300				B/S		091	86	76	ESE	13			3	Cu	E20				9	Cs	
1400				B/S		082	85	76	ESE	10			3	Cu	E20				9	Cs	
1500				B/S		075	91	76	E	9	8	2.0	3	Cu	E20	1	As	E120	9	Cs	
1600				B/S		072	90	78	ENE	9			2	Cu	E20	1	As	E120	7	Cs	
1700				B/S		069	92	77	ENE	9			4	Cu	E20	1	Ac	120	8	Cs	
1800				S/S		070	88	76	ENE	12	6	0.5	5	Cu	E25				3	Cs	
1900			E20	S/B		077	88	77	ENE	15			6	Cu	E20	1	As	E120	2	Cs	
2000				S/S		080	82	77	E	15			5	Cu	E15	1	As	E120			
2100				S/S		087	82	77	ENE	15	4	1.7	2	Cu	E15	1	Ac	E120			
2200				S/S		093	82	77	E	15			2	Cu	E15	2	Ac	E100	1	Cc	
2300				B/S		097	82	77	E	14			3	Cu	E15	7	Ac	E100			
2400				B/S		097	82	78	E	15	1	1.0	2	Cu	E15	8	Ac	E100	1	Ci	

SECRET

SECRET

ZEBRA DAY

SURFACE OBSERVATIONS

Ship or Station: USS BAIROKO CVE-115

Date: 15 MAY 19 48

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS. (MBS)	TEMPERATURE (°F)	WET BULB (F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0513				S/S		075	82	77	E	7			1	Cu	E20				3	Cs	
0516				S/S		076	82	77	E	7			1	Cu	E20				3	Cs	
0519				S/S		076	82	77	E	10			1	Cu	E20				3	Cs	
0522				S/S		077	83	77	ENE	7			1	Cu	E20				3	Cs	
0525				S/S		076	83	77	E	7			1	Cu	E20				3	Cs	
0528				S/S		076	83	77	E	7			1	Cu	E20				3	Cs	
0531				S/S		078	83	77	E	9			1	Cu	E20				3	Cs	
0534				S/S		078	82	77	E	8			1	Cu	E20				3	Cs	Towering Cu on Port Bow
0537				S/S		078	82	77	E	7			1	Cu	E20				3	Cs	Tops at 8000
0540				S/S		078	82	77	E	7			1	Cu	E20				3	Cs	Tops at 8000
0543				S/S		078	82	77	E	7			1	Cu	E20				3	Cs	Tops at 8000
0546				S/S		078	82	77	E	6			1	Cu	E20				3	Cs	Tops at 7000
0549				S/S		079	82	77	E	7			1	Cu	E20				3	Cs	
0552				S/S		079	83	78	E	7			2	Cu	E20				3	Cs	Tops at 5000
0555				S/S		079	83	78	E	8			2	Cu	E20				3	Cs	
0558				S/S		079	84	78	ENE	8			2	Cu	E20				4	Cs	
0601				S/S		079	84	78	ENE	8			2	Cu	E20				4	Cs	
0604				B/S		079	84	78	ENE	9			2	Cu	E20				6	Cs	
0607				B/S		079	84	78	ENE	8			3	Cu	E20				6	Cs	
0610				O/S		079	84	78	ENE	6			3	Cu	E20				10	Cs	
0613				O/S		079	82	77	ENE	7			3	Cu	E20				10	Cs	
0616				O/S		080	82	77	ENE	7			3	Cu	E20				10	Cs	TOWERING Cu ALL QUADS
0619				O/S		080	83	78	ENE	7			3	Cu	E20				10	Cs	
0622				O/S		080	83	78	ENE	9			3	Cu	E20				10	Cs	
0625				O/S		080	82	77	ENE	7			3	Cu	E20				10	Cs	
0628				O/S		081	83	78	ENE	7			3	Cu	E20	1	As	E220	10	Cs	
0631				O/S		082	83	78	ENE	8			3	Cu	E20	1	As	E220	10	Cs	

SECRET

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ZEBRA DAY

SURFACE OBSERVATIONS

Ship or Station USS CURTISS AV- 4

Date 15 May 19 48

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (III)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0100				S/S		082	82	75	NE	12	9	0.9	1	Cu	E20	0			3	Cs	
0200				S/S		077	82	75	ENE	11	9	1.7	1	Cu	E20	0			2	Cs	
0300				S/S		072	82	75	ENE	12	8	2.3	1	Cu	E20	0			2	Cs	
0400				S/S		072	82	75	E	12	6	1.0	1	Cu	E20	0			1	Cs	
0500				S/S		073	82	75	E	12	5	0.4	2	Cu	E20	0			3	Cs	
0600				S/S		078	82	76	ENE	12	4	0.6	2	Cu	E20	0			3	Cs	
0700				B/S		082	82	74	E	12	3	1.0	2	Cu	E20	0			7	Ci	
0800				O/S		090	84	75	E	12	3	1.7	3	Cu	E20	0			10	Ci/Cs	
0900				O/S		095	84	76	E	16	3	1.7	5	Cu	E20	0			10	Ci/Cs	
1000				B/S		097	86	75	E	14	3	1.5	3	Cu	E20	0			8	Ci/Cs	
1100				B/S		097	86	75	E	14	1	0.7	2	Cu	E20	0			8	Ci/Cs	
1200				B/S		097	87	75	E	12	1	0.2	4	Cu	E20	0			8	Ci/Cs	
1300				O/S		094	86	75	E	13	9	0.3	3	Cu	E20	0			10	Ci/Cs	
1400				O/S		086	86	75	E	10	9	1.1	4	Cu	E20	0			10	Cs	
1500				O/S		080	85	76	E	9	8	1.7	3	Cu	E20	0			10	Ci/Cs	
1600				B/S		075	87	76	NE	9	8	1.9	4	Cu	E20	0			7	Ci/Cs	
1700				B/S		075	85	76	NE	10	6	1.1	4	Cu	E20	0			8	Ci	
1800				S/S		074	84	77	NNE	14	8	0.6	3	Cu	E20	0			2	Ci	
1900				S/S		078	84	76	NE	17	4	0.3	2	Cu	E20	0			1	Ci	
2000				S/S		084	84	76	ENE	14	4	0.9	1	Cu	E20	0			1	Ci	
2100				S		091	83	77	ENE	15	3	1.7	1	Cu	E20	0			0		
2200				S		095	83	78	ENE	17	3	1.7	2	Cu	E20	0			0		
2300				S/S		100	83	76	ENE	17	3	1.6	1	Cu	E20	5			0		
2400				B/S		101	83	76	ENE	15	3	1.0	1	Cu	E20	6			0		

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SECRET

ZEBRA DAY

SURFACE OBSERVATIONS

Ship or Station USS. MT. MCKINLEY AGC-7

Date 15 May 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS. (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY (MPH)	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0030				S/20S		080	83	76	ENE	5	0	1.1	3	Cu	E20				3	Ci/Cs	
0130				S/20S		078	83	76	ENE	5			2	Cu	E20				2	Ci/Cs	
0230				S/20S		070	82	78	ENE	5			4	Cu	E20				2	Ci/Cs	
0330				S/20S		068	82	79	ENE	4	6	1.2	4	Cu	E20				2	Ci	
0430				S/20S		070	82	79	ENE	3			4	Cu	E20				2	Ci	
0530				S/20S		074	82	79	ENE	3			4	Cu	E20				2	Ci	
0630				B/20S		077	83	76	E	4	4	0.9	3	Cu	E20				6	Ci	
0730				O/20S		084	82	77	E	7			2	Cu	E20				10	Ci	
0830				O/20S		093	83	78	E	7			4	Cu	E20				10	Ci	
0930				O/20S		087	84	77	E	6	3	2.0	4	Cu	E20	1	Ac	E120	10	Ci	
1030				O/20S		097	84	77	ESE	10			2	Cu	E20				10	Ci	
1130				O/20S		097	85	78	ESE	9			2	Cu	E20				10	Ci	
1230				O/20S		095	85	78	ESE	8	7	0.2	3	Cu	E20				10	Ci	
1330				O/20S		089	85	78	E	6			3	Cu	E20				10	Ci	
1430				O/20S		082	86	79	E	3			4	Cu	E20				10	Ci	
1530				B/20S		071	88	80	E	1	8	2.4	1	Cu	E20				9	Ci	
1630				B/20S		071	88	80	ENE	2			2	Cu	E20	3	As/Ac	E90	6	Ci/Cs	90S
1730				B/20S		072	86	75	NE	5			2	Cu	E20	2	As/Ac	E90	8	Ci/Cs	90S
1830				S/20S		075	84	80	ENE	6	2	0.4	3	Cu	E20				5	Ci/Cs	
1930				B/20S		081	83	78	ENE	11			3	Cu	E20	2	As/Ac	E80	6	Ci/Cs	80S
2030				B/20S		087	82	77	ENE	10			3	Cu	E20	2	As/Ac	E80	7	Ci/Cs	80S
2130				S/20S		090	81	77	ENE	10	3	1.5	5	Cu	E20				5	Ci/Cs	
2230			E70	S/B		091	82	78	ENE	9			2	Cu	E20	6	Ac	E70	4	Ci/Cs	20S
2330			E70	S/B		088	82	79	ENE	10			3	Cu	E20	6	Ac	E70	4	Ci/Cs	20S

SECRET

ZEBRA DAY

SURFACE OBSERVATIONS

Ship or Station Eniwetok

Date 15 May 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (III)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS. (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY (MPH)	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0000				B/S		025	81	68	E	5	3	005	3	Cu	E25				5	Cs	
0300				S/S		081	81	74	ENE	10	8	040	3	Cu	E25				2	Cs	
0600				S		081	81	74	E	6	5	010	3	Cu	E25						
0900				O/S		105	83	76	E	8	3	075	5	Cu	E25				5	Cs	
1200				B/S		108	85	69	ESE	10	1	005	3	Cu	E20				6	Cs	
1500				O/S		081	85	75	E	6	8	080	3	Cu	E20				7	Cs	
1800				S/S		068	84	74	E	7	6	030	3	Cu	E20				2	Cs	
2100				S		088	82	78	E	5	3	060	3	Cu	E20						

SECRET

XRAY DAY - Weather Observations at five minute intervals for H-hour

SURFACE OBSERVATIONS

Ship or Station U.S.S. Bairoko - Eniwetok Area　　Latitude ____ Longitude ____　　Date 15 April 19 48

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (III)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0517	—	—		15S		122	81	75	086	10	-	-	5	Cu	15						
0522	—	—		15S		122	81	75	076	10			5	Cu	15						
0527	—	—		15S		123	81	75	073	10			5	Cu	15						
0532	—	—		15S		123	81	75	070	10			5	Cu	15						
0537	—	—		15S		123	80	75	090	11			5	Cu	15						
0542	—	—		15S		123	80	76	093	11			5	Cu	15						
0547	—	—		15S		124	80	76	072	11			5	Cu	15						
0552	—	—		15S		123	80	76	049	11			5	Cu	15						
0557	—	—		15S		123	80	77	041	13			5	Cu	15						
0602	—	—		15S		123	79	76	056	11			5	Cu	15						
0607	—	—	E15	B		123	79	76	038	10			6	Cu	15						
0610	—	—	E15	B	RW	125	79	76	044	9			6	Cu	15						
0612	—	—	E15	B	RW	126	80	77	051	11			6	Cu	15						
0613	—	—	E15	B		125	79	76	057	12			7	Cu	15						
0617	—	—	E15	B		126	79	76	068	14			6	Cu	15						
0619	—	—	E15	B	RW	126	79	76	069	11			6	Cu	15						
0622	—	—		15S		126	79	76	071	9			5	Cu	15						
0627	—	—		15S		126	79	76	070	7			4	Cu	15						
0632	—	—		15S		126	80	77	076	10			4	Cu	15						
0637	—	—		15S		126	80	77	080	11			3	Cu	15	1	AS	-			
0642	—	—		15S		126	80	77	088	11			4	Cu	15	1	AS	-	1	Ci	
0647	—	—	-S/15S			126	80	76	084	11			3	Cu	15	-	-	-	1	Ci	
0652	—	—	-S/15S			126	80	76	081	10			3	Cu	15	-	-	-	1	Ci	
0657	—	—	-S/15S			128	80	76	085	9			2	Cu	15	-	-	-	2	Ci	
0702	—	—	-S/15S			128	80	76	076	10			2	Cu	15	-	-	-	2	Ci	
0707	—	—	-S/15S			128	81	77	078	9			2	Cu	15	-	-	-	2	Ci	
0712	—	—	-S/15S			129	81	76	080	11			2	Cu	15	-	-	-	2	Ci	
0717	—	—	-S/15S			129	81	76	050	12			2	Cu	15	-	-	-	2	Ci	

SECRET

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YOKE DAY - Weather Observations at five minute intervals for H-hour

SURFACE OBSERVATIONS

Ship or Station U.S.S. Bairoko - Eniwetok Area   Latitude ________   Longitude ________   Date 1 May 1948

TIME (LOCAL)	LATITUDE (QLLL)	LONGITUDE (lll)	CEILING (HNDS OF FEET)	SKY	WEATHER	SEA LEVEL PRESS (MBS)	TEMPERATURE (°F)	DEW POINT (°F)	WIND DIRECTION	VELOCITY	PRESSURE TENDENCY	NET 3 HOUR PRESSURE CHANGE	AMOUNT LOW CLOUDS	TYPE LOW CLOUDS	HEIGHT LOW CLOUDS	AMOUNT MIDDLE CLOUDS	TYPE MIDDLE CLOUDS	HEIGHT MIDDLE CLOUDS	AMOUNT HIGH CLOUDS	TYPE HIGH CLOUDS	REMARKS
0515				S			81	72	-	-			4	Cu	E20						Tops Cu 5000, 3000
0520				S			80	73	-	-			3	Cu	E20						Tops Cu 5000, 3000
0525				S			80	72	-	-			4	Cu	E20						Tops Cu 5000, 3000
0530				S			80	72	-	-			3	Cu	E20						Tops Cu 3500
0535				S			80	73	-	-			2	Cu	E20						Tops Cu 3500
0540				S			80	72	065	15			2	Cu	E20						Tops Cu 3500
0545				S			80	72	064	12			2	Cu	E20						Tops Cu 3000
0550				S			80	74	077	14			2	Cu	E20						Tops Cu 3000
0555				S			80	72	078	14			2	Cu	E20						Tops Cu 3000
0600				S			80	73	075	12			2	Cu	E20						Tops Cu 3000
0605				S			80	72	097	15			2	Cu	E20						Tops Cu 3000
0610				S			80	73	066	14			2	Cu	E20						Tops Cu 3500
0615				S			80	72	055	14			4	Cu	E20						Tops Cu 4500, 3000
0620				S			80	73	059	13			4	Cu	E20						Tops Cu 4000, 3000
0625				S			81	74	078	13			4	Cu	E20						Tops Cu 4000, 3000
0630				S			80	72	081	12			4	Cu	E20						Tops Cu 4000, 3000
0635				S/S			80	72	063	12			3	Cu	E20				2	Cs	Tops Cu 4000, 3000
0640				S/S			80	72	078	12			3	Cu	E20				3	Cs	Tops Cu 5000, 3000
0645				S/S			80	73	069	14			3	Cu	E20				5	Cs	Tops Cu 4000, 3000
0650				S/S			80	72	067	12			3	Cu	E20				5	Cs	Tops Cu 4000, 3000
0655				S/S			80	72	060	14			2	Cu	E20				5	Cs	Tops Cu 4000, 3000
0700				S/S			80	71	079	15			2	Cu	E20				5	Cc Cs	Tops Cu 4000, 3000
0705				S/S			80	73	081	13			2	Cu	E20				5	Cc Cs	Tops Cu 4000, 3000
0710				S/S			80	71	055	12			2	Cu	E20				5	Cc Cs	Tops Cu 4000, 3000
0715				S/S			80	72	-	-			2	Cu	E20				5	Cs	Tops Cu 5000, 3000, few 8000
0730				S/S			-	-	-	-			3	Cu	-				4	Ci	--

~~SECRET~~

Zebra Day

Weather Observations for 15 min. intervals for H-hour

Time	Sky	Weather	Amount Low Cld.	Type Low Cld.	Base Low Cld.	Top Low Cld.	Amount Mid. Cld.	Type Mid. Cld.	Height Mid. Cld.	Amount High Cld.	Type High Cld.	Height High Cld.
0600	O/S	-	.2	Cu	1800	2000	-	-	-	1.0	Ci	20,000
0615	O/S	-	.2	Cu	1800	2000	-	-	-	1.0	Ci	20,000
0630	O/S	-	.3	Cu	1800	2000	-	-	-	1.0	Ci	20,000
0645	O/S	-	.3	Cu	1800	2000	-	-	-	1.0	Ci	20,000
0700	O/S	-	.3	Cu	1800	2000	-	-	-	1.0	Ci	20,000
0730	O/S	-	.2	Cu	1800	2000	-	-	-	1.0	Ci	20,000
0830	O/S	-	.4	Cu	1800	2400	-	-	-	1.0	Ci	20,000

UPPER WIND OBSERVATIONS
XRAY, YOKE and ZEBRA DAYS

USS Albemarle
USS Bairoko
USS Curtiss
USS Mt. Mc Kinley
USAF Weather Station Eniwetok

SECRET

XRAY DAY

UPPER WIND OBSERVATIONS

DD - Wind Direction
VV - Velocity (Knots)

Time Local	Eniwetok 0000		Eniwetok 0200		Eniwetok 0300		Eniwetok 0300		Eniwetok 0800		Eniwetok 0900		Eniwetok 1000		Albemarle 1000		Eniwetok 1600		Barioko 1600		Eniwetok 2000		Eniwetok 2100	
	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV
Hgt. In Ft.																								
SURFACE	120	09	090	06	080	08	090	08	090	10	070	14	120	08	100	08	090	11	090	11	100	14	080	11
2000	120	11	100	10	090	11	090	12	100	13	070	20	100	10	090	08	090	15	090	14	070	16	090	16
4000	100	17	100	13	100	10	100	12	100	10	090	20	100	11	110	06	080	16	070	13	090	20	100	22
6000	120	08	120	10	100	09	090	12	110	12	100	22	120	17	110	06	080	12	090	12	100	26	100	20
8000	160	10	130	12	130	11	130	10	110	18	090	20	120	19	100	14	100	18	110	13	090	16	110	14
10000	130	14	140	11	140	10	140	10	130	13	080	14	120	12	040	08	100	14	120	11	100	18	100	10
12000	150	08	150	07	150	07	140	08	120	11	080	10	120	09			110	10	110	09	110	13	100	09
14000	140	06	150	05	170	08	150	08	140	08	070	08	160	09			120	18	120	08	100	16	070	07
16000	150	11	160	10	160	11	170	08	140	09	080	06	140	14			140	10	160	09	040	02	050	05
18000	180	09	190	10	200	07	160	14	140	08	360	06	120	10			110	03	140	03			350	05
20000	190	04	190	07	240	06	180	12	140	02	210	02	270	06			230	08	210	03			310	09
25000	210	13	200	14	250	11	240	10	220	10	120	08	290	06			280	08	260	10			280	09
30000	280	12	270	09	260	13	250	12	210	13			240	15			260	13	270	15			220	19
35000	220	15	220	14	210	21	230	22	210	18			200	12			210	27	220	25				
40000	190	28	190	27	210	28	220	08	220	18			200	37			170	35	140	27			230	12
45000	220	29	220	22	230	25			220	32			200	20			330	22	230	27			210	16
50000	260	16	260	14	230	25			230	18			240	12			240	22	210	23			210	07
60000													210	15					130	10				
70000													050	05										
80000													360	11										

SECRET

UPPER WIND OBSERVATIONS

DD - Wind Direction (Degrees)
VV - Velocity (Knots)

YOKE DAY

Time Local	Eniwetok 0000		Eniwetok 0200		Eniwetok 0300		Albemarle 0300		Bairoko 0400		Eniwetok 0900		Albemarle 1000		Eniwetok 1200		Eniwetok 1500		Bairoko 1600		1600		Eniwetok 2000		Eniwetok 2100	
	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV
Hgt. in Ft.																										
SURFACE	080	14	080	14	090	12	090	14	080	13	070	13	080	16	070	11	080	12	070	16	065	15	080	14	070	12
2000	080	21	080	15	090	21	070	20	080	19	070	18	070	18	070	15	060	18	060	13	065	13	060	18	070	16
3000	080	22	080	15	090	20					070	16					060	15			065	12	060	18	060	13
4000	080	22	080	18	090	17	070	18	080	19	090	10	080	14	070	09	060	11	010	08	050	05	060	12	050	11
5000	080	18	080	20	090	14					170	06					090	08			035	02	060	01	070	09
6000	080	17	080	17	100	13	070	16	090	12	180	08	120	06	160	02	210	10	010	04	040	04	200	04	190	06
7000	080	16	090	11	120	10					120	28					200	12			025	11	200	08	250	07
8000	080	14	100	09	120	09	150	12	130	06	130	29	190	10	190	12	200	12	010	13	020	14	200	06	220	09
9000	090	12	110	11	100	10					150	33					200	11			005	13	200	08	220	10
10000	090	10	110	11	100	10	140	10	130	10	150	34	200	10	180	10	220	07	010	12	010	11	240	04	220	08
11000	090	08	100	09	100	09					110	34					170	04			045	06			170	02
12000	090	08	080	08	090	07	130	08	100	06	090	27	100	02	110	05	090	02	130	03	120	05	240	04	170	05
13000	080	08	060	09	070	06					[illegible]	33					070	03			040	03			170	02
14000	070	07	050	10	060	05	120	12	050	06	080	36	080	08	070	04	090	02	170	03	170	03	180	06	070	03
15000	060	06			020	03					090	25					180	02			150	03			070	05
16000	080	04	030	05	340	02	140	04	090	05	100	24	140	06	130	13	170	02	270	03	275	02	280	01	080	04
17000	100	04	030	03	280	02					110	30					160	04			320	01			120	03
18000	120	04	040	02	220	05	020	08	130	03	180	30	180	02	170	06	170	05	170	03	165	03	360	02	190	08
19000	140	05	140	02	240	08					190	36					190	07			195	08			200	09
20000	170	07	230	04	230	10	070	16	260	06	170	37	170	14	190	09	190	06	190	07	200	06	170	08	230	09
21000	190	09	230	07	220	17					170	51					240	08			230	08			270	08
22000	210	12	220	11	220	20					170	61					250	12			240	12			320	05
23000	220	15	220	15	220	16					180	63					240	14			235	12			320	09
24000	230	17	210	19	220	25					210	61					210	12			230	09			300	09
25000	220	20	210	23	200	22			210	16	250	61	210	12	200	11	210	10	220	06	235	06			140	17
26000	220	22	210	24	200	24					270	45					200	13			225	09			170	17
27000	220	22	200	24	200	18					300	48					190	17			190	14			210	20
28000	210	21	200	23	220	14					280	53					210	23			195	23			210	24
29000	210	19	210	22	230	24					270	44					210	23			205	23			210	26
30000	220	21	210	18	230	31			220	24	270	41	200	18	200	26	210	28	210	29	210	29			210	30
31000	220	25	210	28	230	37											210	33			220	26			210	40
32000	220	31	210	27	230	42											210	45			210	29			210	48
33000	220	45	220	40	220	45											210	48			215	40			220	46
34000	220	48	230	44	220	51											210	53			215	40			220	45
35000	220	48	240	42	220	46			220	45			210	38	230	42	200	54	210	50	205	49			220	52
36000	220	49	250	24	220	43											210	52			205	50			210	55
37000	210	51	250	20	220	44											210	40			215	49			220	56
38000	210	53	250	30	220	46											210	51			215	50			220	52
39000	210	52	240	33	210	48											210	49			205	54			220	46
40000	210	54	230	33	210	43			210	65			210	36	200	24	210	46	190	56	195	56			220	36
41000	210	57	220	36	220	37											210	53			215	48			220	45
42000	220	48	210	35	220	38											210	57			220	50			220	52
43000	220	38	200	34	220	49											220	55			215	49			220	56
44000	230	35	200	34	230	44											220	45			210	49			220	46
45000	220	36			220	38							200	50			220	50	210	51	210	50			220	49
46000	230	31			230	40											220	47			210	50			220	52
47000	240	28			230	40											220	46			230	53			210	45
48000	240	26			220	36											220	46			230	48			200	39
49000					210	38											220	42			240	32			200	38
50000					200	48							210	46			220	39	240	31					200	38
51000					200	45																				
52000					200	45																				
53000					200	40																				
54000					200	31																				
55000					200	35																				

SECRET

UPPER WIND OBSERVATIONS

ZEBRA DAY

DD - Wind Direction (Degrees)
VV - Velocity (Knots)

Time Local	Eniwetok 0000		Eniwetok 0200		Eniwetok 0300		Albemarle 0300		Bairoko 0400		Eniwetok 0600		Eniwetok 0800		Eniwetok 0900		Albemarle 1000		Eniwetok 1200		Eniwetok 1500		Bairoko 1600		Eniwetok 2100	
Hgt. in Ft.	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV
SURFACE	090	09	080	08	080	08	100	10	070	08	080	09	100	08	090	08	120	12	090	10	090	06	090	09	080	09
1000	070	09	090	08	090	13	080	16	080	10	080	12	110	13	090	13	110	16	120	12	100	11	090	10	080	17
2000	090	09	100	11	090	11	080	16	090	12	100	15	110	14	100	15	110	16	120	16	100	11	100	11	090	17
3000	110	10	100	11	100	09	090	16	100	13	100	19	110	14	110	16	120	20	120	18	110	13	130	16	090	16
4000	120	12	110	09	130	07	110	08	110	11	110	14	110	13	110	15	120	16	120	17	140	07	140	21	100	12
5000	140	10	130	07	160	06	120	12	150	06	130	11	110	13	110	12	110	16	140	16	140	13	140	11	110	10
6000	160	07	140	08	170	05	120	12	160	06	130	08	120	11	140	13	110	12	150	13	140	13	140	09	130	07
7000	190	06	160	11	180	07	170	08	190	12	180	11	120	09	160	07	130	12	160	13	160	11	140	11	140	05
8000	200	07	180	13	190	11	180	08	190	12	200	15	180	07	060	08	140	12	160	13	180	07	160	08	140	06
9000	210	10	210	11	220	11	160	08	200	12	200	11	200	09	200	08	160	08	160	09	180	05	200	05	160	09
10000	230	14	220	12	220	11	170	16	220	13	220	11	190	10	200	12	210	12	190	07	180	06	180	08	100	10
11000	220	16	190	14	220	14					220	15	190	11	200	14			190	08	180	11			170	07
12000	220	17	200	15	220	14	210	14	170	08	230	15	190	12	210	15	200	16	190	11	190	13	200	10	200	09
13000	220	17	210	14	220	10					270	08	200	13	220	15			200	12	190	07			120	08
14000	230	14	230	11	220	08	220	16	200	07	240	06	230	10	230	10	210	12	210	10	190	05	180	09	200	06
15000	230	08	230	07	220	07					270	12	240	06	240	07			220	08	190	05			220	04
16000	240	08	220	08	230	10	210	16	240	12	270	16	250	07	260	10			220	05	210	07	210	20	240	07
17000	250	10	230	13	240	16					260	19	250	10	270	12			230	07	220	13			240	11
18000	240	13	230	19	240	18	230	12	250	19	250	16	250	10	270	14			240	10	220	16	220	23	230	14
19000	230	13	230	17	250	17					240	18	250	11	260	20			240	14	240	15			230	15
20000	240	12	240	16	250	19	230	10	250	17	240	16	250	17	260	21			230	16	250	16	260	15	230	15
21000	250	13	250	09	250	20					240	22	240	24	250	19			230	18	240	17			230	14
22000	250	17	250	20	250	21					240	25	240	22	250	22			230	20	230	19			240	14
23000	240	18	250	19	250	23					250	25	250	20	250	24			240	20	240	20			250	15
24000	230	17	250	18	250	22					240	25	260	20	240	29			250	22	240	21			260	15
25000	240	16	240	19	250	21	230	12	230	26	250	27	260	25	250	31			260	23	260	25	250	24	220	18
26000	240	20	240	24	250	26					250	26	250	26	270	33			260	24	270	27			290	22
27000	250	21	240	27	260	30					260	27	250	23	270	36			270	26	270	23			280	24
28000	250	23	250	27	260	35					260	32	260	26	270	37			270	28	280	35			260	25
29000	260	27	260	28	260	38					270	39	260	30	270	39			270	33	270	32			270	22
30000	260	30	260	30	250	41	240	10	250	27	270	43	260	39	270	38			270	36	260	30	270	43	280	20
31000	250	33	250	35	250	44					240	46	260	42	260	38			270	36	260	30			280	26
32000	240	45	250	40	260	42					260	46	260	41	260	36			270	36	280	28			270	26
33000	250	43	250	44	260	38					270	40	260	40	270	36			280	34	300	37			260	28
34000	260	43	260	46	260	45					280	41	260	40	280	35			290	36	300	44			260	31
35000	260	46	260	48	250	50	230	16			280	43	260	40	290	38			290	39	300	40	260	30	270	33
36000	260	52	260	48	280	54					280	49	270	41	290	45			290	42	280	38			270	34
37000	260	50	250	48	280	54					280	46	280	43	300	50			280	46	270	44			280	32
38000	260	49	260	48	280	54					280	58	290	44	290	54			270	46	280	41			280	34
39000	270	50	270	49	280	63					270	61	290	44	290	55			270	44	260	36			260	32
40000	280	51	280	52	280	67					270	72	290	42	290	49			260	38	260	35			270	35
41000	270	53	280	54	270	54					270	61	280	49	280	47			270	39	260	35			280	28
42000	270	54	280	56	270	51					270	50	280	54	270	47			270	40	270	38			290	22
43000	260	56	270	58	260	45					270	36	280	49	270	46			270	40	270	39			290	43
44000	260	54	270	62	260	40					270	35	280	42	270	47			260	35	280	44			290	49
45000	260	53	270	64	260	44					270	35			270	48			250	31	290	50			290	52
46000	270	51	270	65	270	50					260	34			280	48			250	30	280	53				
47000	280	50	260	56	270	55					260	38			280	42			260	30	280	56				
48000	280	50	260	51	270	52					260	43			270	41			270	30	280	50				
49000			260	49	270	56					270	42			260	45			280	36	260	47				
50000					270	64									260	48			270	30	250	44				
51000					260	57									260	49					220	42				
52000					250	51									260	51										
53000					250	50									260	54										
54000					250	50									260	59										
55000					260	47																				
56000					260	41																				

SECRET

UPPER AIR OBSERVATIONS
XRAY, YOKE and ZEBRA DAYS

USS Albemarle

USS Bairoko

USS Curtiss

USS Mt. McKinley

USAF Weather Station Eniwetok

SECRET

XRAY DAY

UPPER AIR OBSERVATIONS

TIME LOCAL

0200 Aircraft Sounding

PPP	TT	U
960	24.0	81
900	20.7	79
850	18.2	78
800	16.3	48
750	13.4	54
700	10.2	46
650	05.9	85
600	01.9	67
550	-01.9	90
500	-06.2	80
450	-10.7	80
400	-12.9	71
350	-16.6	98

0300 Eniwetok

PPP	hhh	TT	U	um
1012	000	27	83	18.6
1000	350	26	80	18.0
863	4600	19	70	11.8
850	5000	19	60	10.0
820	6000	18	30	6.1
805	6600	16	50	8.4
740	8900	14	20	3.8
700	10410	11	40	5.1
674	11500	09	50	6.0
570	15900	00	40	2.9
507	18900	-06	60	3.2
500	19300	-06	50	2.5
447	22200	-11	20	1.0
423	23500	-13	10	X
400	24900	-16	20	0.8
377	36500	-18	10	X
300	31820	-32	X	X
294	32400	-32	X	X
274	34000	-36	X	X
200	40840	-54	X	X
173	43800	-61	X	X
136	48800	-72	X	X

0800 Eniwetok

PPP	hhh	TT	U	um
1013	000	26	87	18.4
1000	370	26	80	17.9
960	1600	23	80	15.5
937	2300	23	80	15.2
864	4600	18	80	12.9
850	5010	18	70	11.8
826	5800	18	60	10.3
730	9300	11	40	5.5
700	10400	10	50	6.1
683	11400	08	60	6.4
605	14300	02	50	4.3
580	15400	01	30	2.1
543	17200	-04	50	3.1
500	19260	-06	30	1.9
482	20200	-07	20	1.2
400	24900	-16	10	X
375	26400	-20	X	X
300	31810	-30	X	X
275	33900	-35	X	X
200	40740	-54	X	X
135	48700	-72	X	X
100	54700	-78	X	X
093	56100	-79	X	X
025	62700	-46	X	X

1000 Bairoko

PPP	hhh	TT	U	um
1014	000	28	73	17.5
1000	400	27	70	16.0
875		17	80	11.4
867		19	60	10.4
850	5020	18	60	10.7
742		11	30	4.1
700	10360	09	40	4.2
613		03	50	4.4
500	19260	-07	X	X
400	X	-17	X	X
300	31700	-33	X	X

1600 Curtiss

PPP	hhh	TT	U	um
1012	000	28	67	16.0
1000	360	28	70	15.5
942		24	90	17.9
898		22	70	11.9
884		26	30	7.8
850	4990	19	60	10.3
788		18	60	9.5
764		16	60	9.7
700	10470	12	60	8.0
646		08	60	6.5
596		05	30	2.9
528		-02	50	3.4
500	19440	-04	40	2.3
448		-09	X	X
400	X	-14	X	X
348		-21	X	X
300	32050	-29	X	X
246		-40	X	X
226		-31	X	X
200	41100	-52	X	X
168		-60	X	X

PPP - Pressure (Mb)
hhh - Height (Ft)

TT - Temperature (C)
U - Relative Humidity (%)

um - Mixing Ratio
X - Missing

SECRET

XRAY DAY

UPPER AIR OBSERVATIONS

1500 Eniwetok

PPP	hhh	TT	U	ww
1011	000	30	66	17.7
1000	340	29	60	17.1
935	2300	22	80	14.5
913	3000	21	60	10.8
890	3700	22	20	4.8
863	4600	20	60	11.3
850	4990	19	60	10.3
805	6600	17	40	7.3
750	8500	14	50	7.8
723	9400	12	50	6.1
700	10380	10	50	6.4
683	11000	09	60	6.2
652	14500	03	30	2.4
543	17200	-02	50	3.1
500	19310	-04	30	1.6
400	25000	-15	10	X
300	31890	-29	X	X
267	34300	-35	X	X
200	40990	-50	X	X
117	X	-74	X	X

2000 Bairoko

PPP	hhh	TT	U	ww
1014	000	28	79	18.9
1000	400	27	70	17.2
850	5050	20	40	8.1
818		19	30	5.6
800		18	40	8.0
725		14	40	6.4
700	10490	11	50	6.2
666		08	50	5.8
576		01	40	3.0
500	19440	-06	50	2.6
439		-11	X	X
400	X	-16	X	X
300	32000	-30	X	X
200	41010	-54	X	X

2100 Eniwetok

PPP	hhh	TT	U	ww
1012	000	27	83	18.7
1000	360	26	80	17.8
914	1800	18	100	14.3
875	4100	18	70	11.4
850	4980	18	60	10.4
709	10000	11	50	6.3
700	10360	10	50	6.1
637	12900	04	60	5.4
536	17500	-04	50	3.1
500	19250	-07	30	1.7
476	20600	-09	20	1.2
417	23900	-15	30	0.8
400	24900	-16	30	1.0
364	27000	-21	X	X
358	27600	-20	X	X
300	31790	-32	X	X
283	33100	-35	X	X
200	40680	-54	X	X
142	47600	-70	X	X

PPP - Pressure (Mb)
hhh - Height (Ft)
TT - Temperature (C)
U - Relative Humidity (%)
ww - Mixing Ratio
X - Missing

SECRET

YOKE DAY

UPPER AIR OBSERVATIONS

PPP - Pressure (Mb)
hhh - Height (Ft)

TT - Temperature (C)
U - Relative Humidity (%)

uu - Mixing Ratio
X - Missing

TIME LOCAL

0300 Eniwetok

PPP	hhh	TT	U	uu
1011	000	26	81	17.2
1000	320	26	80	16.7
850	4950	16	80	11.9
814	6300	12	70	8.2
792	6900	13	20	3.4
732	9100	12	10	2.2
700	10300	10	10	X
674	11300	08	10	X
659	11500	08	20	2.6
610	14000	04	10	1.6
574	15600	01	10	X
545	16500	-01	20	1.5
537	17300	-02	30	2.2
500	19220	-05	20	2.5
480	20200	-07	20	1.1
400	24800	-17	10	X
300	31690	-32	X	X
258	34900	-40	X	X
200	40680	-53	X	X
100	54190	-84	X	X
095	55100	-84	X	X

0900 Eniwetok

PPP	hhh	TT	U	uu
1010	000	28	72	17.3
1000	300	27	70	16.7
949	1800	22	80	15.2
867	4300	18	60	9.5
850	4740	17	60	9.8
809	6300	15	70	10.3
790	7000	13	50	6.1
773	7600	14	20	2.8
760	8100	14	40	5.6
726	9300	12	10	2.2
706	10100	12	10	X
700	10320	11	X	X
573	15700	01	20	1.5
547	16900	00	30	2.1
500	19250	-05	20	1.3
468	21000	-09	X	X
445	22200	-10	X	X
400	24900	-16	X	X
313	30800	-30	X	X

1000 Bairoko

PPP	hhh	TT	U	uu
1011	000	27	77	17.4
1000	320	26	70	16.6
952		22	80	15.4
860		17	70	10.3
850	4650	16	70	9.6
780		14	30	3.2
753		14	50	7.6
740		13	10	X
700	10250	11	X	X
670		09	X	X
602		10	X	X
500	19260	-03	X	X
460		-06	X	X
446		-06	X	X
400		-14	X	X
300	32020	-28	X	X
200	41240	-48	X	X
140		-66	X	X
128		-73	X	X

1500 Curtiss

PPP	hhh	TT	U	uu
1008	000	30	65	17.6
1000	240	28	60	17.2
982	720	24	60	13.3
907	3000	19	70	10.9
879	3900	19	60	9.8
850	4870	17	60	9.5
768	7700	13	50	7.1
757	8100	13	50	6.7
735	8900	10	20	2.9
719	9500	10	20	2.9
700	10240	09	10	X
679	11000	08	X	X
669	11400	09	X	X
500	19170	-06	X	X
400	24800	-16	40	1.1
300	31710	-32	X	X
265	34500	-36	X	X
200	40720	-52	X	X
122	50600	-76	X	X

2100 Eniwetok

PPP	hhh	TT	U	uu
1009	000	27	75	17.0
1000	270	26	70	16.2
953	1700	22	80	14.1
932	2400	22	70	12.8
879	3900	20	70	12.2
850	4900	18	70	11.8
819	5900	16	70	10.5
794	6600	16	30	5.2
746	8600	12	60	7.5
700	10280	10	X	X
642	12600	06	X	X
626	13300	06	X	X
500	19190	-05	X	X
480	20300	-07	X	X
469	20900	-07	X	X
400	24800	-17	40	1.0
300	31650	-32	X	X
279	33300	-36	X	X
200	40610	-54	X	X
130	49200	-73	X	X

PPP - Pressure (Mb)
hhh - Height (Ft)

TT - Temperature
U - Relative Humidity (%)

uu - Mixing Ratio
X - Missing

SECRET

SECRET

ZEBRA DAY

UPPER AIR OBSERVATIONS

TIME LOCAL

0300 Eniwetok

PPP	hhh	TT	U	uu
1008	000	27	84	19.0
1000	240	26	80	17.9
889	3600	20	70	12.3
850	4880	18	50	9.2
745	8600	12	30	4.6
700	10240	10	50	6.2
677	11200	08	60	6.7
650	12200	06	50	5.5
635	12900	07	20	1.9
510	18700	-05	20	1.3
500	19170	-05	10	X
400	24800	-15	X	X
300	31790	-30	X	X
264	34700	-37	X	X
200	40850	-52	X	X
100	54420	-83	X	X
088	56800	-78	X	X

0600 Eniwetok

PPP	hhh	TT	U	uu
1008	000	27	81	18.4
1000	XXX	26	80	17.8
850	4850	18	50	8.7
766	7800	15	50	7.7
700	10240	10	40	5.1
675	11200	08	60	6.7
534	17400	-01	40	3.1
500	19170	-05	50	2.9
465	21300	-08	50	2.6
450	21900	-08	20	1.2
400	24800	-15	10	X
335	29100	-25	X	X
324	29900	-24	X	X
300	31700	-29	X	X
263	34700	-37	X	X
200	40750	-52	X	X
128	49700	-74	X	Y

0900 Eniwetok

PPP	hhh	TT	U	uu
1010	000	29	76	19.8
1000	300	28	70	18.5
850	4970	19	60	9.7
746	8600	14	20	3.4
700	10370	11	50	5.9
673	11400	09	60	7.2
626	13400	05	40	4.4
609	14600	05	20	1.8
531	17700	-01	50	3.9
500	19340	-04	60	3.5
400	25000	-14	20	0.9
300	32010	-27	X	X
269	34100	-34	X	X
200	40700	-52	X	X
106	43400	-80	X	X

1000 Bairoko

PPP	hhh	TT	U	uu
1010	000	29	76	19.3
1000	290	28	70	18.8
923	X	21	80	14.0
850	4980	16	80	10.8
842	X	15	80	10.6
817	X	15	40	6.2
776	X	13	50	7.1
716	X	11	X	X
700	10280	10	X	X
565	X	00	X	X
500	19190	-05	X	X
400	X	-15	X	X
300	31790	-28	X	X
268	X	-32	X	X

1500 Eniwetok

PPP	hhh	TT	U	uu
1008	000	33	61	19.5
1000	240	30	60	17.1
993	500	27	60	14.8
850	4920	19	50	9.7
820	5900	17	40	7.2
728	9200	13	30	4.2
700	10300	11	60	7.4
661	11900	08	60	6.2
637	12800	07	10	1.9
575	15700	02	30	2.4
500	19260	-05	60	3.7
455	22000	-08	40	2.2
415	24000	-13	20	0.9
400	24900	-15	X	X
300	31920	-28	X	X
276	X	-33	X	X
200	40990	-51	X	X
118	51900	-75	X	X

PPP - Pressure (Mb)
hhh - Height (Ft)
TT - Temperature (C)
U - Relative Humidity (%)
uu - Mixing Ratio
X - Missing

SECRET

SECRET

ZEBRA DAY

UPPER AIR OBSERVATIONS

2100 Eniwetok

PPP	hhh	TT	U	uu
1008	000	28	78	18.8
1000	200	28	70	18.2
878	4000	19	70	11.8
850	4920	18	70	10.4
783	7200	15	50	7.1
761	8000	15	40	6.2
700	10300	10	50	6.3
675	11300	09	60	6.7
616	13700	04	X	X
MISDA				
555	16500	-01	X	X
500	19220	-06	X	X
400	24800	-19	20	0.5
300	31660	X	X	X
274	33600	-37	X	X
200	40680	-31	X	X
162	45100	-26	X	X

2200 Bairoko

PPP	hhh	TT	U	uu
1010	000	28	81	19.5
1000	290	27	80	19.0
950	X	22	80	15.5
850	4950	16	70	10.3
760	X	13	30	3.9
732	X	10	30	4.1
700	10250	08	50	5.4
643	X	04	80	6.3
618	X	03	30	2.9
500	19100	-08	70	3.1
447	X	-13	100	3.1
438	X	-15	90	2.5
425	X	-15	60	1.6
400	X	-19	X	X
394	X	-19	X	X
380	X	-20	X	X
300	31520	-33	X	X
200	40420	-55	X	X
150		-69	X	X

0100 Aircraft Sounding

PPP	TT	U
960	23.5	87
900	20.8	71
850	18.2	72
800	17.0	34
750	13.2	59
700	10.2	58
650	7.4	25
600	4.4	31

0145 Aircraft Sounding

PPP	TT	U
650	7.0	14
600	5.0	13
550	1.0	30
500	-2.0	29
450	-6.0	16

0200 Aircraft Sounding

PPP	TT	U
550	-1.1	39
500	-1.6	20
450	-4.0	24
400	-6.5	12
350	-11.8	10

PPP - Pressure (Mb)
hhh - Height (Ft)

TT - Temperature (C)
U - Relative Humidity (%)

uu - Mixing Ratio
X - Missing

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Appendix III

Meteorological Report on the Visible Atomic Clouds

Operation SANDSTONE

METEOROLOGICAL CHARTS
for
TEST PERIODS

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C9-1138, AF

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Table of Contents

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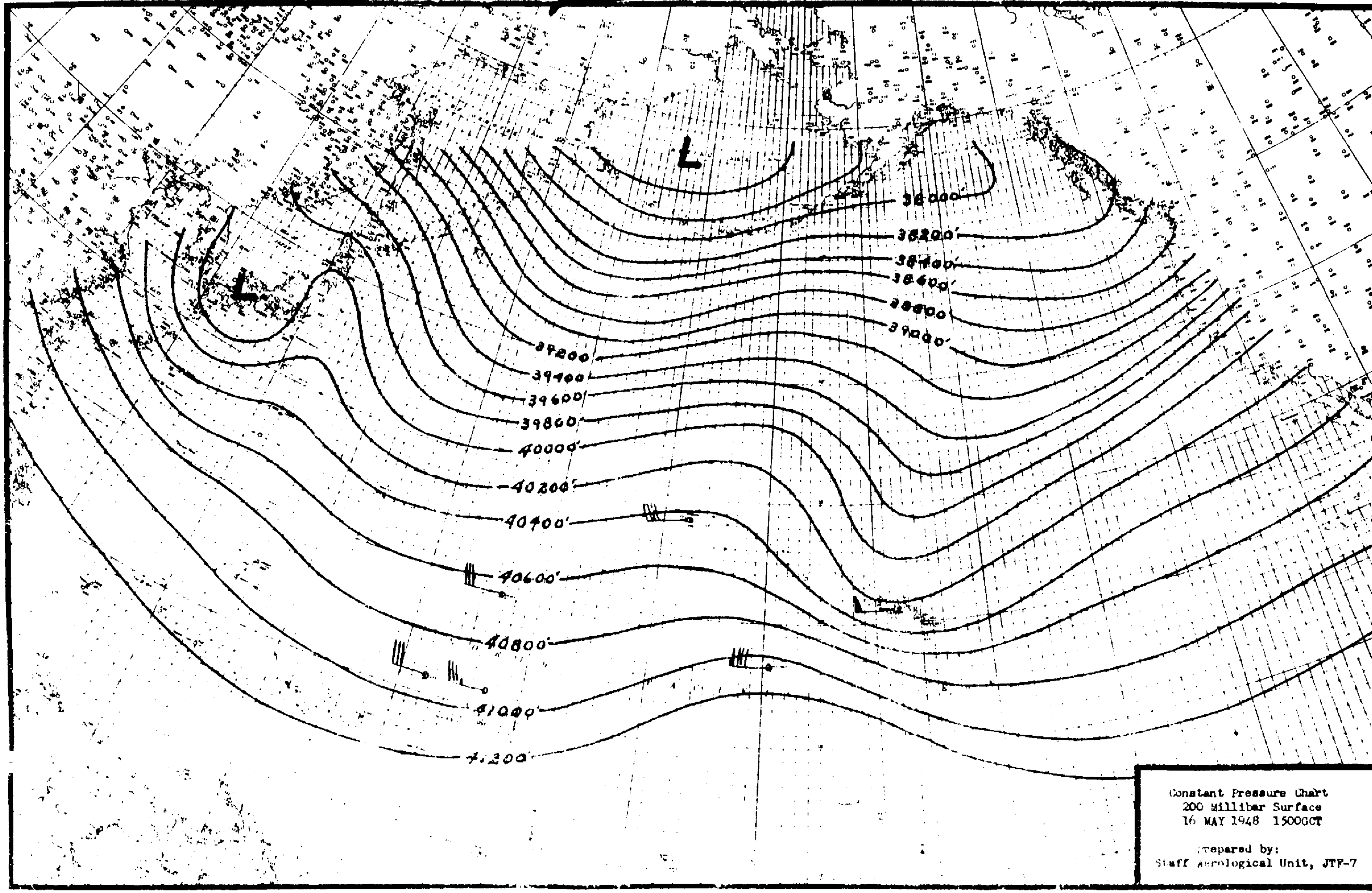
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38000
38200'
38400'
38600'
38800
39000'
39200
39400
39600
39800
40000'
40200'
40400'
40600'
40800'
41000'
4,200'
Constant Pressure Chart
200 Millibar Surface
16 MAY 1948 1500GCT
Prepared by:
Staff Aerological Unit, JTF-7

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Explanatory Note

The following meteorological charts have been included in this appendix because they are useful in arriving at an understanding of the meteorological processes which affected the atomic clouds. The surface charts show the frontal structures and the pressure systems which produced changes in the lowest portions of the atomic clouds, or which influenced cloud observations. The surface charts also permit an estimate of the meteorological phenomena such as clouds or precipitation which may have affected the atomic clouds. The constant level charts show the upper wind circulation up to an altitude of approximately 40,000 feet. These charts show the approximate direction and velocity that each level of the clouds moved.

Data available aboard the U.S.S. Mt. McKinley have been used to construct both the surface and the constant level charts. These charts are traced with slight revision from the working charts used for forecasting during the course of the operation. The forecasting of upper winds during critical periods was accomplished with a high degree of success by the use of the original constant level charts. These charts, as well as the surface charts, are thought to be accurately drawn for the Marshall Islands and vicinity but may be somewhat incorrect in such areas as Japan and the Aleutian Islands because of lack of data.

For ZEBRA DAY, surface charts for two days and upper air charts for three days have been included instead of charts for four days as in the case of XRAY and YOKE days. Forecasting requirements for SANDSTONE diminished with ZEBRA DAY and action was immediately started to move men and equipment out of the operational area. After drawing the charts included in this report, the meteorological staff no longer had available sufficient data from the special observational network.

Further study is being made in detail of the meteorological conditions which affected the atomic clouds. It is believed that the atomic cloud material moved along isentropic surfaces rather than along constant level or constant pressure surfaces. The probability of movement along isentropic surfaces has been made the subject of a current research project sponsored by the Air Force.

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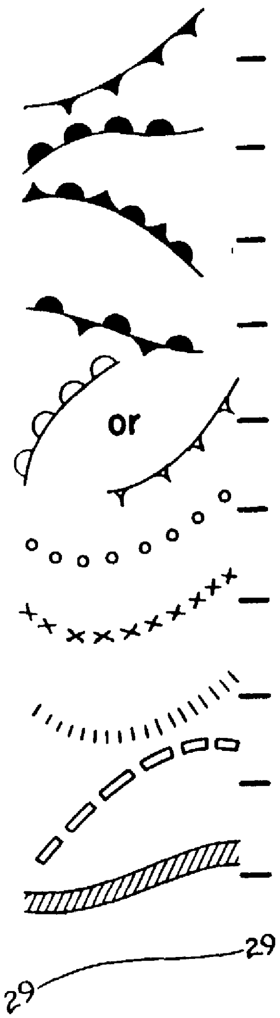
SYMBOLS AND DESIGNATIONS

Surface Charts



— Cold Front

— Warm Front

— Occluded Front

— Stationary Front

— Weak Front or Front Aloft

— Frontogenesis

— Frontolysis

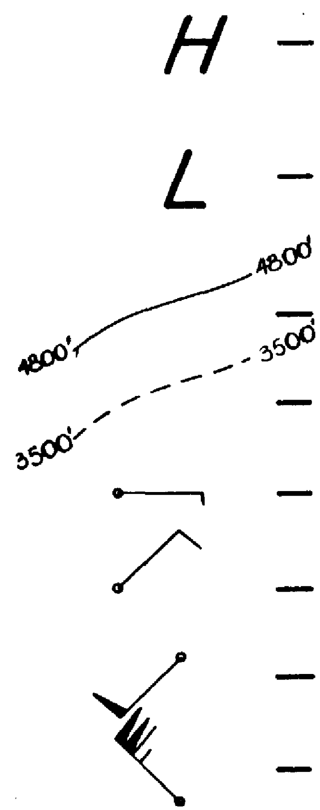
— Diffuse Front

— Easterly Wave

— Intertropical Convergence Zone

1029 Millibar Isobar

Constant Pressure Charts



— Area where altitude of pressure surface is relatively high.

— Area where altitude of pressure surface is relatively low.

— 4800 foot contour line (even hnds

— 3500 foot contour line (odd hnds

— east wind, 5 knots

— northeast wind, 10 knots

— southwest wind, 50 knots

— northwest wind, 115 knots

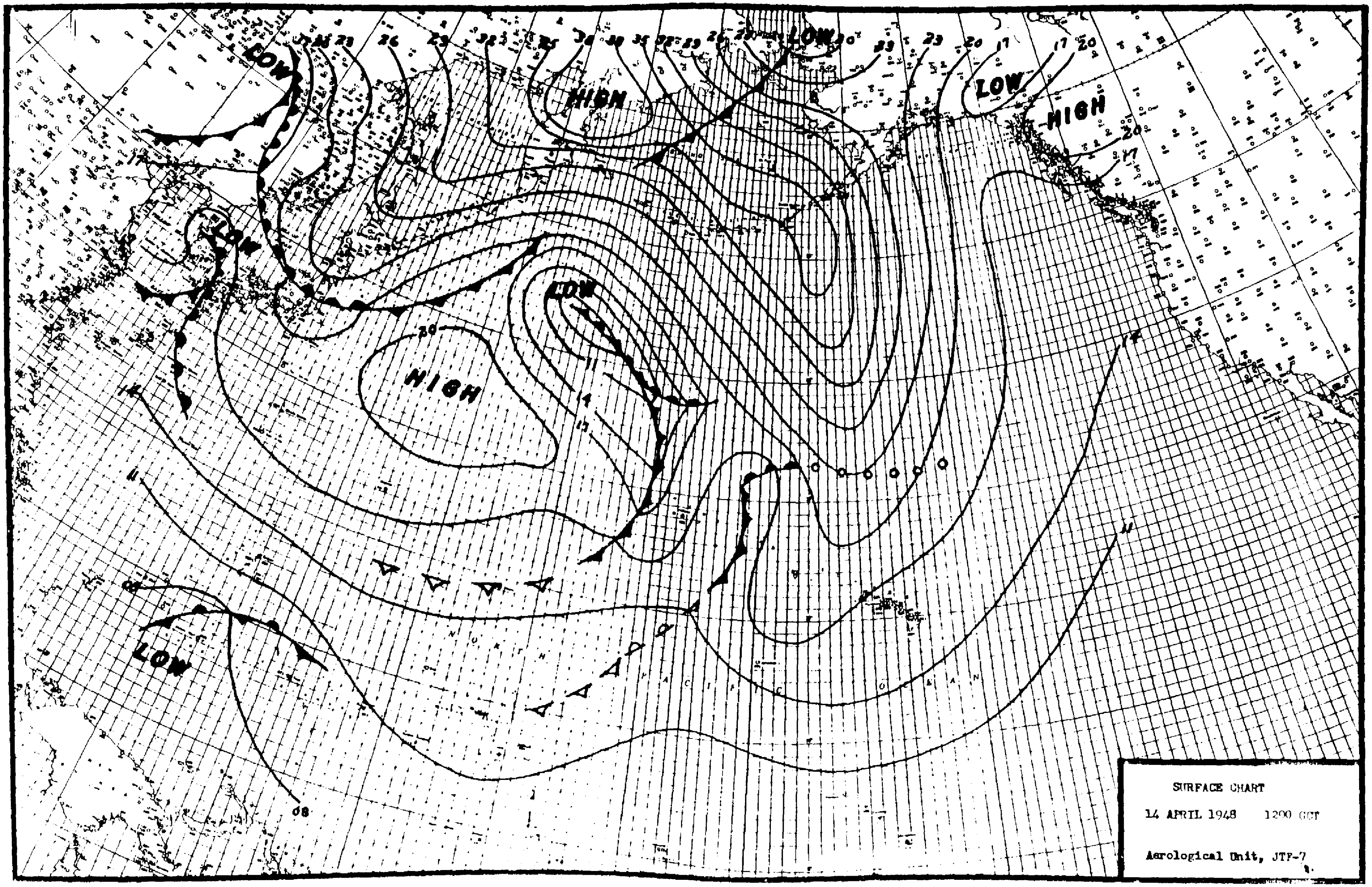
XRAY DAY

Surface Weather Charts

14, 15, 16, and 17 April 1948

1200 GCT

SECRET



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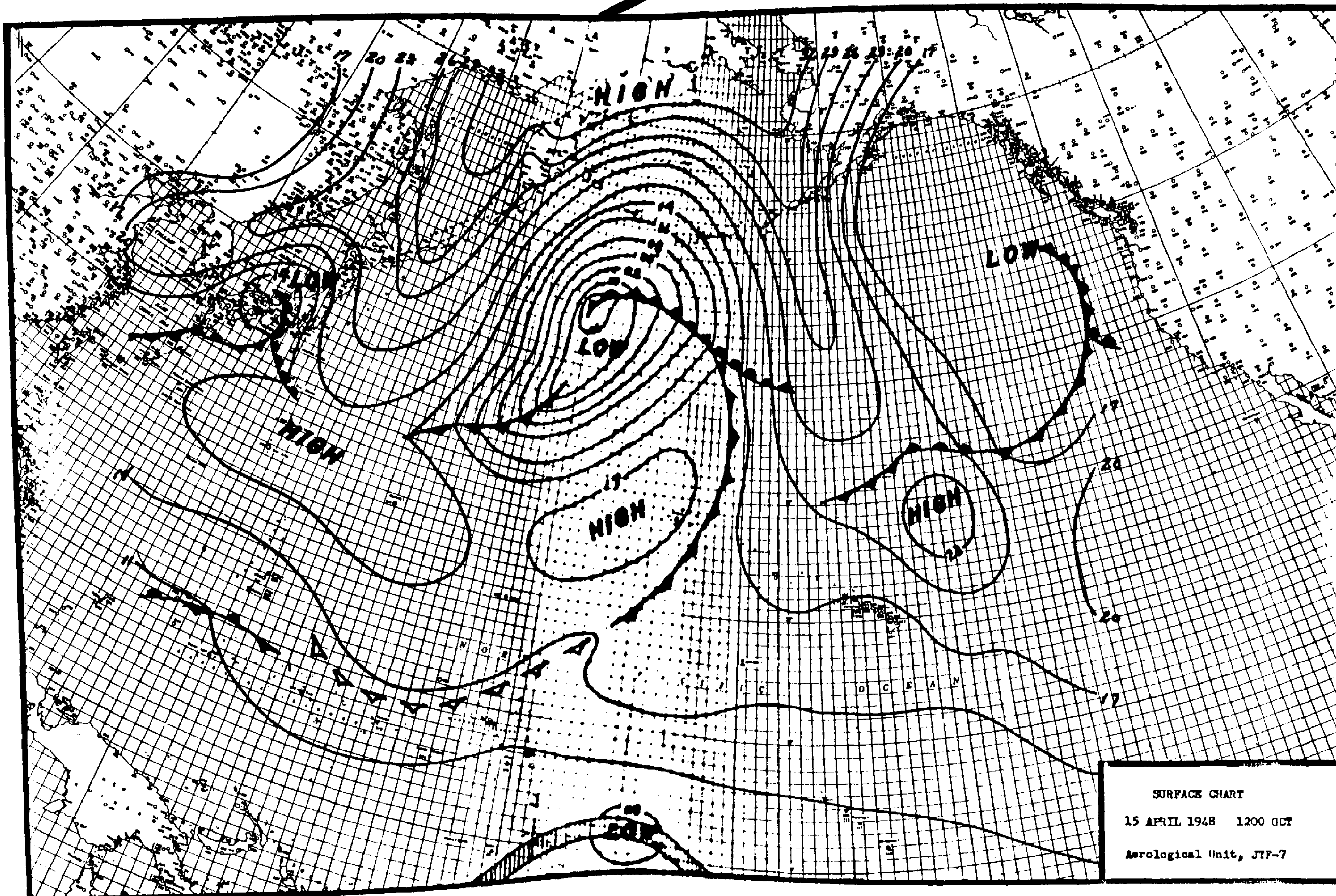

SURFACE CHART

15 APRIL 1948 1200 GCT

Aerological Unit, JTF-7

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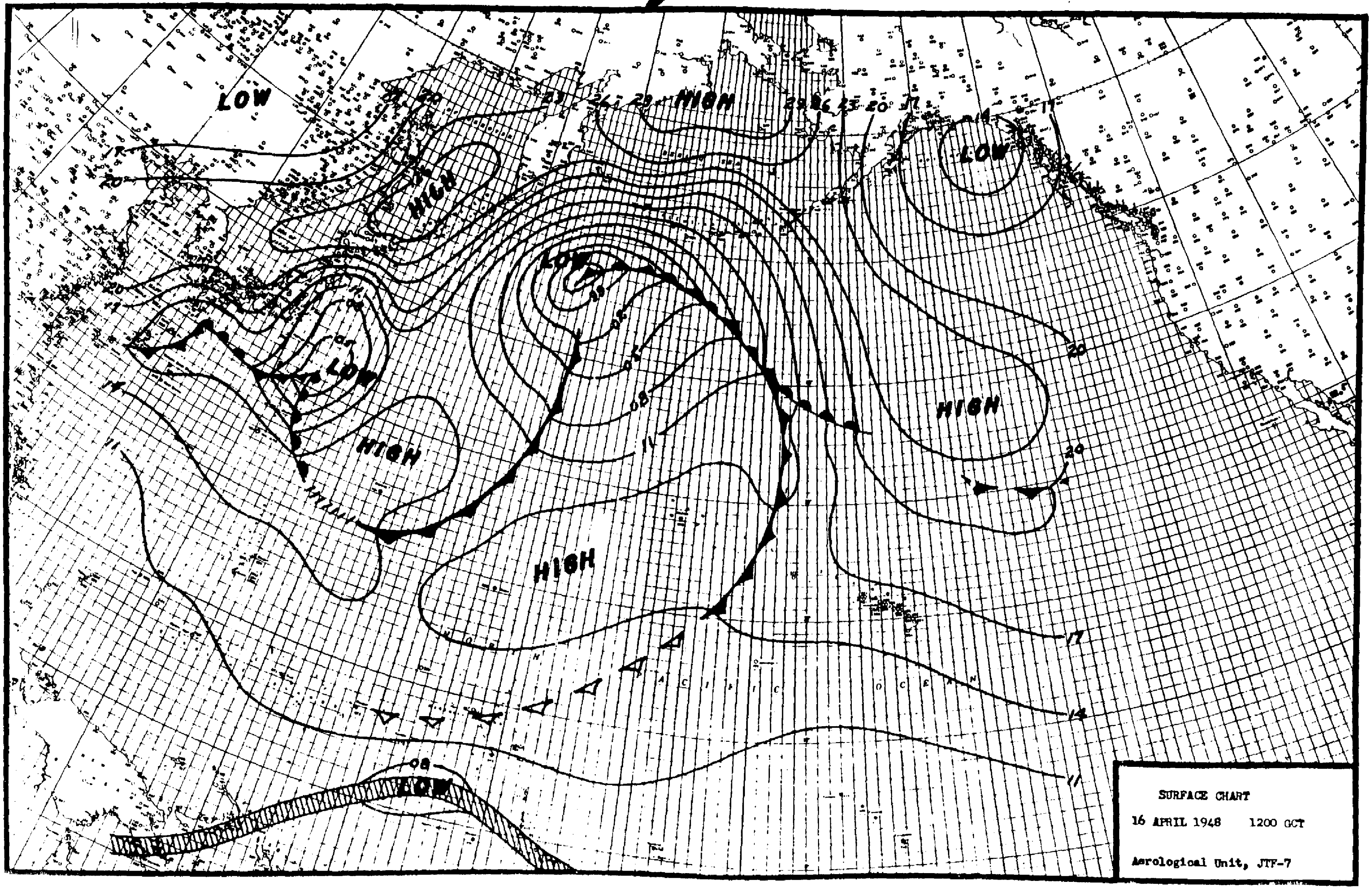

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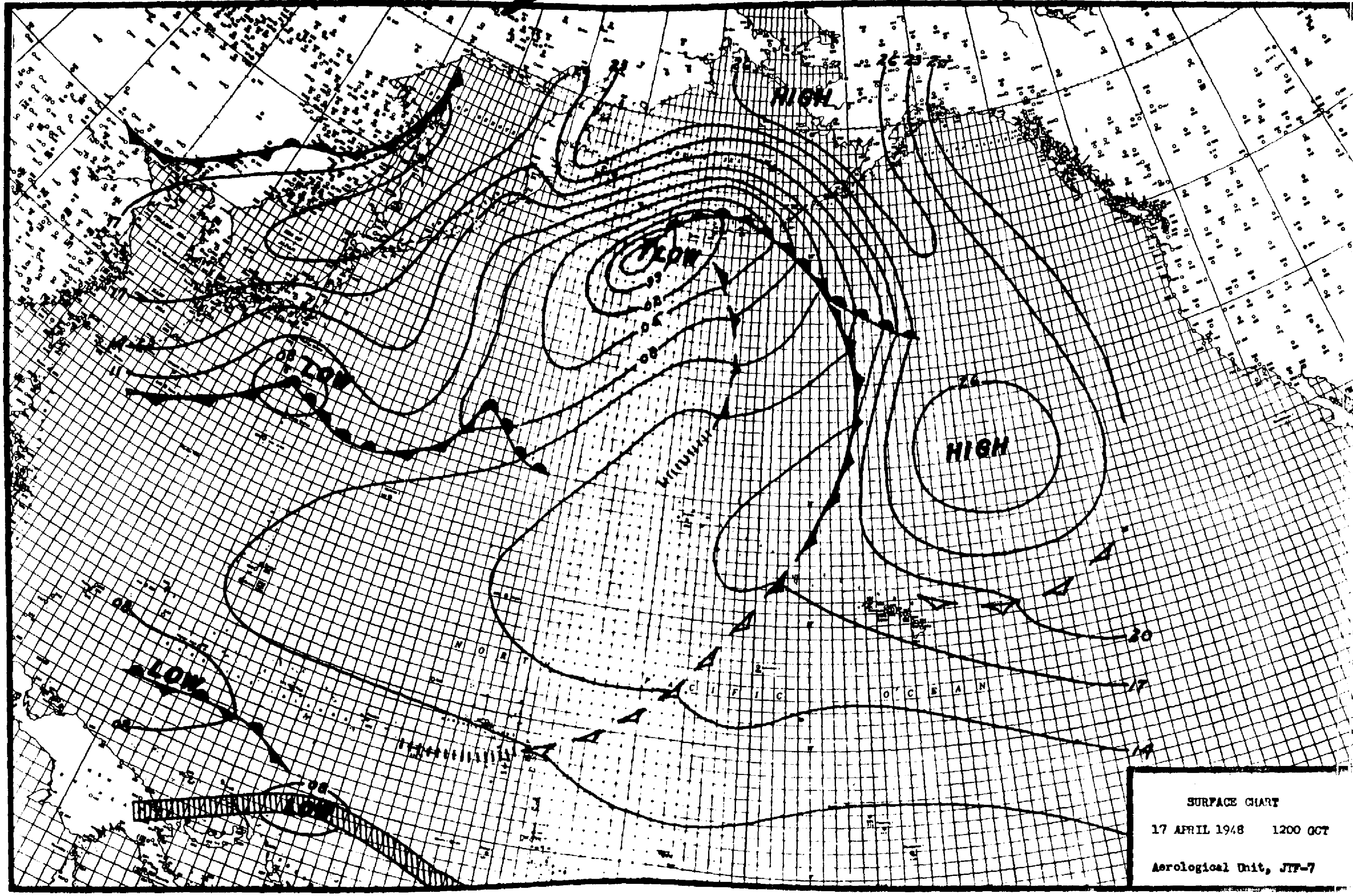

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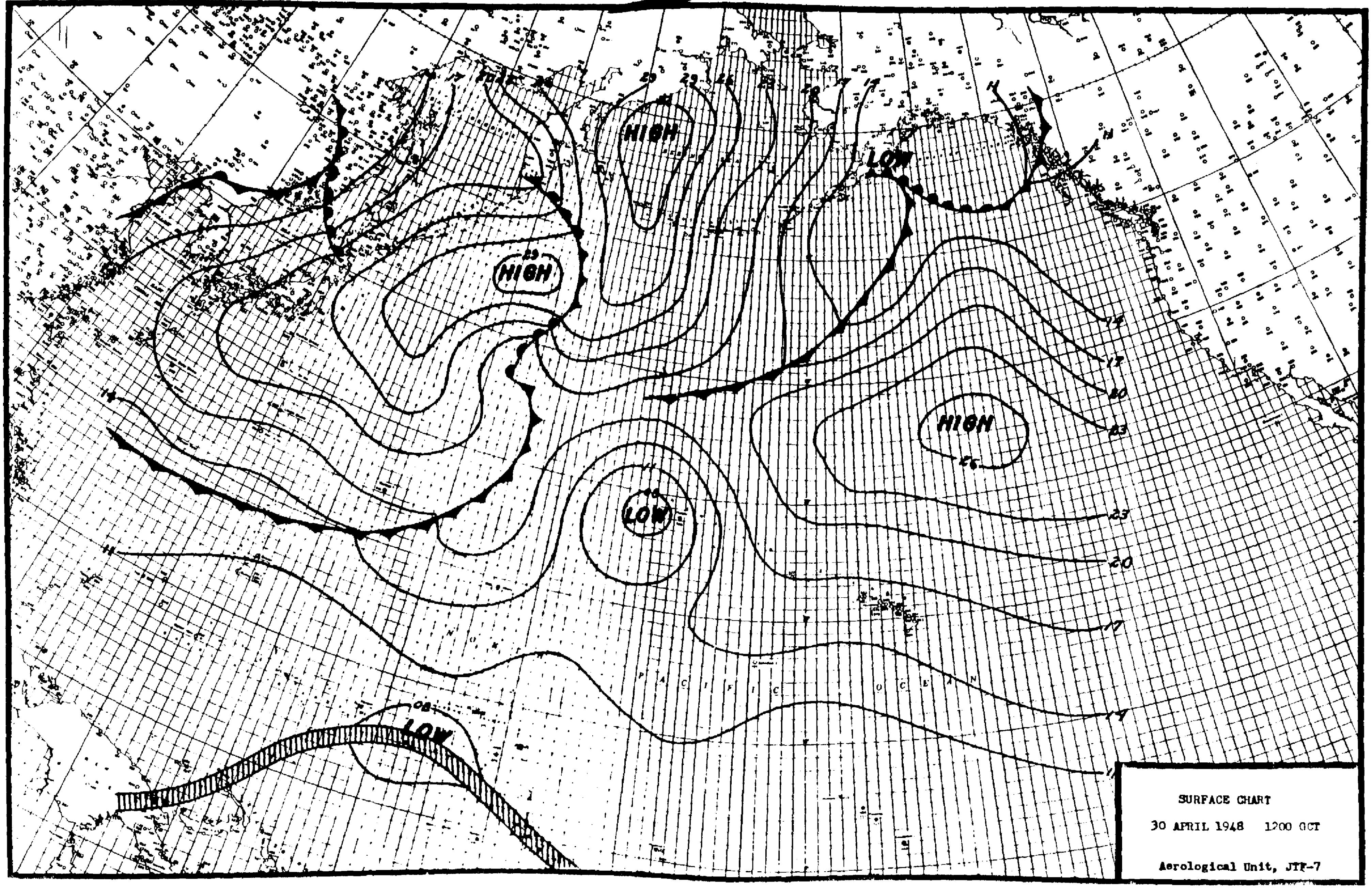
YOKE DAY

Surface Weather Charts

30 April and 1, 2, and 3 May 1948

1200 GCT



SURFACE CHART

30 APRIL 1948 1200 GCT

Aerological Unit, JTF-7

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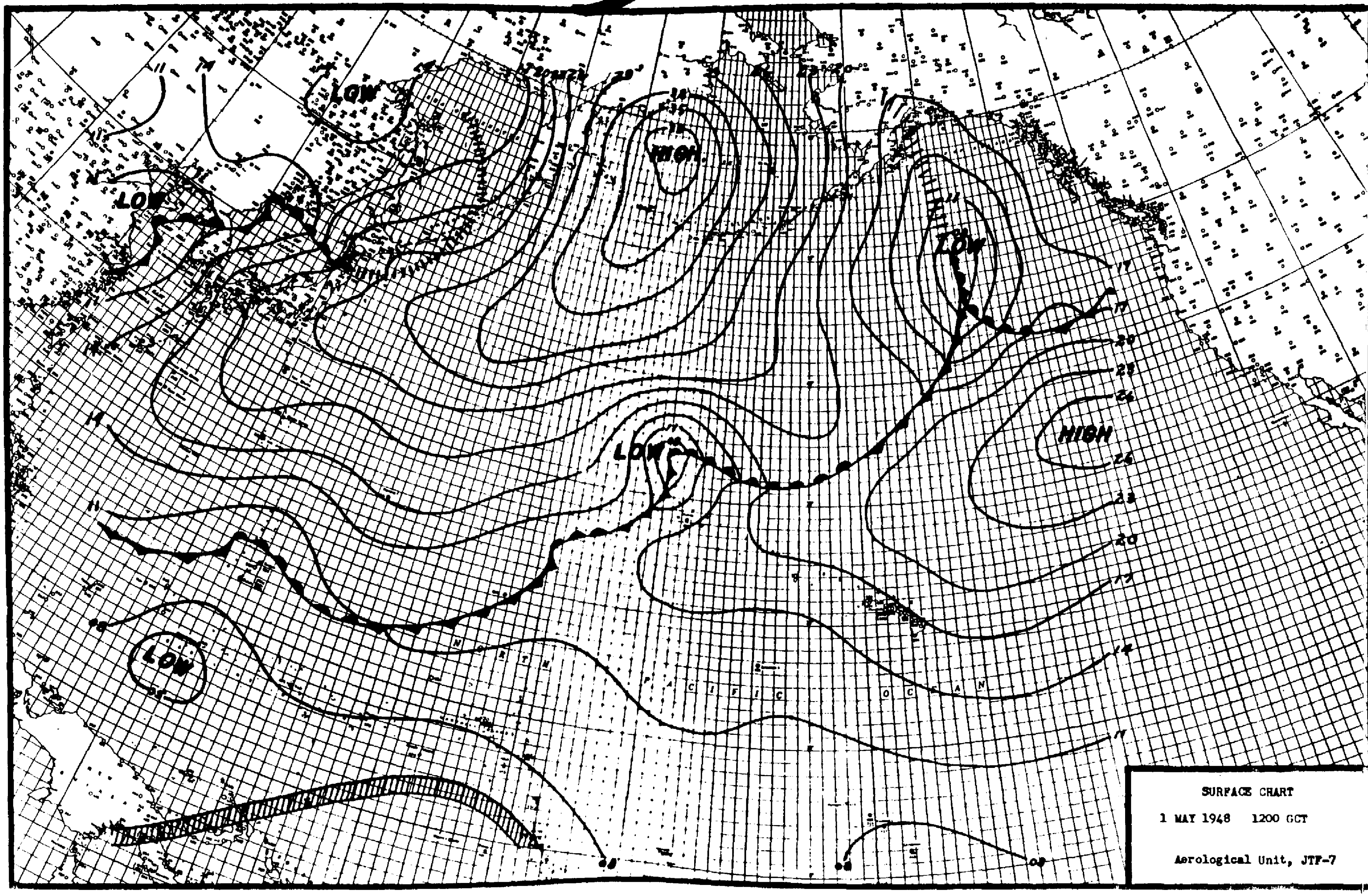

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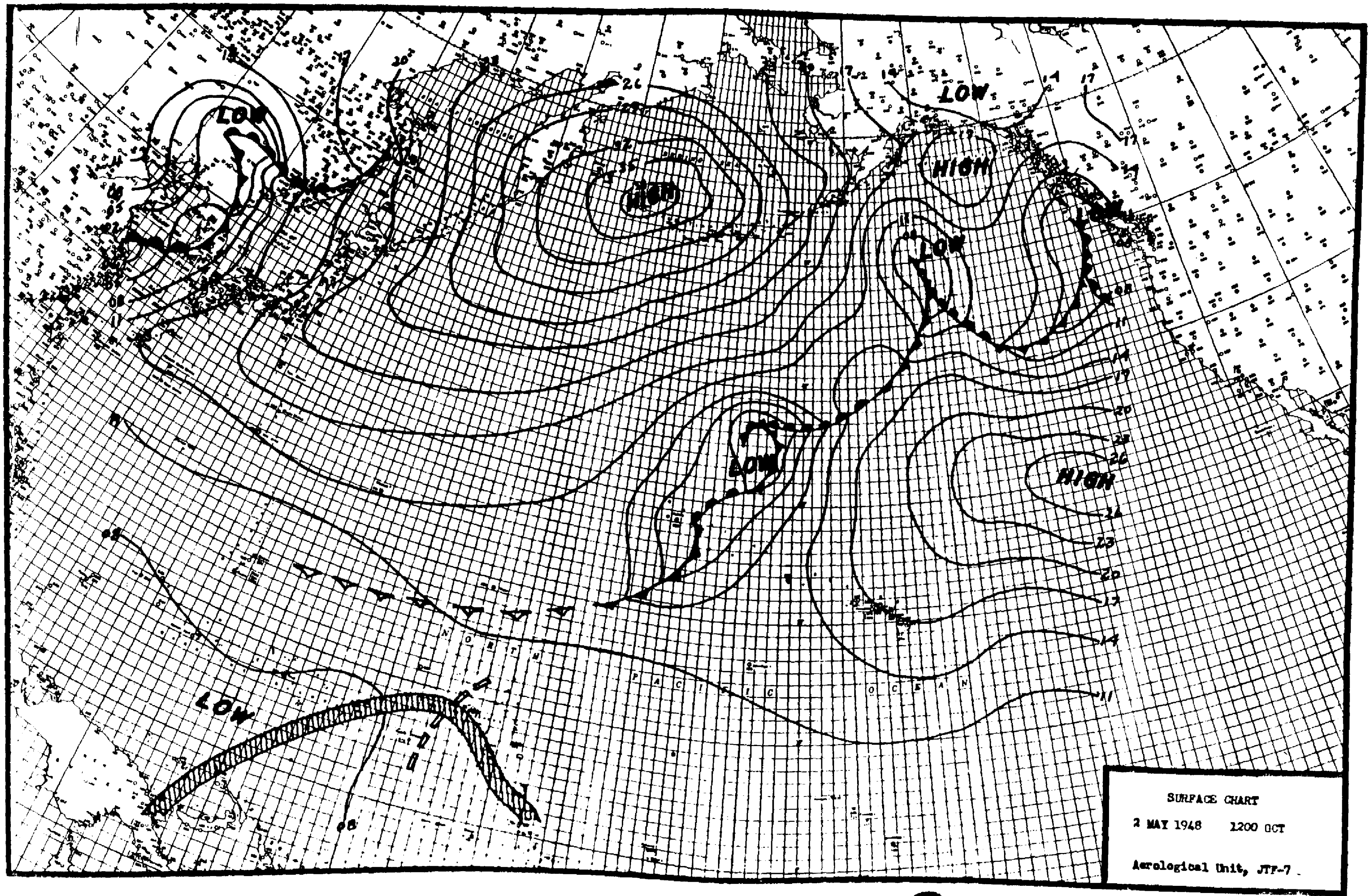

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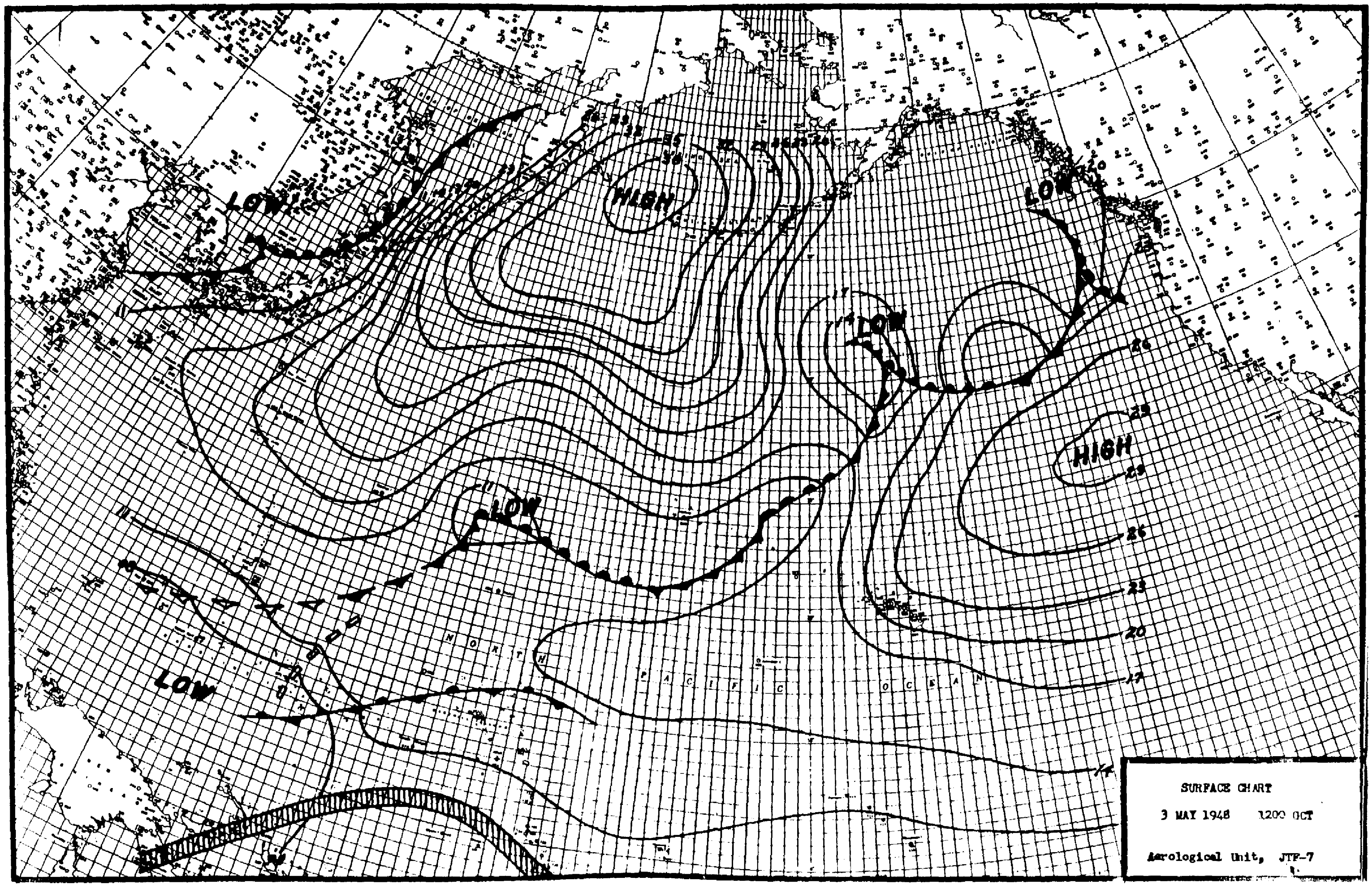

SURFACE CHART
3 MAY 1948 1200 GCT
Aerological Unit, JTF-7
HIGH
HIGH
LOW
LOW
LOW
LOW
LOW
NORTH
PACIFIC
OCEAN
26
23
20
17
14
29
35
38
11

~~SECRET~~

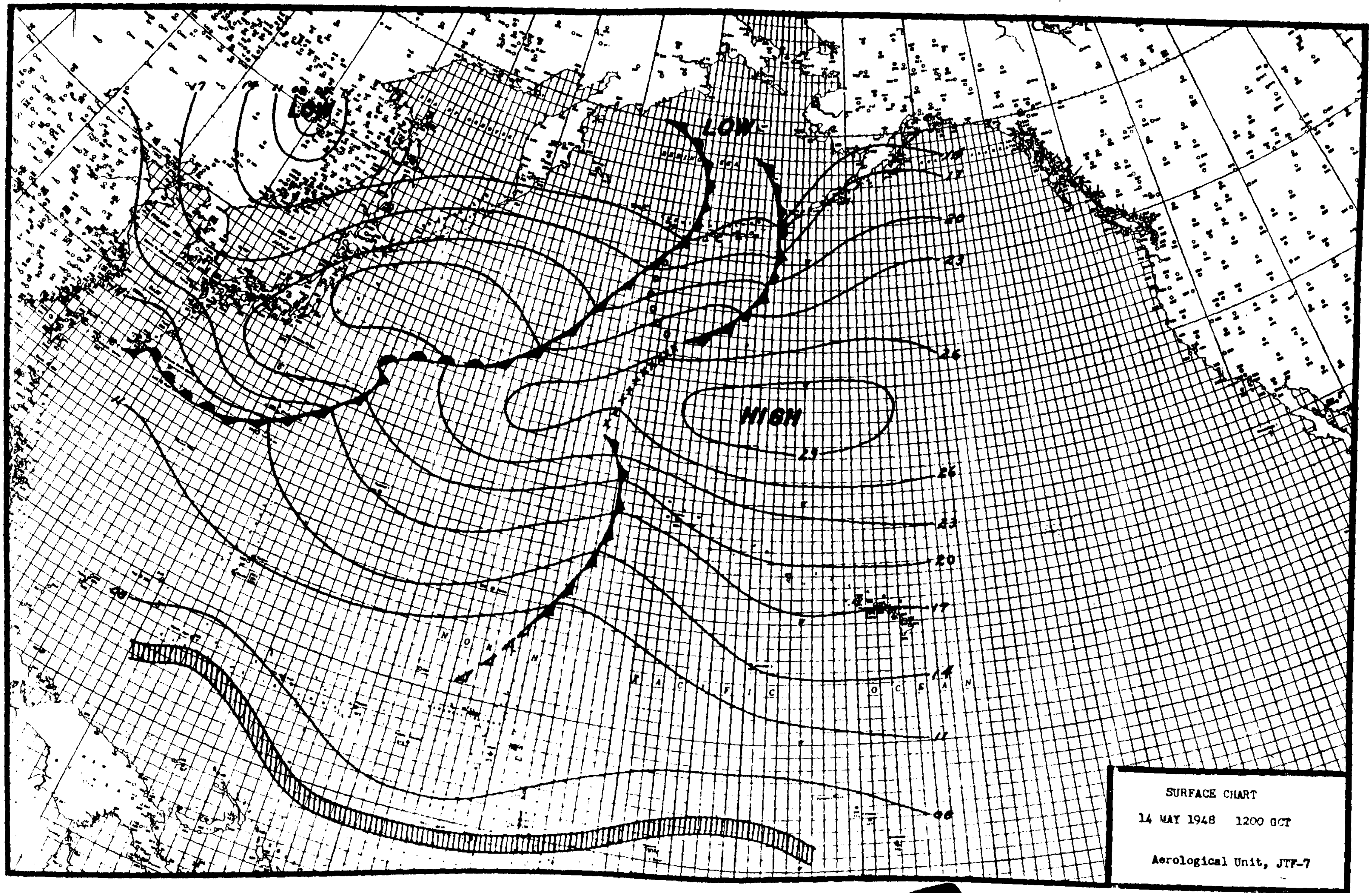
ZEBRA DAY

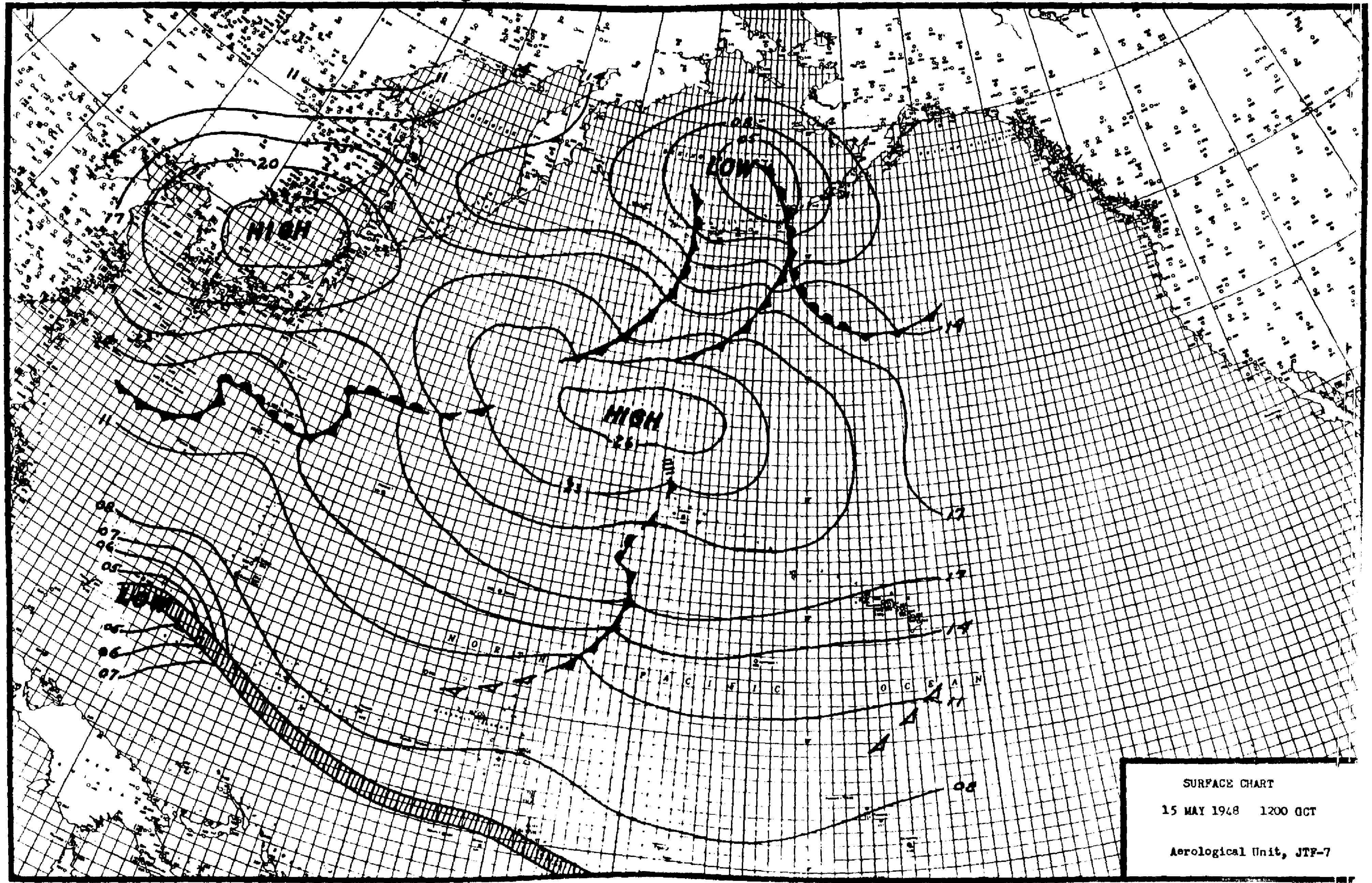
Surface Weather Charts

14 and 15 May 1948

1200 GCT

~~SECRET~~


LOW
LOW
HIGH
NORTH PACIFIC OCEAN
SURFACE CHART
14 MAY 1948 1200 GCT
Aerological Unit, JTF-7


HIGH
LOW
HIGH
LOW
NORTH PACIFIC OCEAN
SURFACE CHART
15 MAY 1948 1200 GCT
Aerological Unit, JTF-7

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CONSTANT PRESSURE CHARTS

for 850, 700, 500, 300, and 200 millibar surfaces

XRAY DAY

YOKE DAY

ZEBRA DAY

and three days following these

test days

~~SECRET~~

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XRAY DAY

850, 700, 500, 300 and 200 Millibar Surfaces

14, 15, 16, and 17 April 1948

1500 GCT

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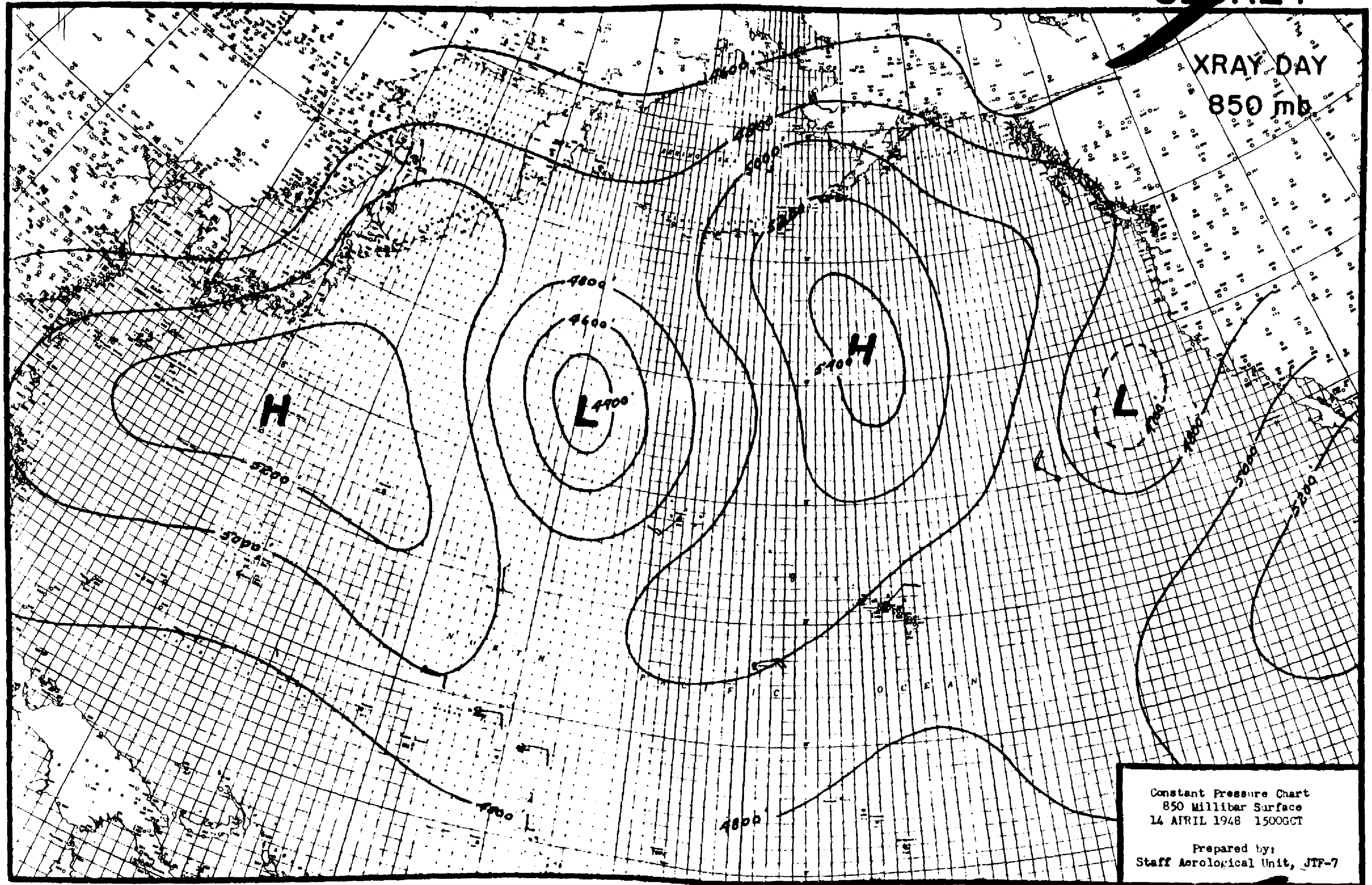

Constant Pressure Chart
850 Millibar Surface
14 APRIL 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

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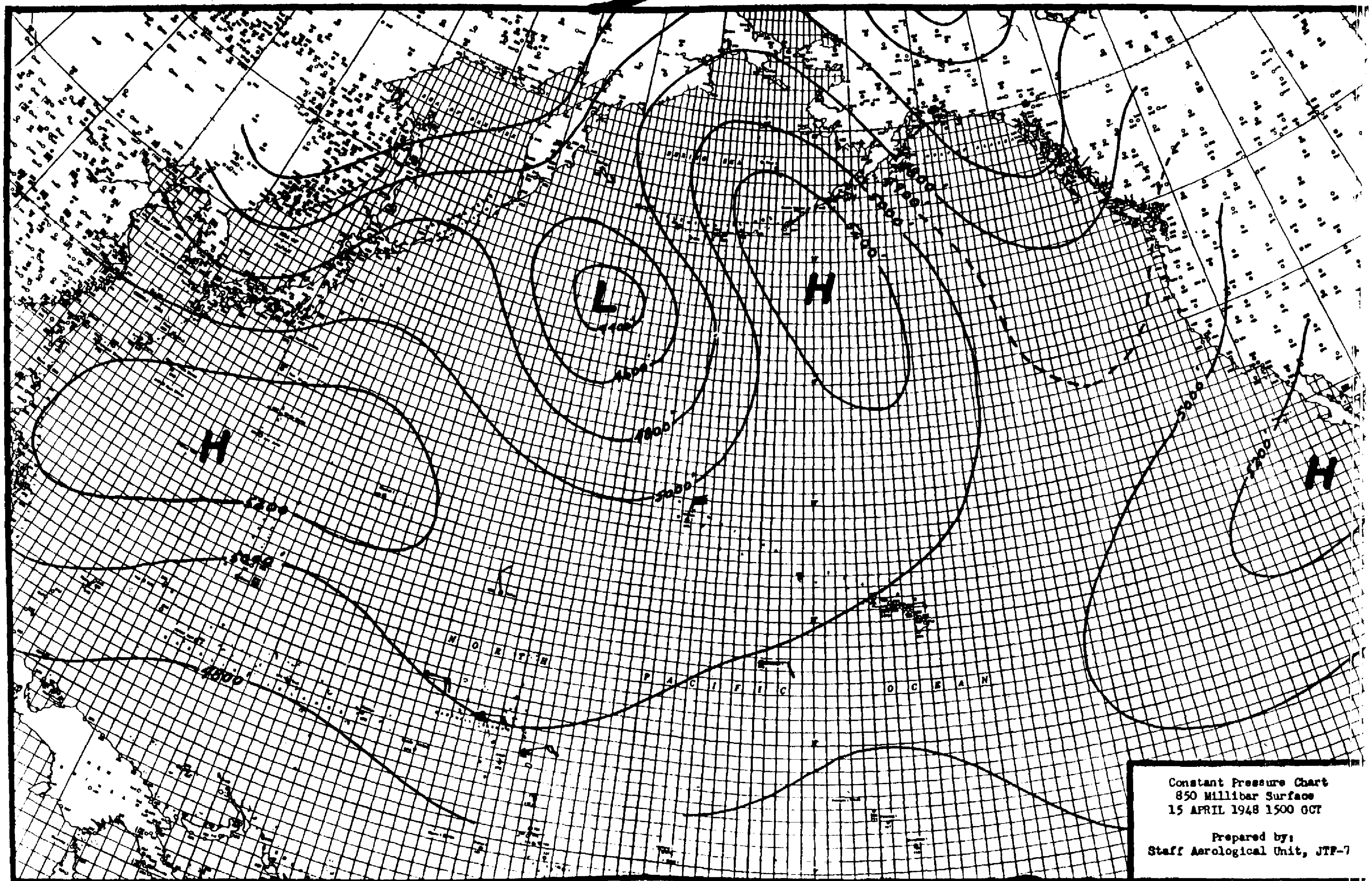

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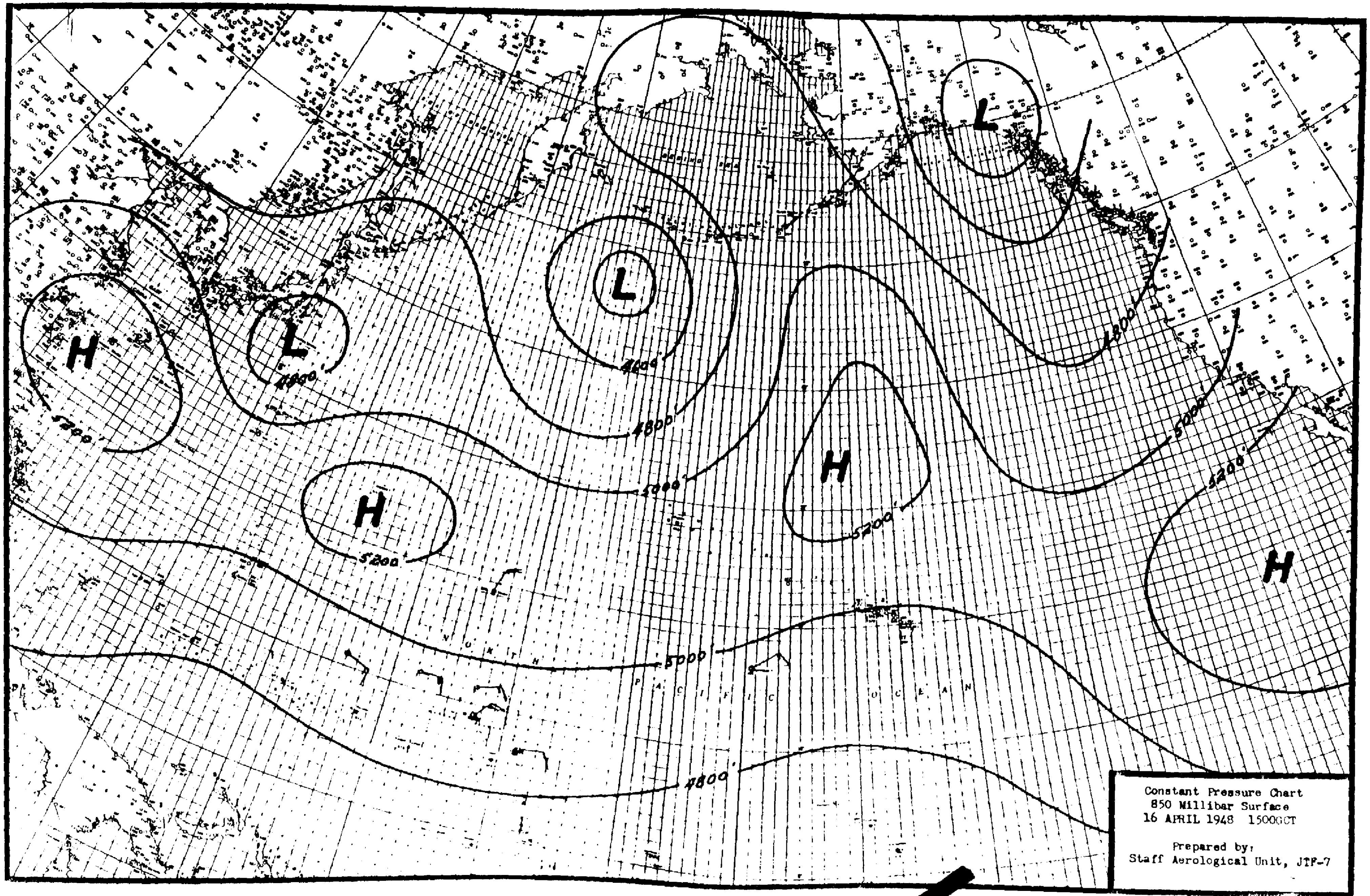
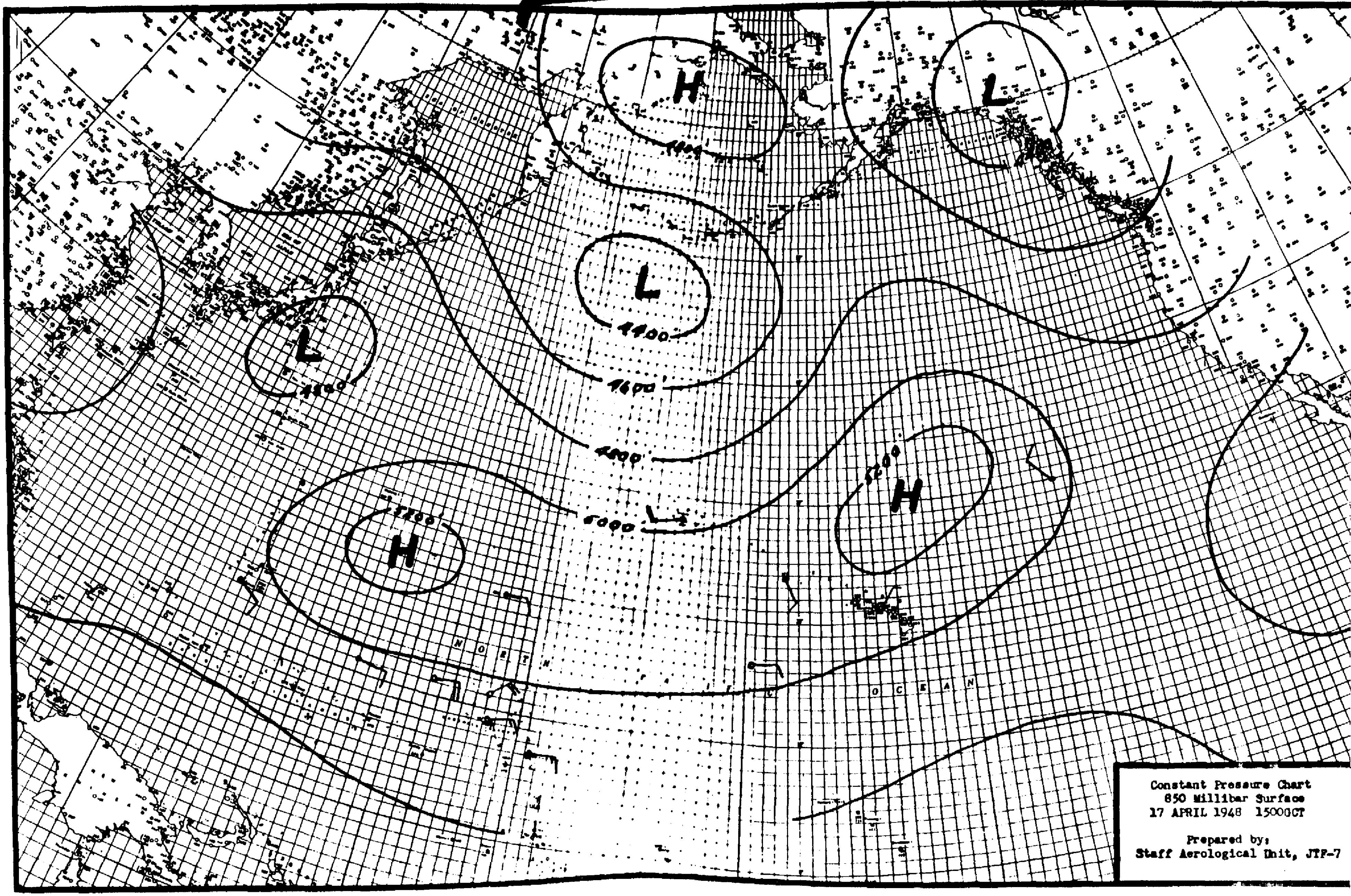


Constant Pressure Chart
850 Millibar Surface
16 APRIL 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

 SECRET


H
L
L
1400
L
4400
4600
4800
5000
H
5200
H
5200
NORTH
OCEAN
Constant Pressure Chart
850 Millibar Surface
17 APRIL 1948 1500GCT
Prepared by:
Staff Aerological Unit, JTF-7

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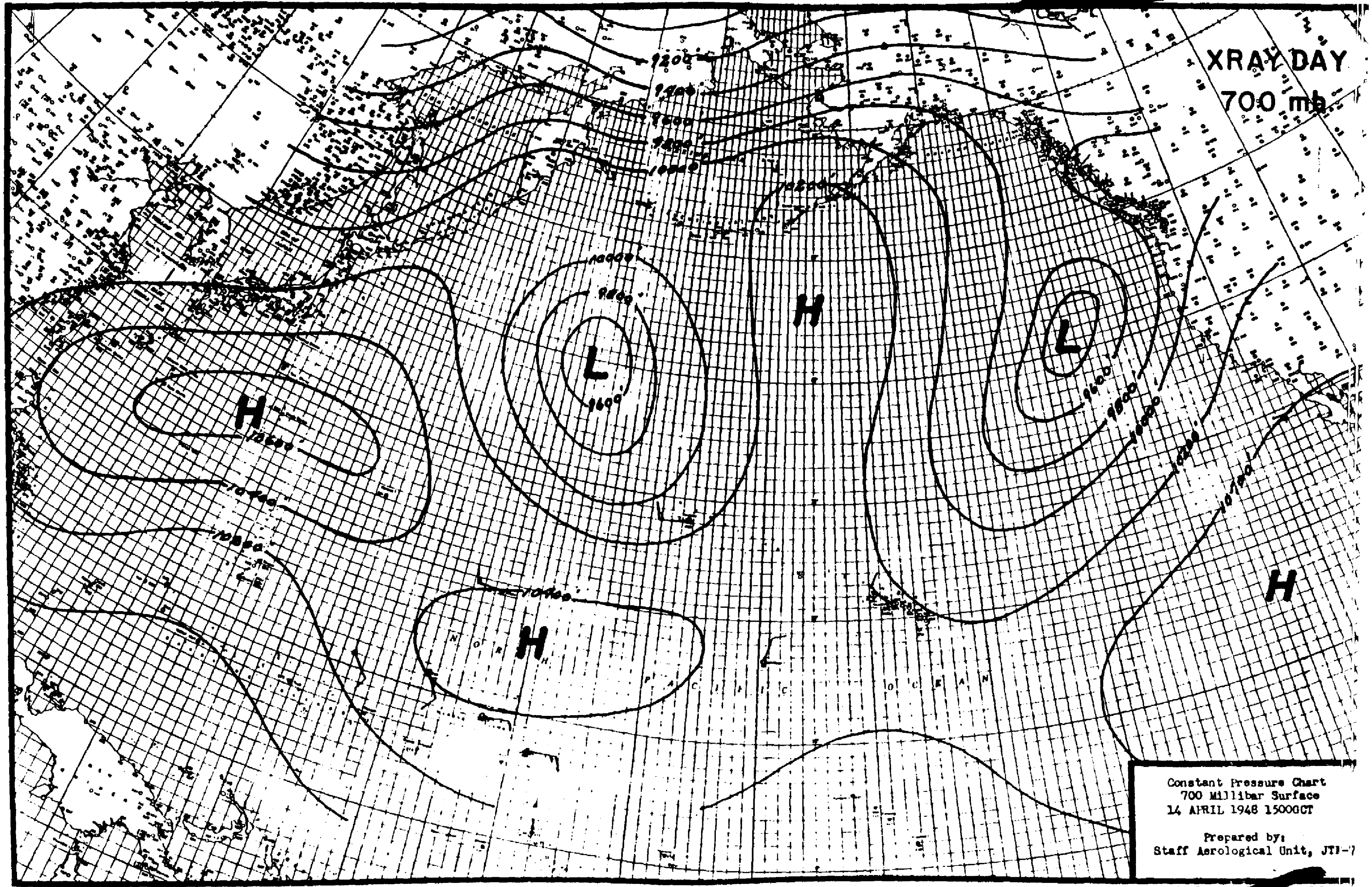

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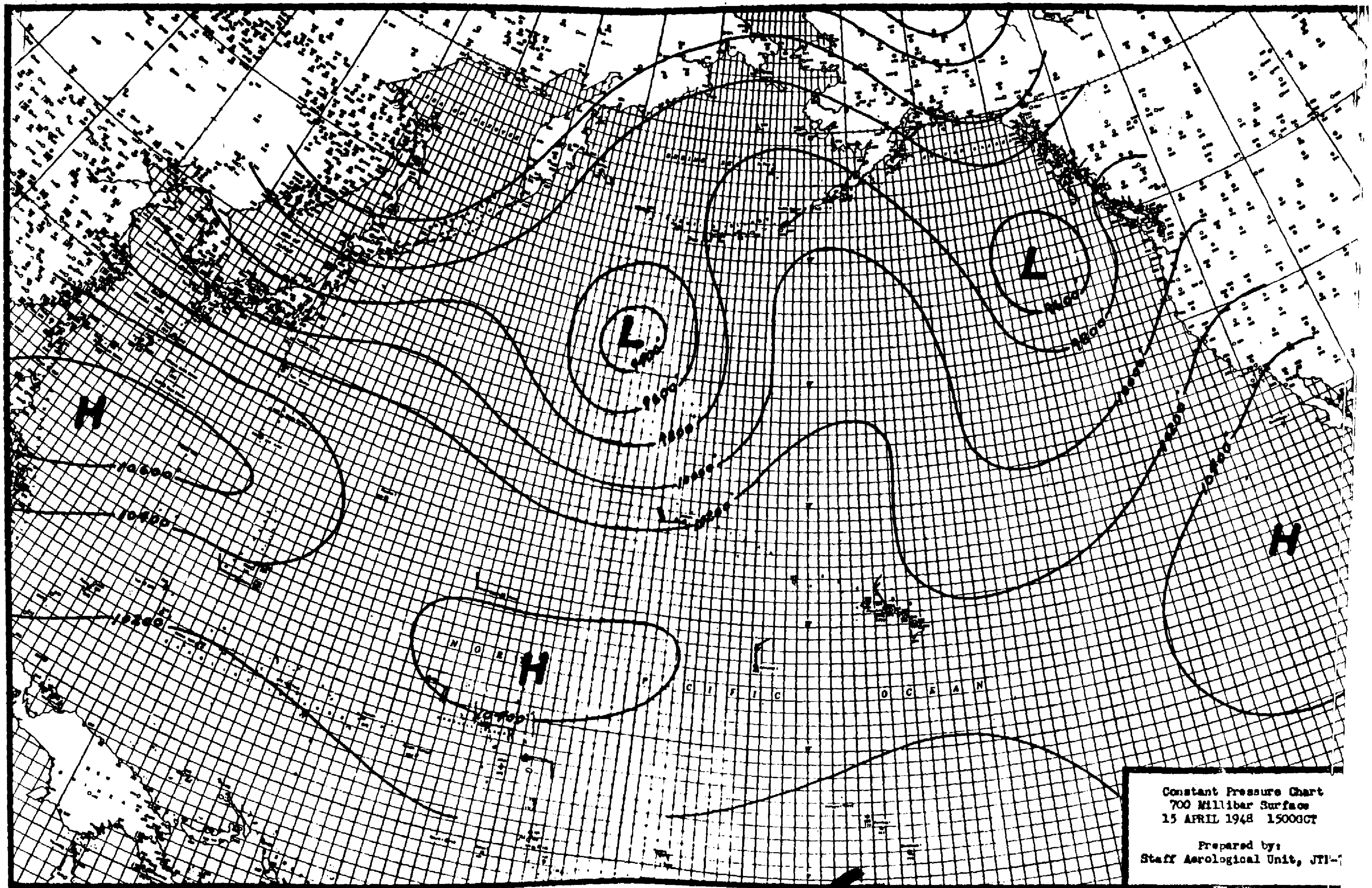
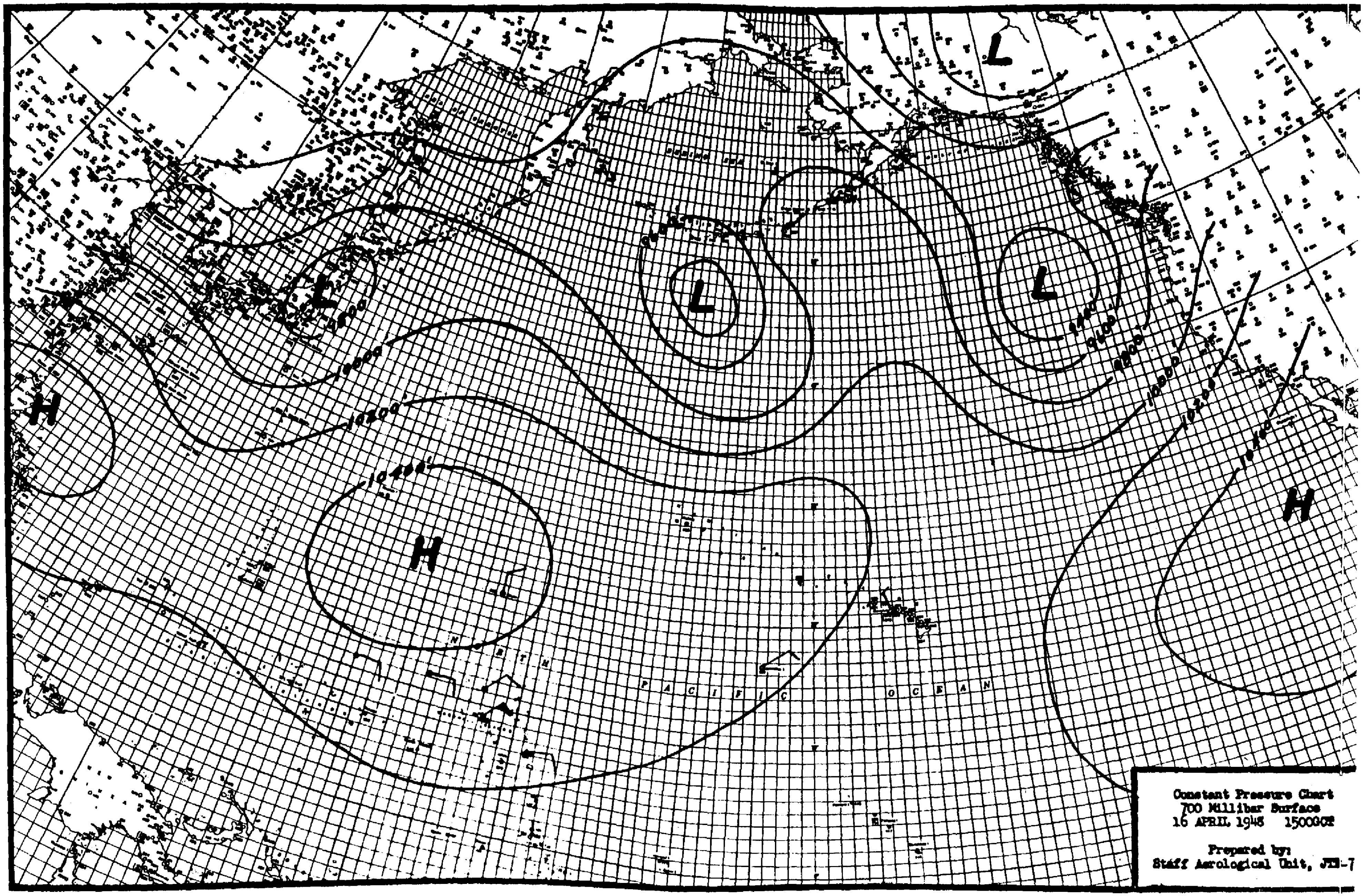


Constant Pressure Chart
700 Millibar Surface
15 APRIL 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-1



Constant Pressure Chart
700 Millibar Surface
16 APRIL 1948 1500GCT

Prepared by:
Staff Aerological Unit, J[illegible]-7

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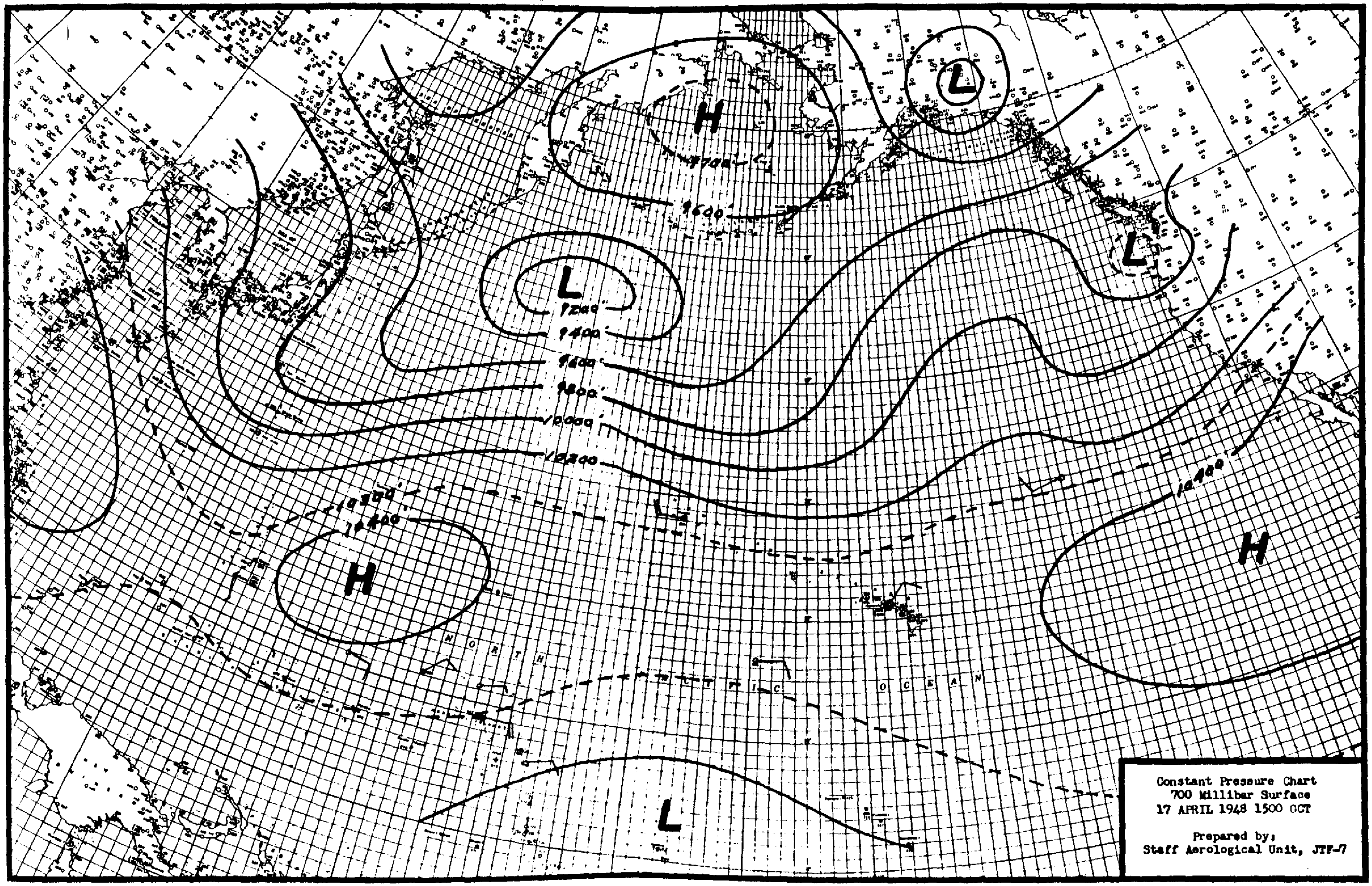

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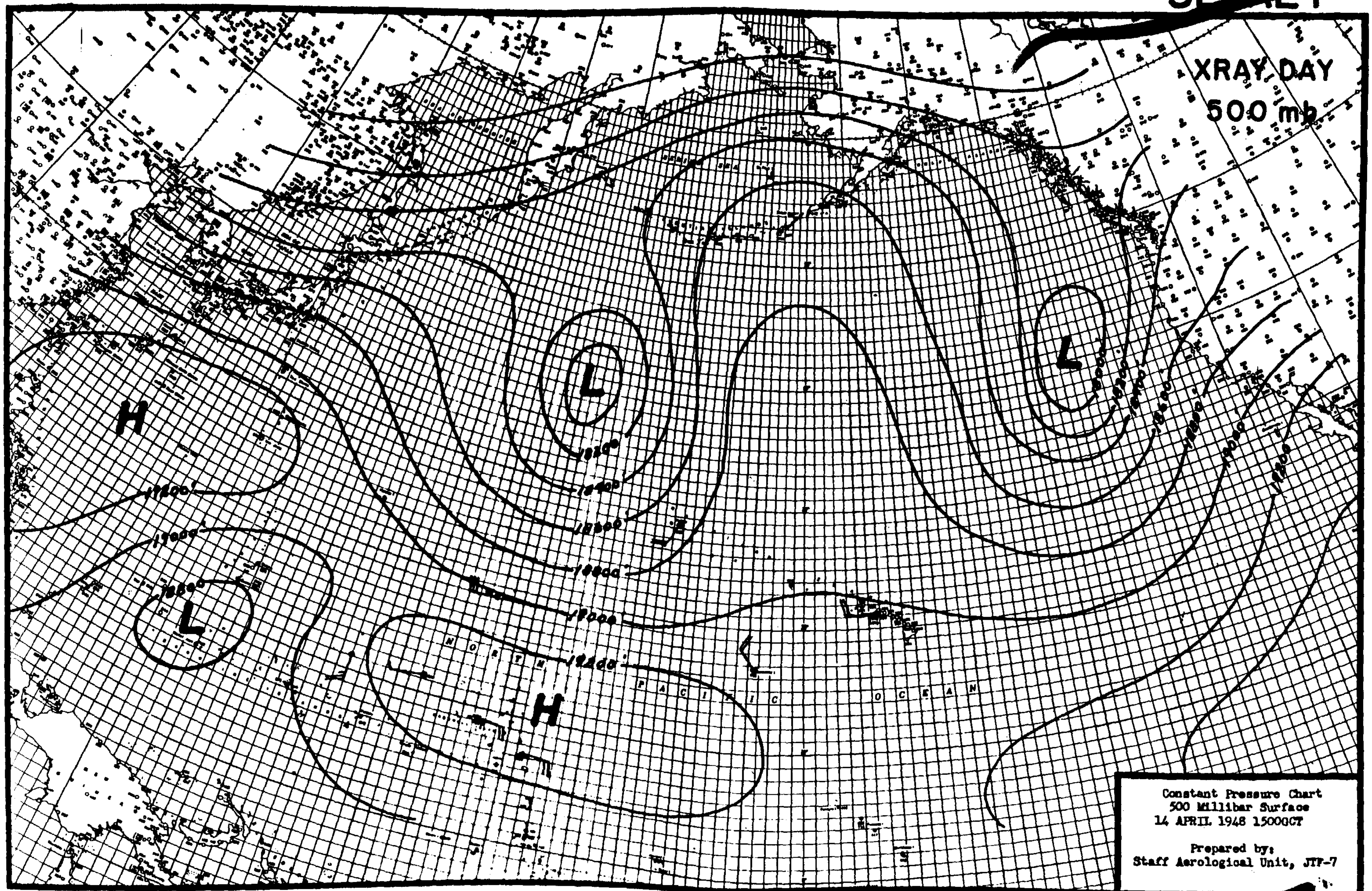

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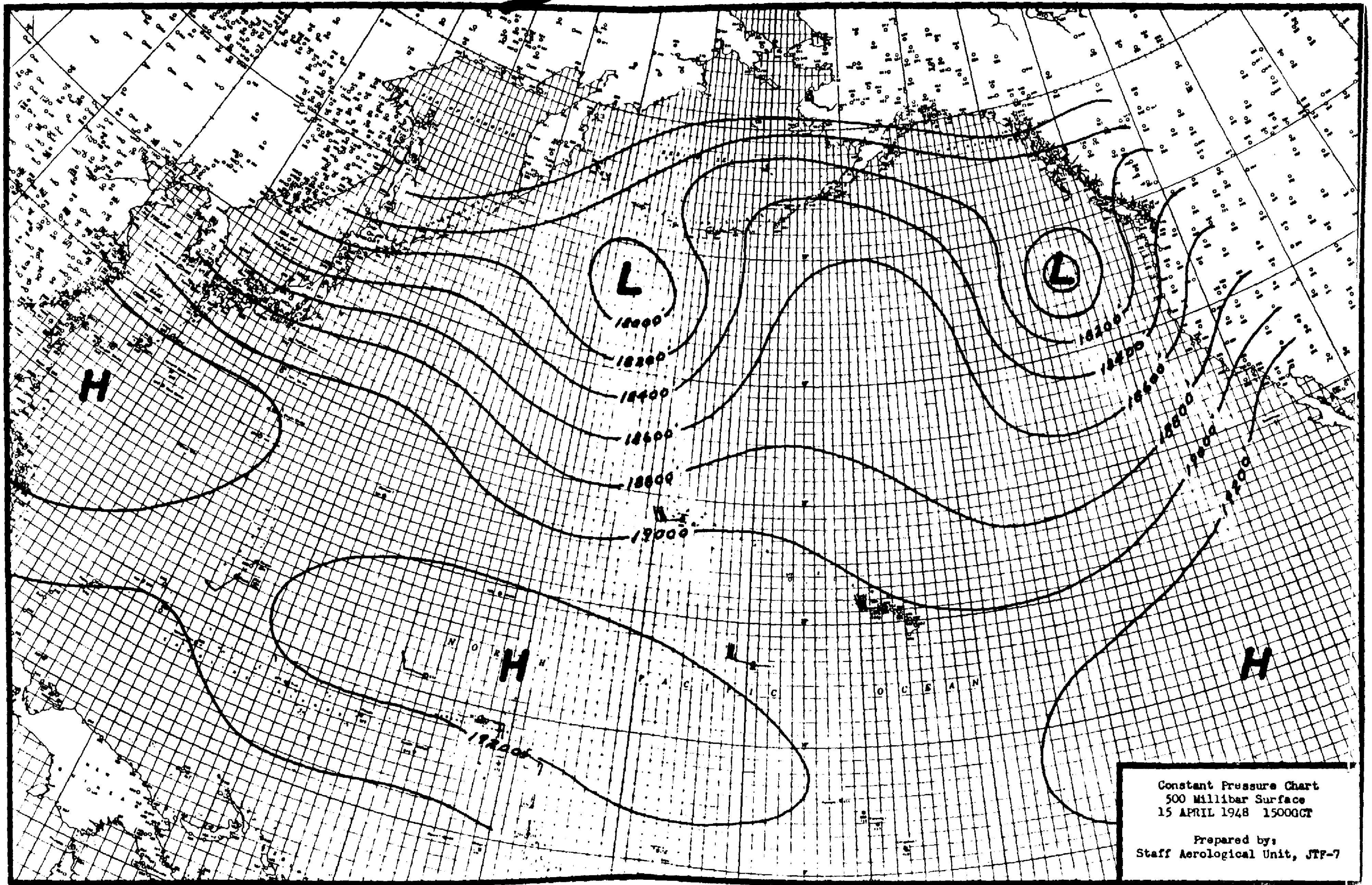

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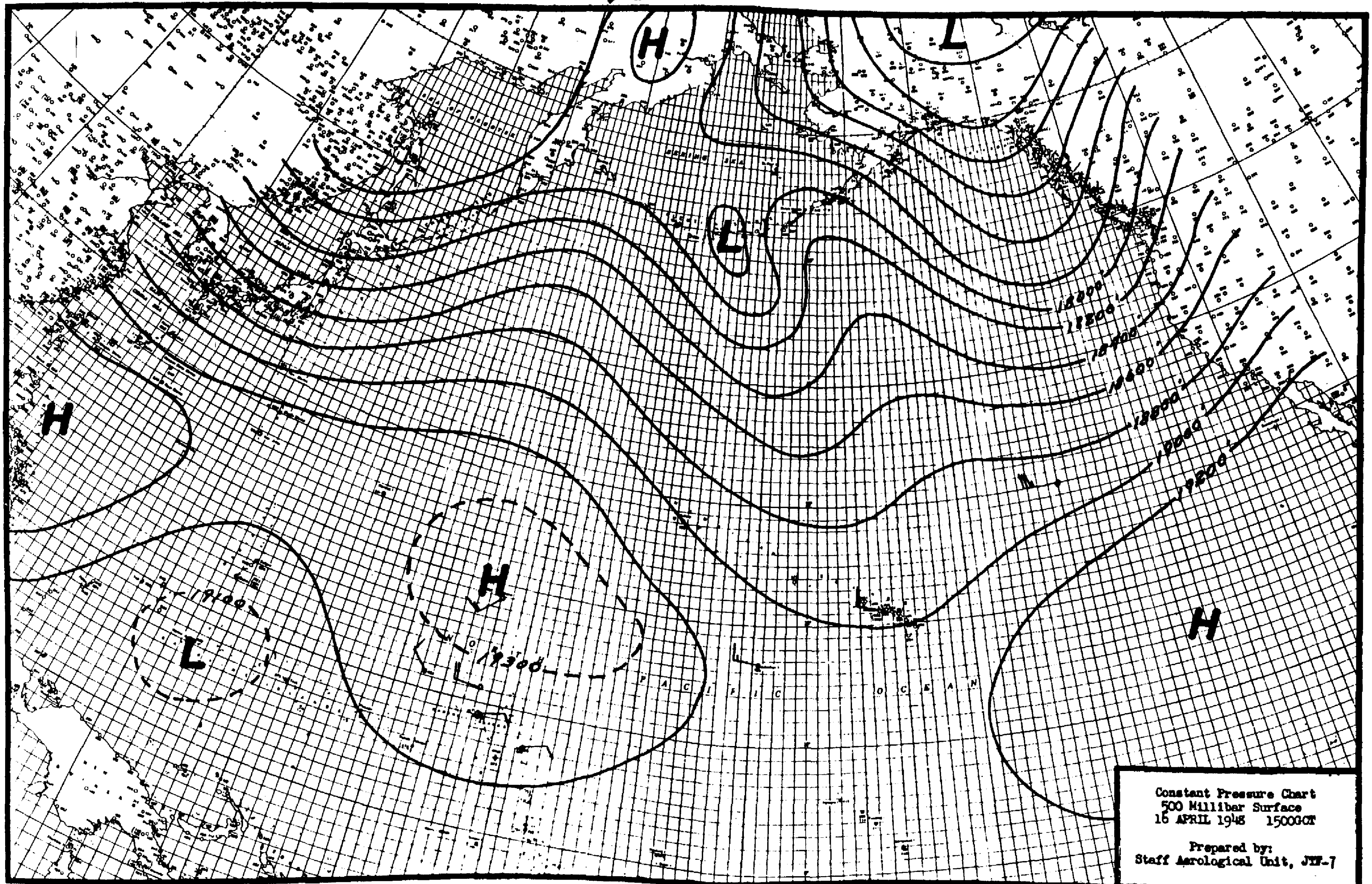

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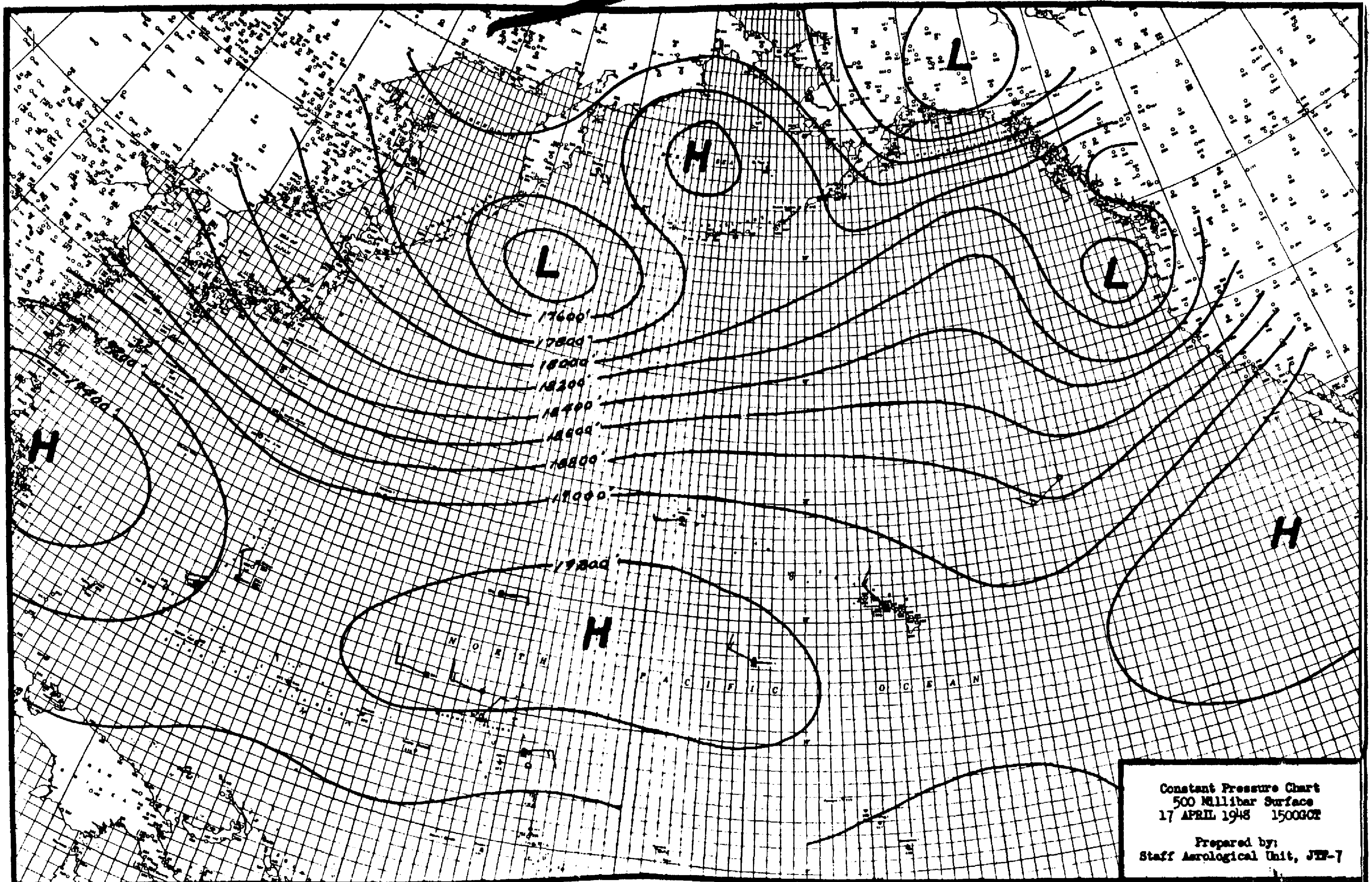

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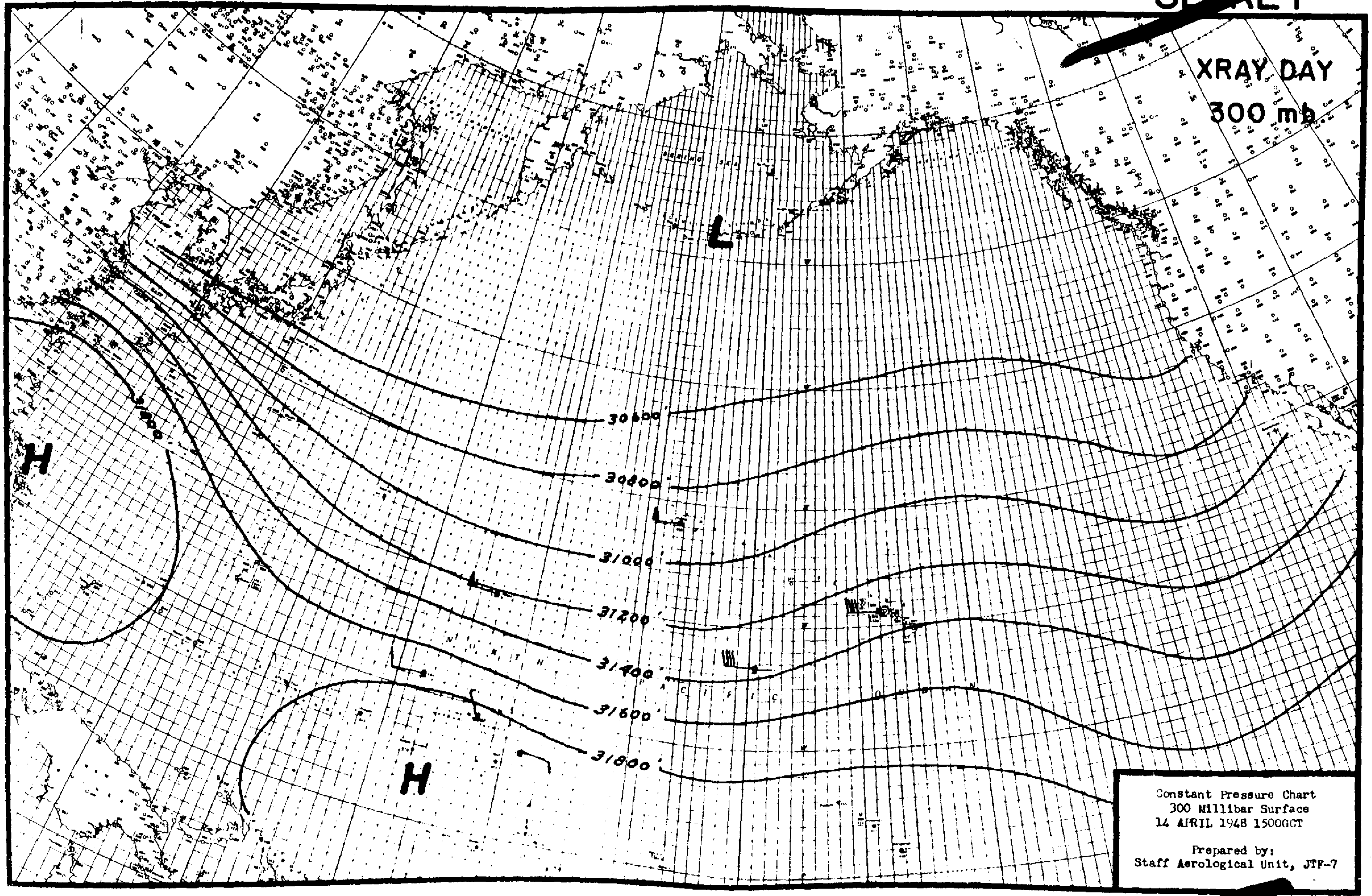
SECRET



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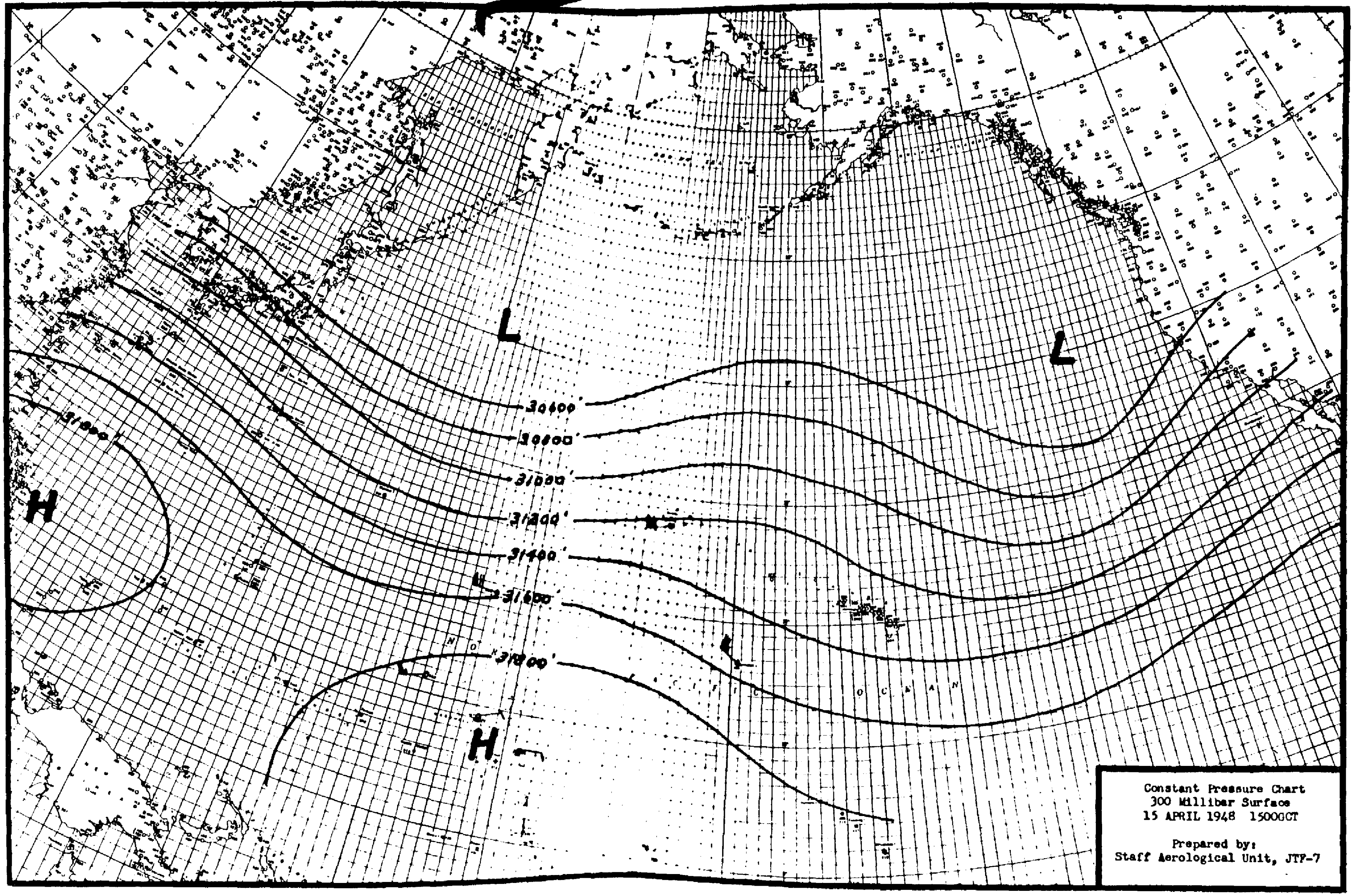
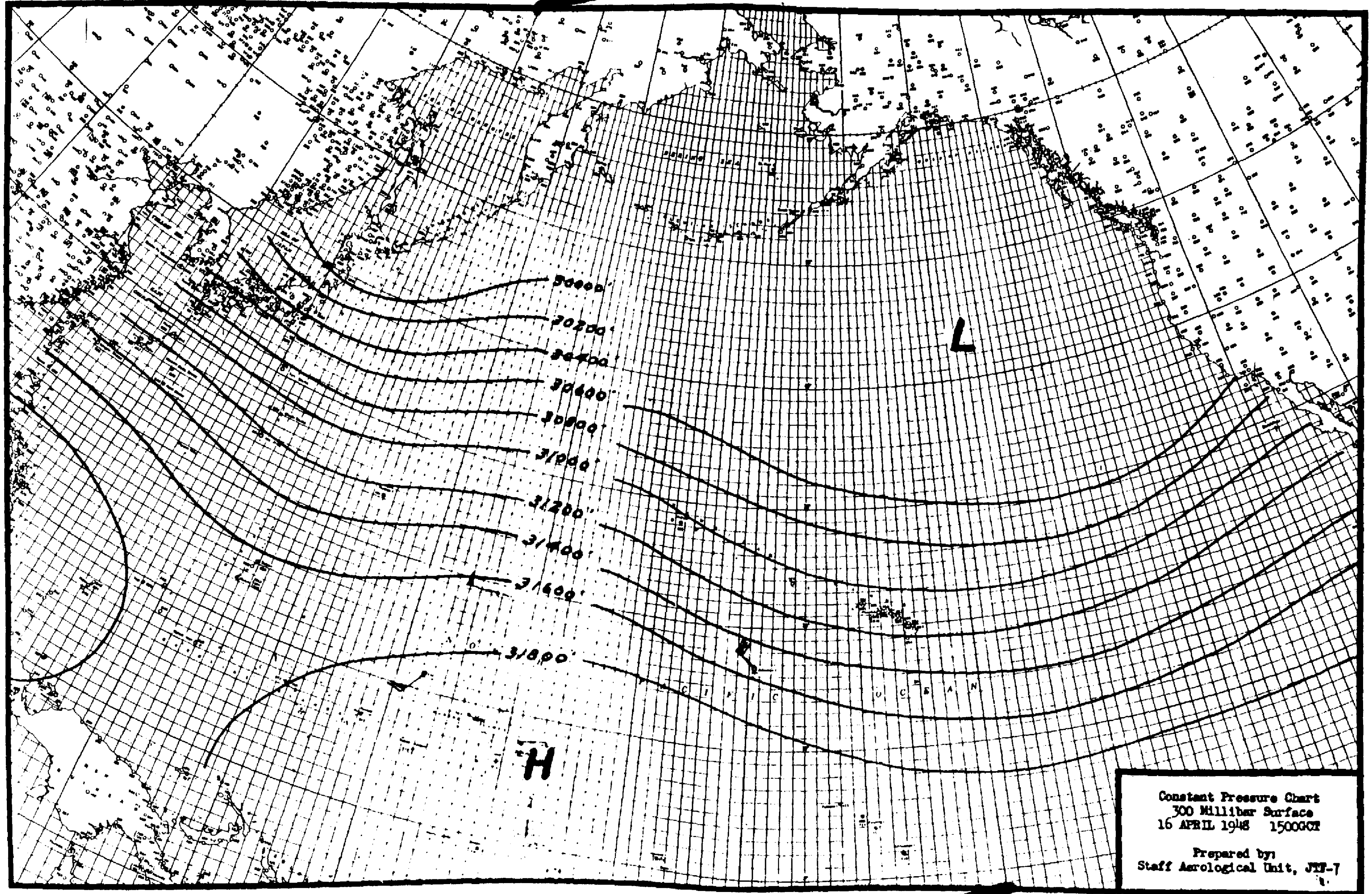

L
L
H
H
30400
30800
31000
31200
31400
31600
31800
31800
Constant Pressure Chart
300 Millibar Surface
15 APRIL 1948 1500GCT
Prepared by:
Staff Aerological Unit, JTF-7


30000
30200
30400
30600
30800
31000
31200
31400
31600
31800
L
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Constant Pressure Chart
300 Millibar Surface
16 APRIL 1948 1500GCT
Prepared by:
Staff Aerological Unit, JTF-7

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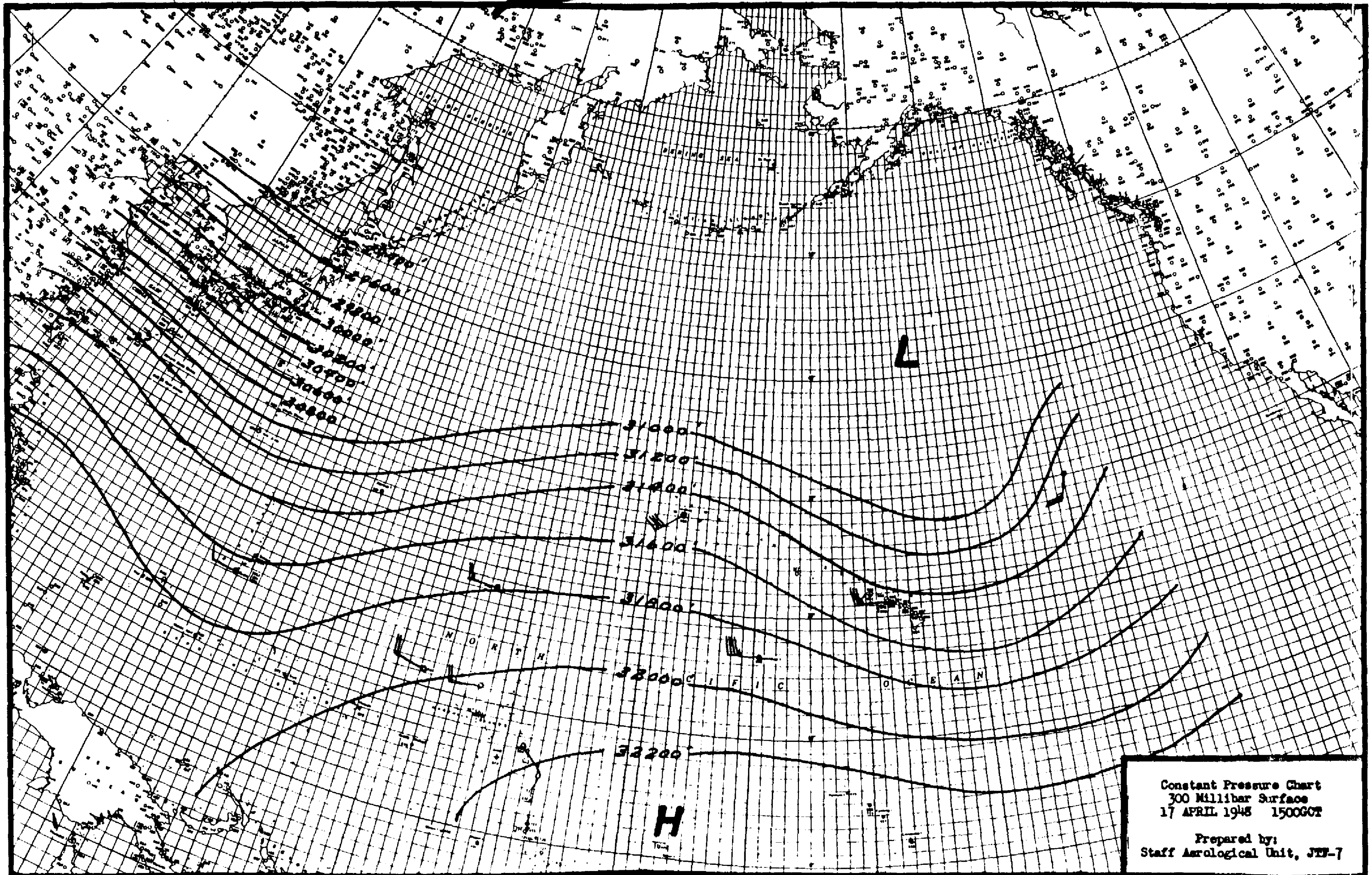

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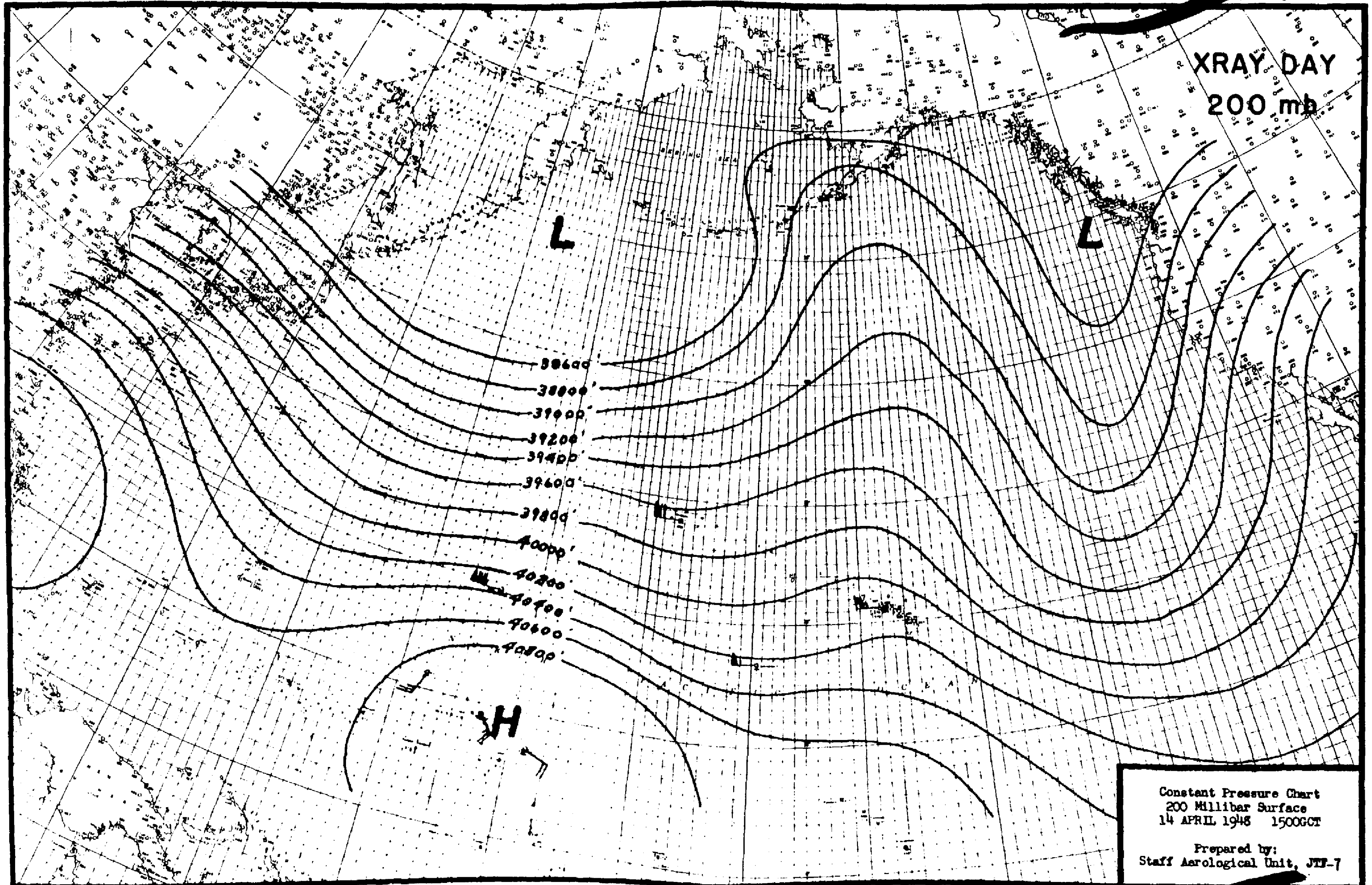

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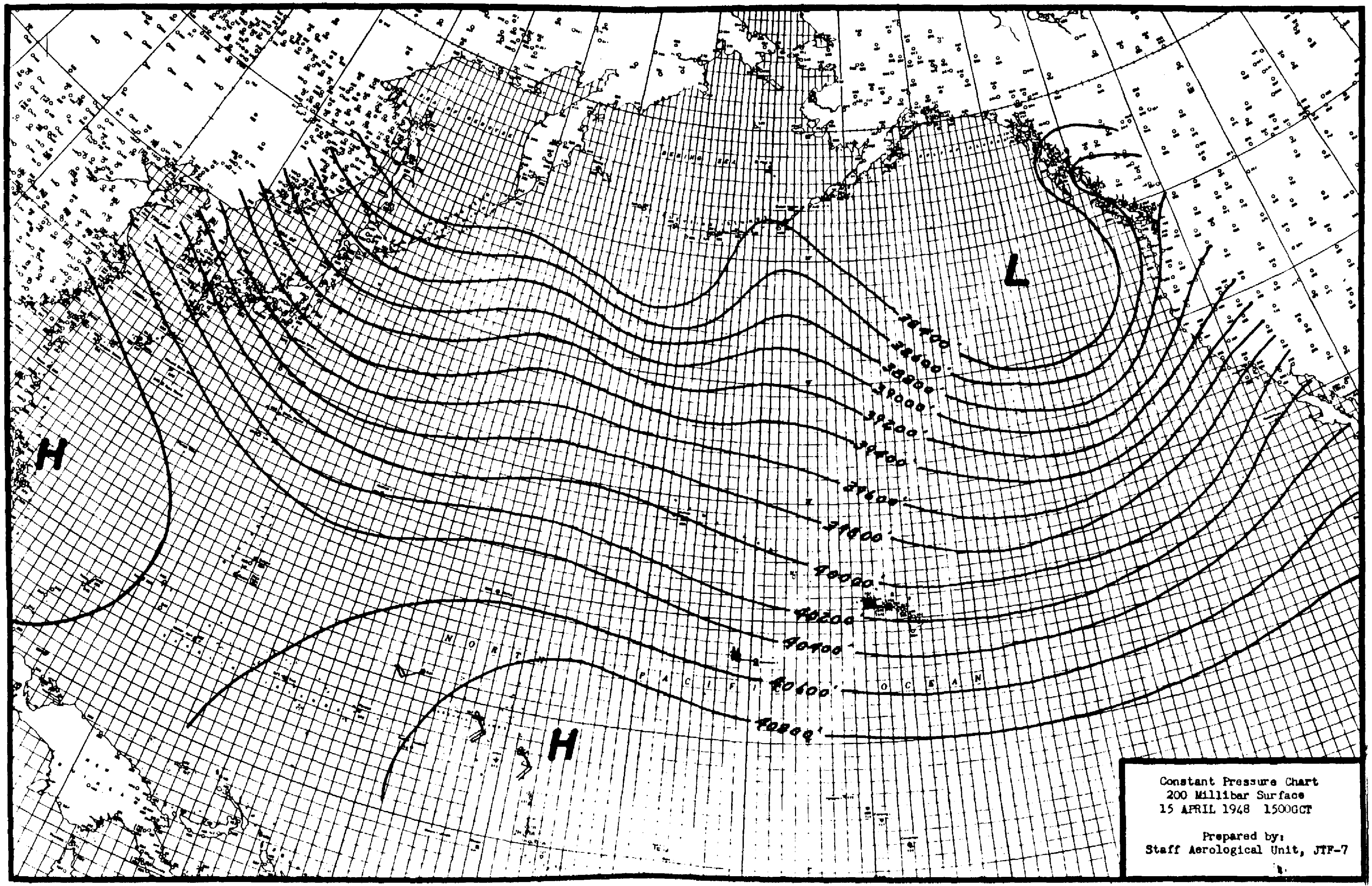

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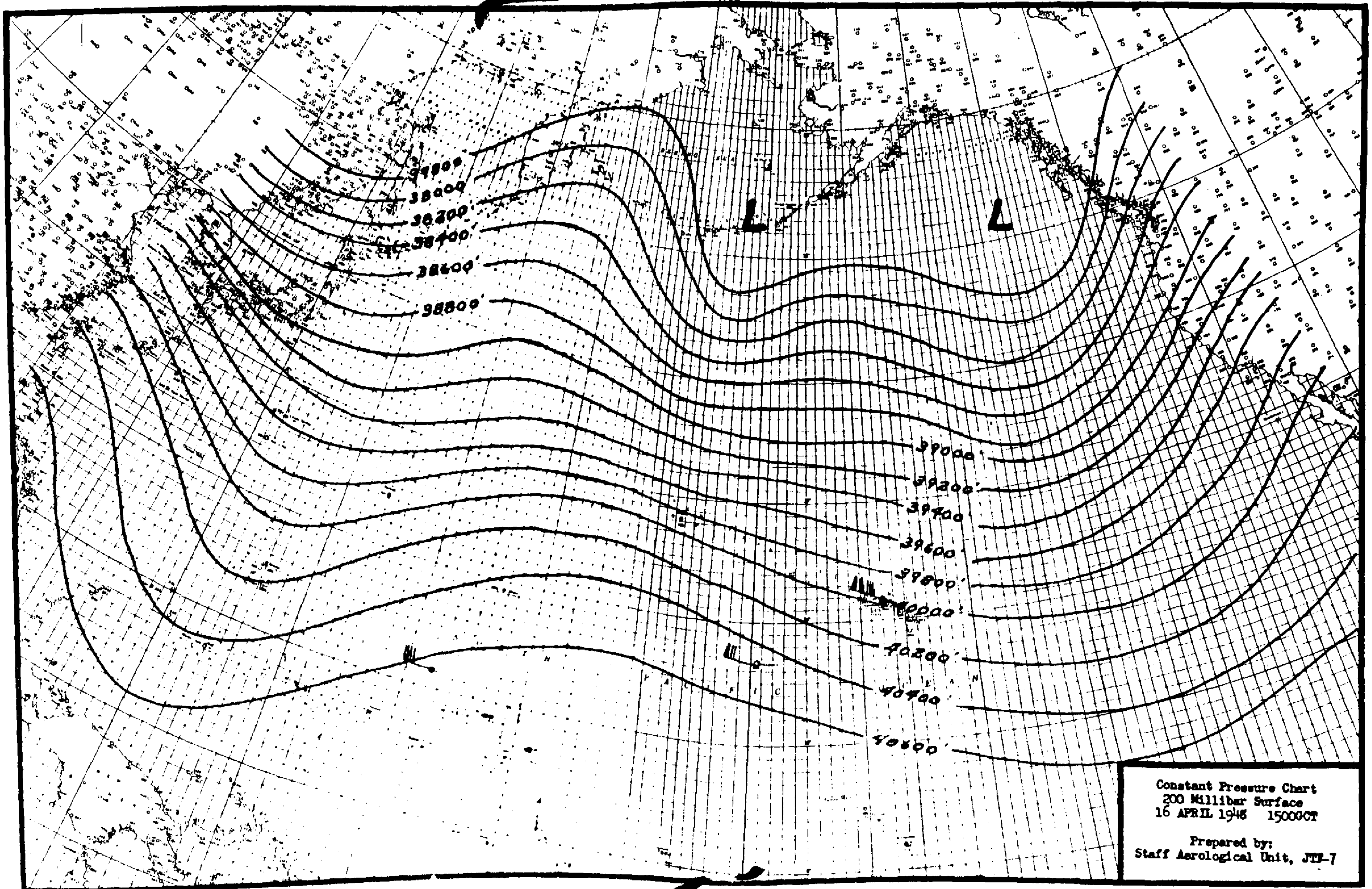

Constant Pressure Chart
200 Millibar Surface
16 APRIL 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

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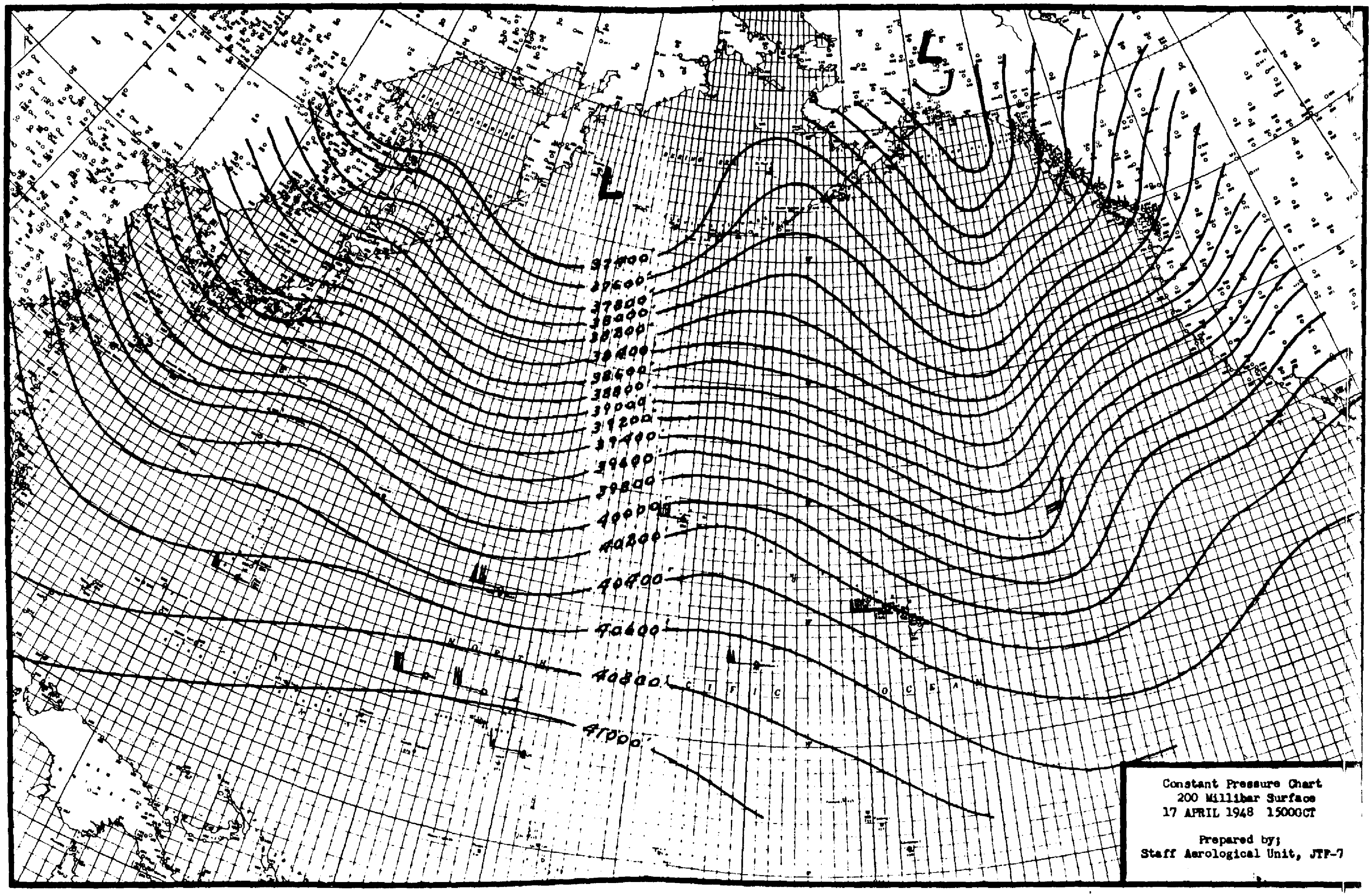

III-42 ~~SECRET~~

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YOKE DAY

850, 700, 500, 300 and 200 Millibar Surfaces

30 April and 1, 2, and 3 May 1948

1500 GCT

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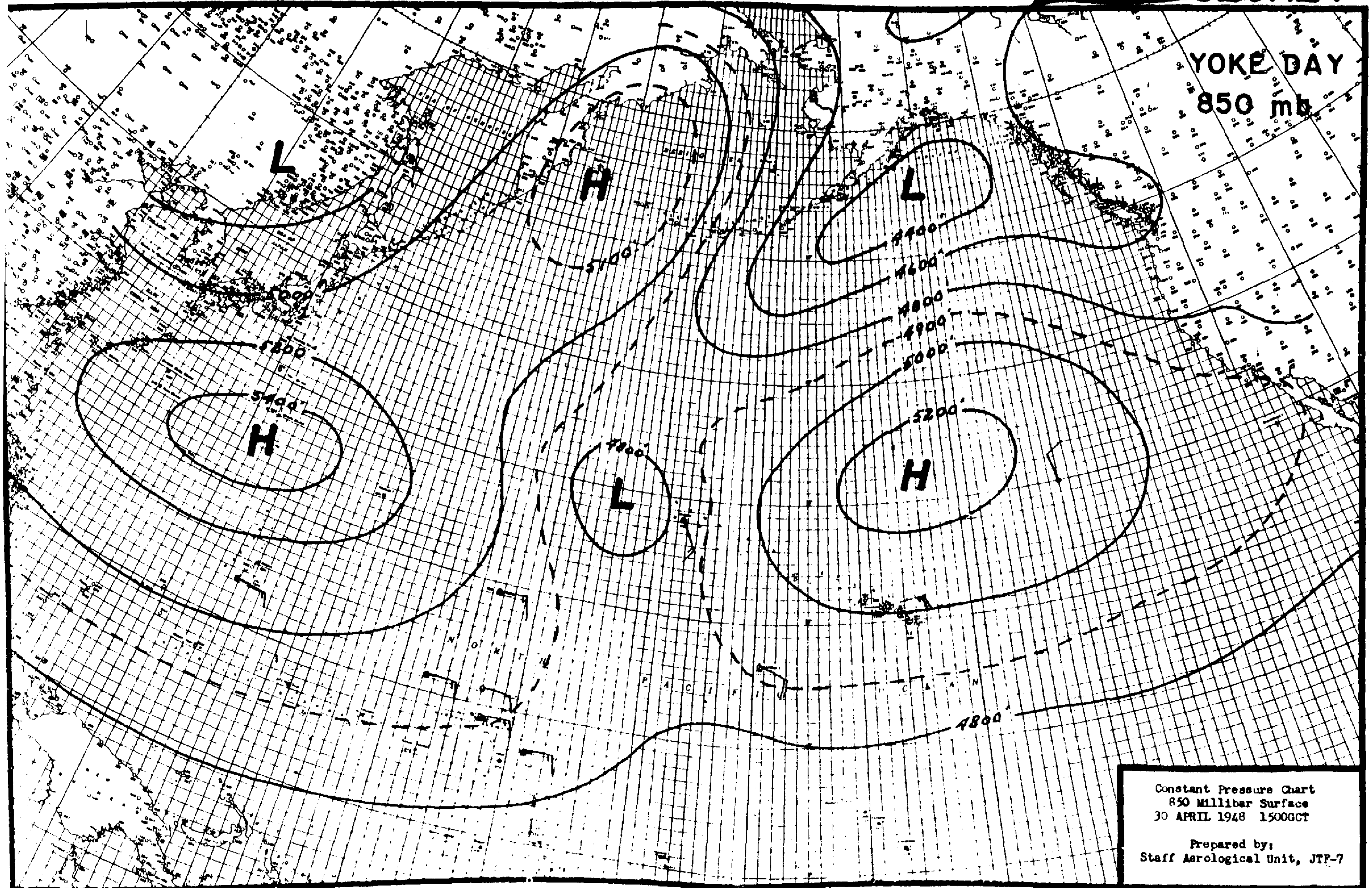

Constant Pressure Chart
850 Millibar Surface
30 APRIL 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

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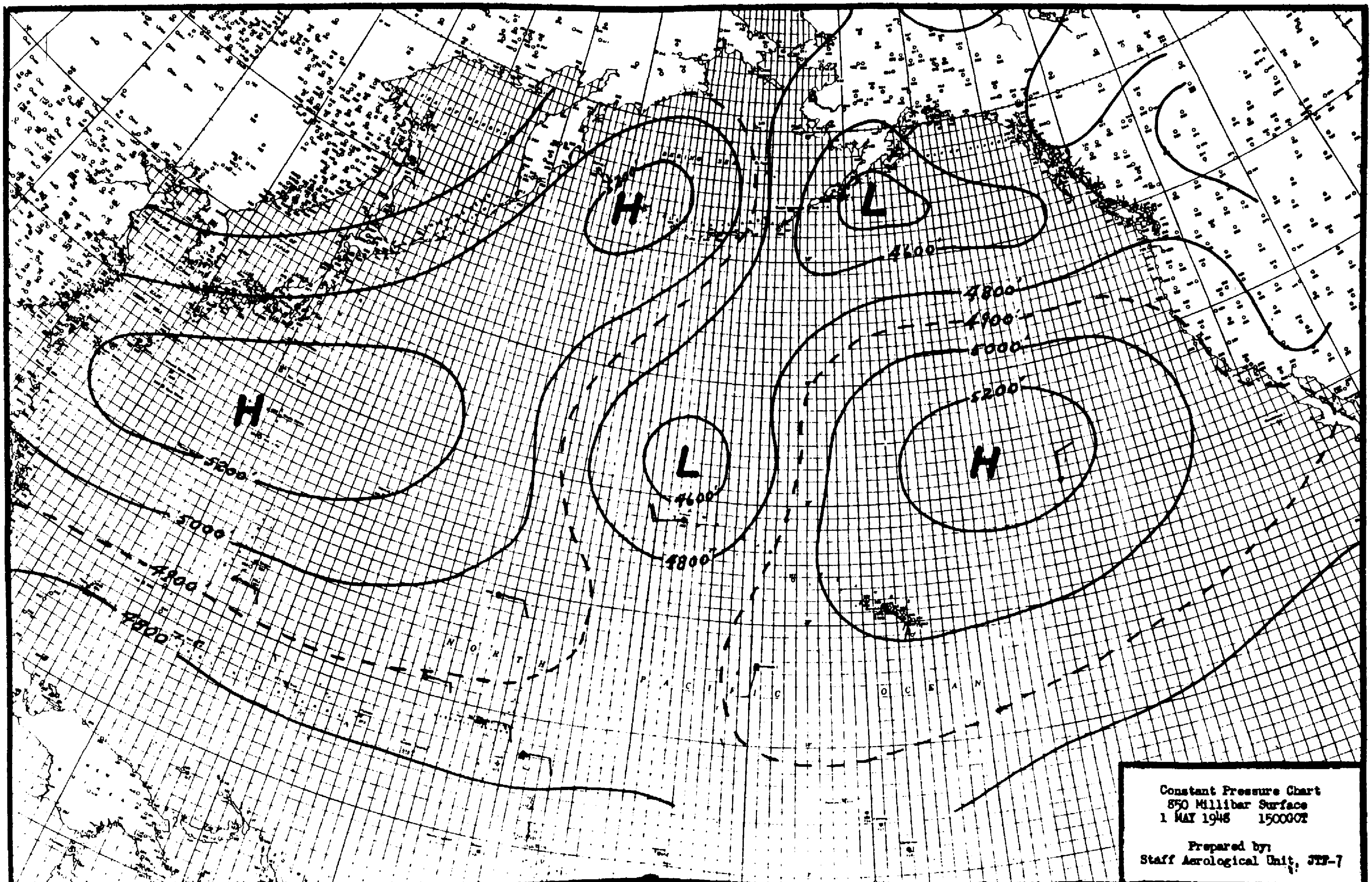

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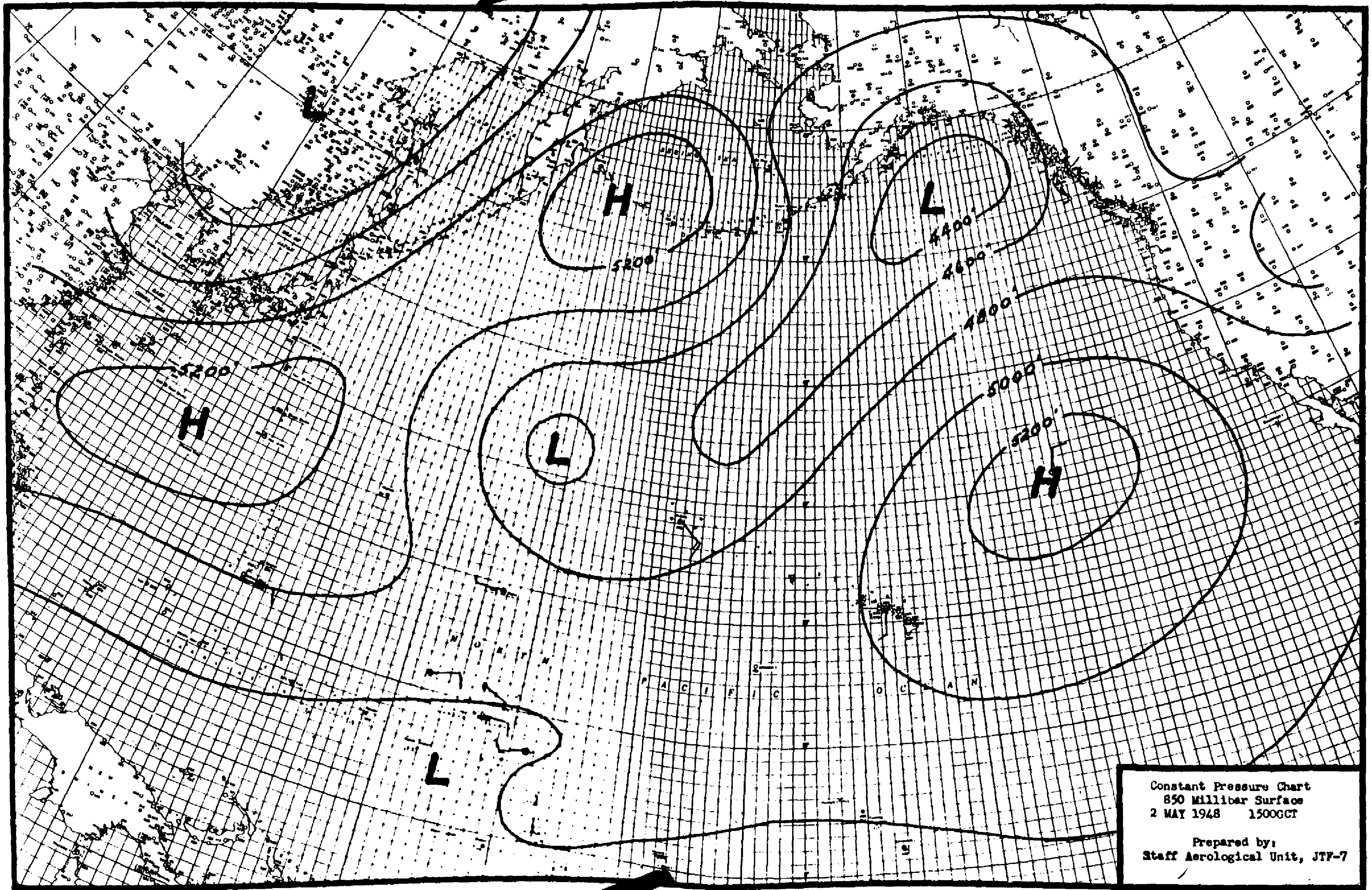

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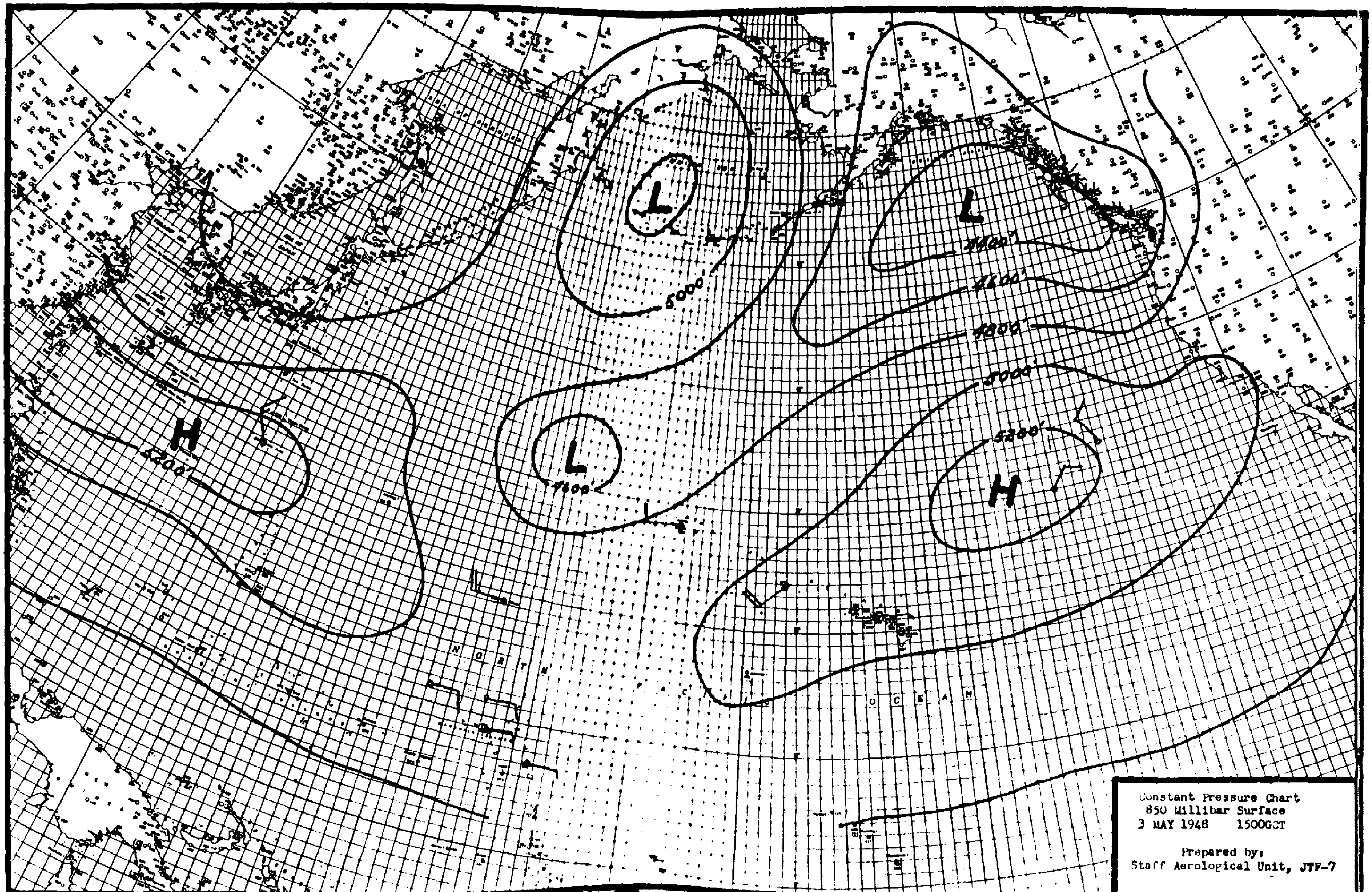

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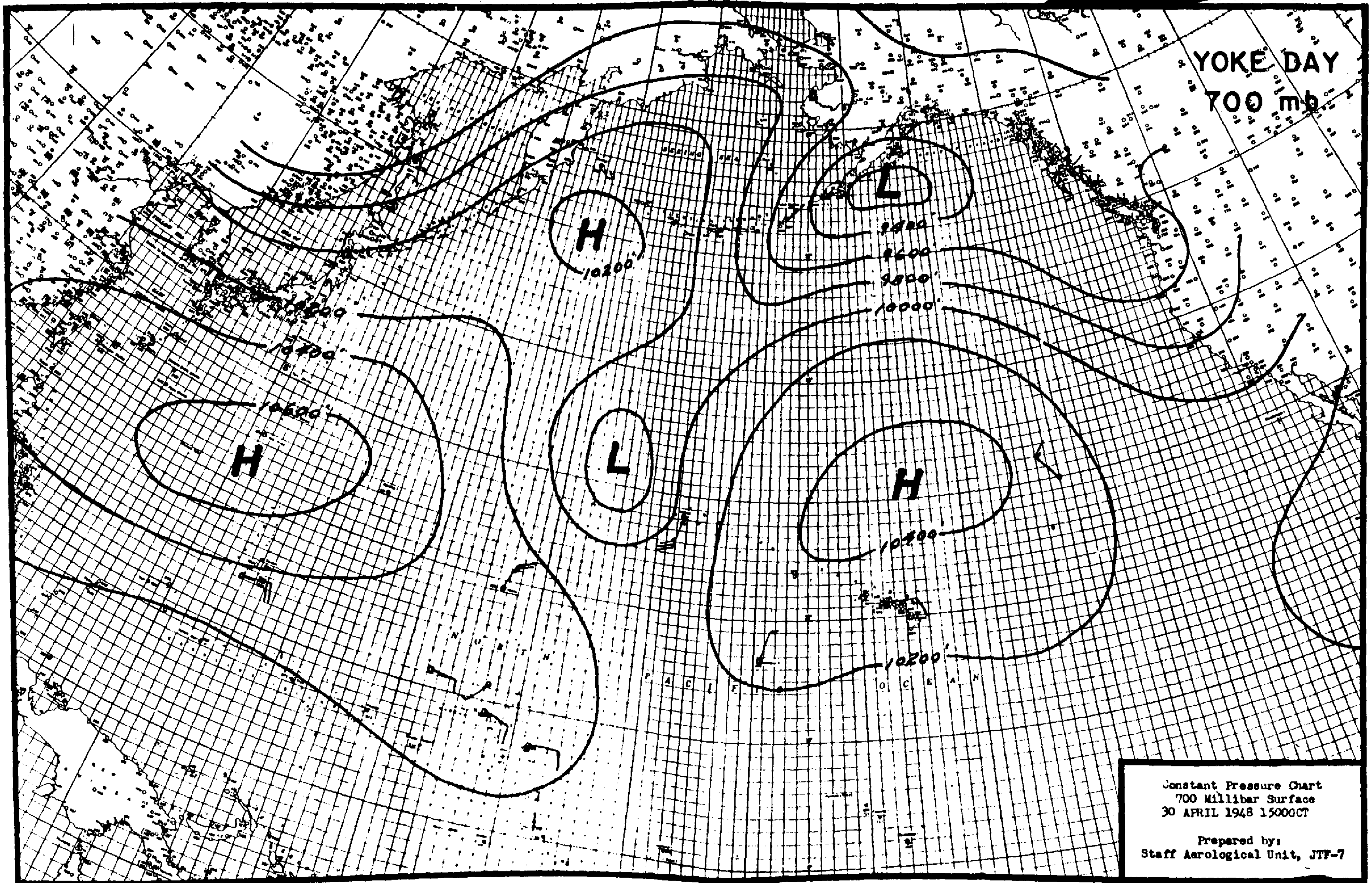
YOKE DAY
700 mb
10200
10000
10400
10600
9400
9600
9800
N O R T H
P A C I F I C
O C E A N
Constant Pressure Chart
700 Millibar Surface
30 APRIL 1948 1500GCT
Prepared by:
Staff Aerological Unit, JTF-7

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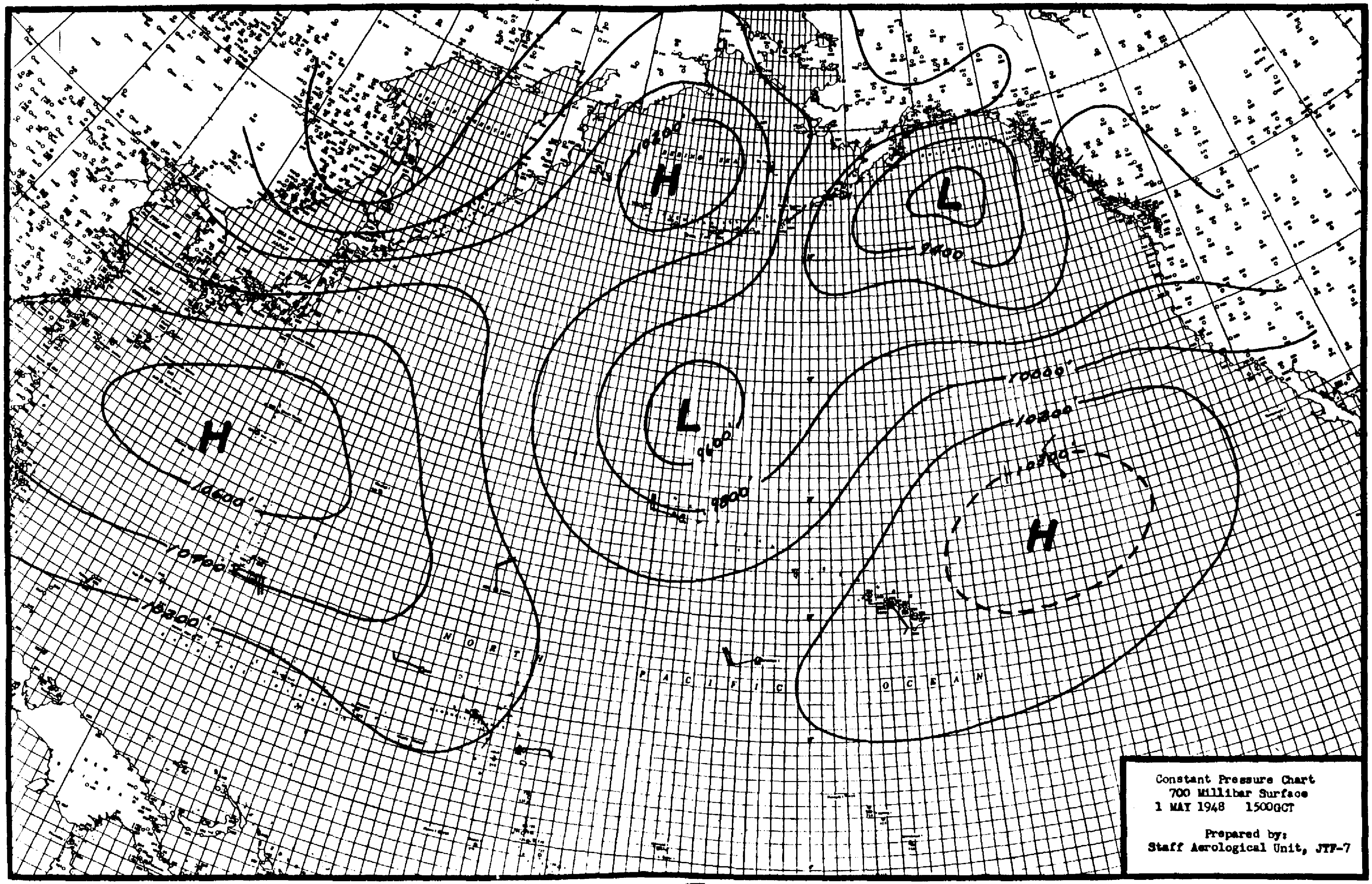

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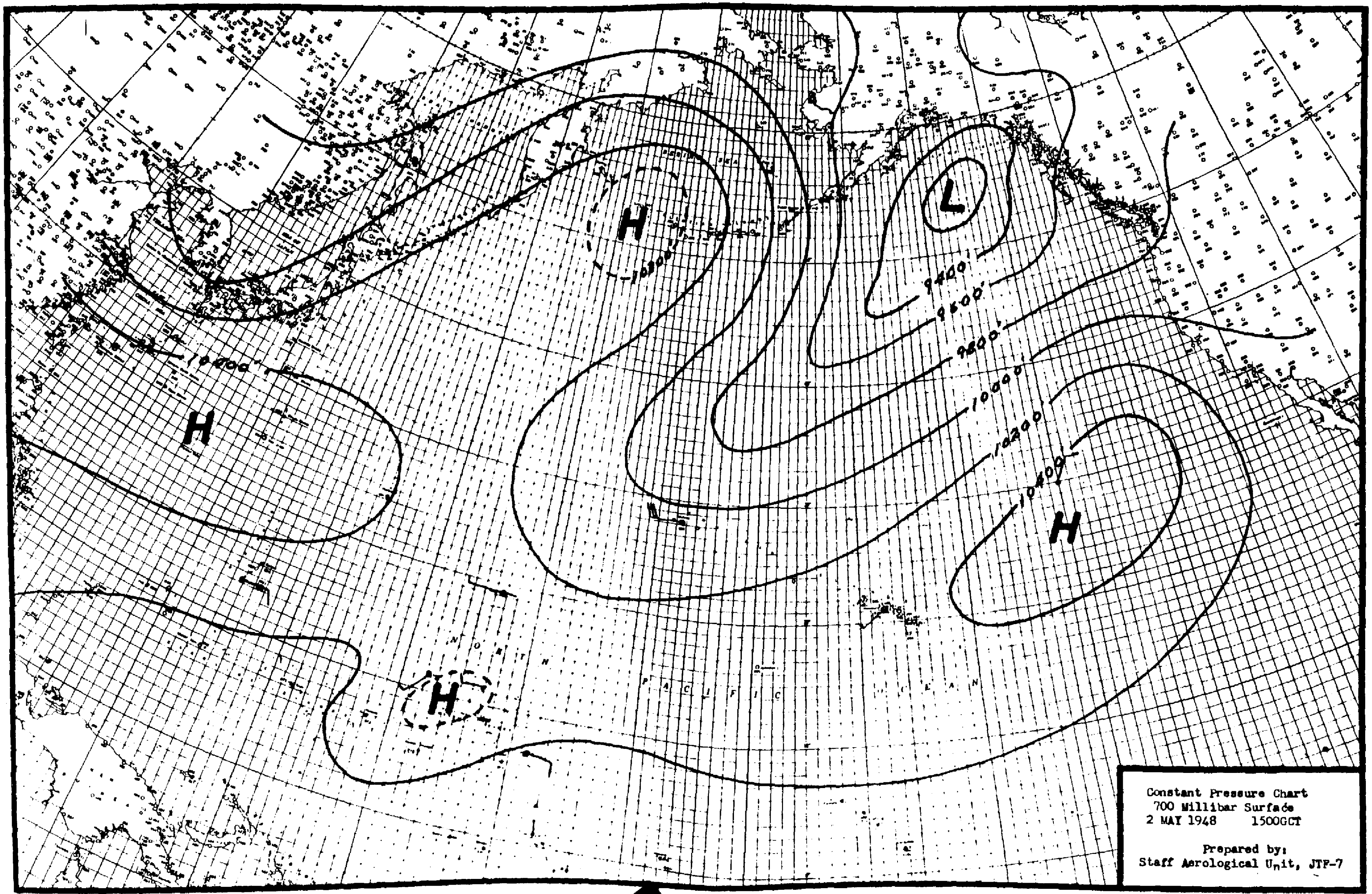

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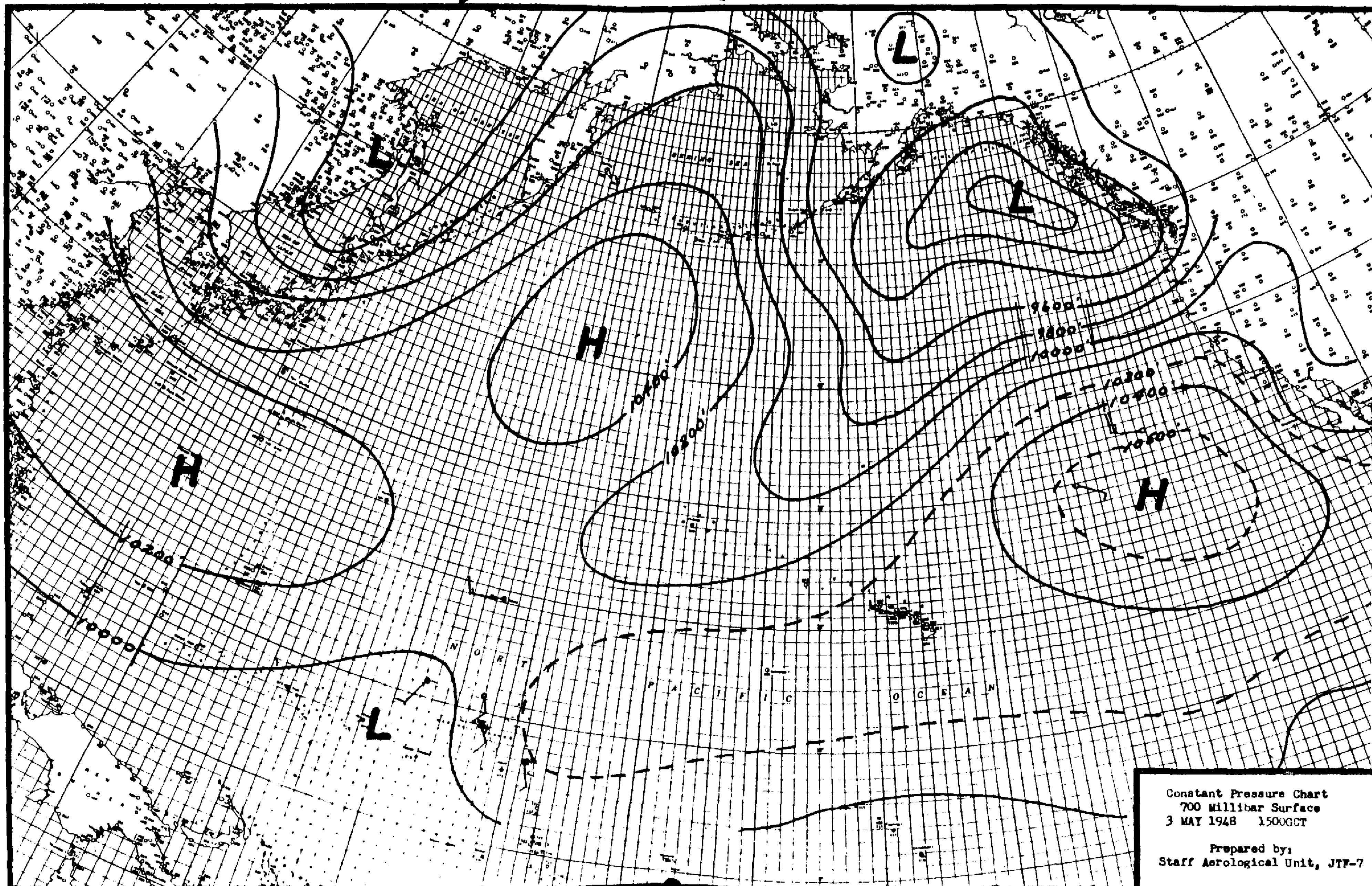

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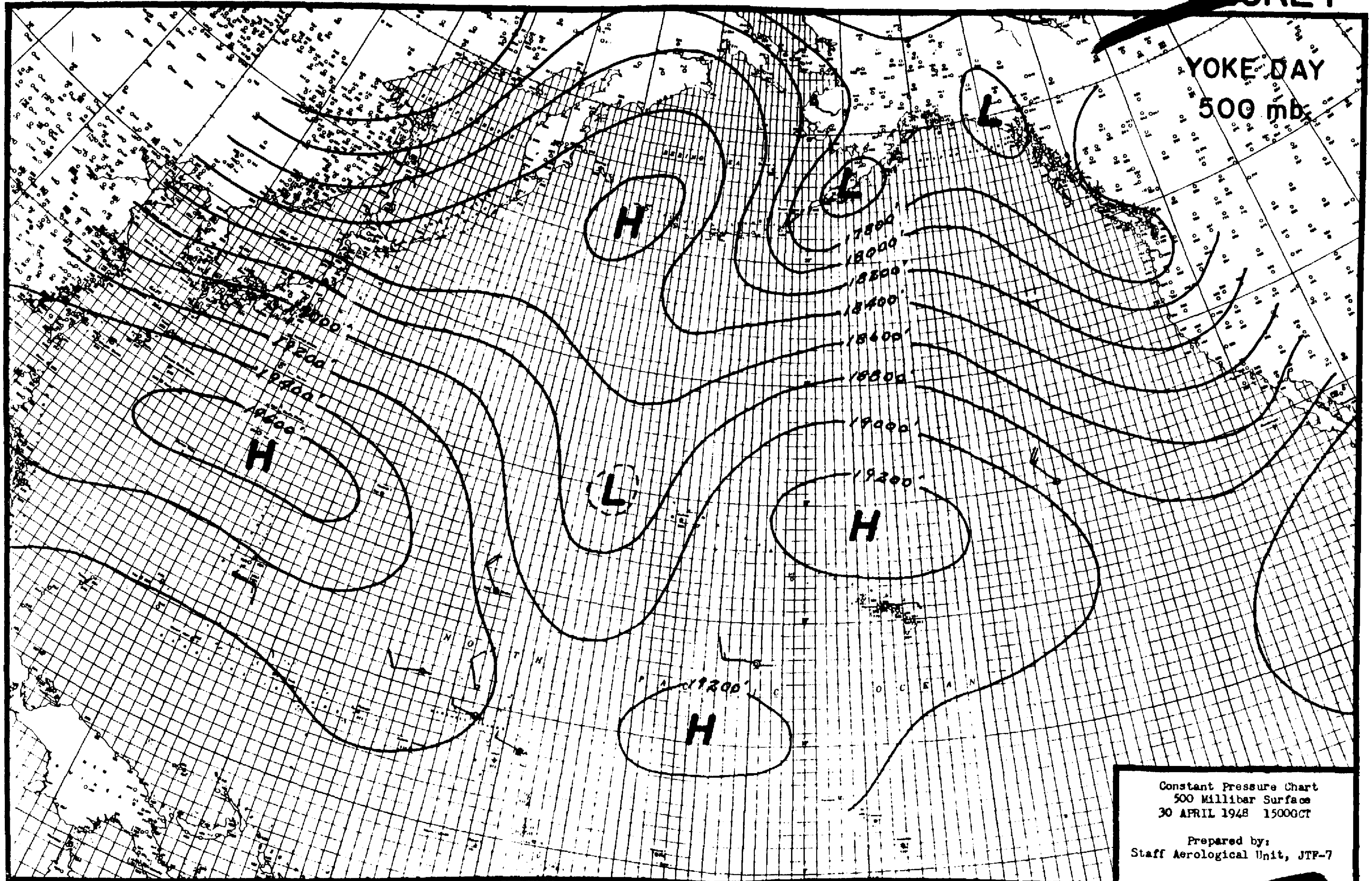

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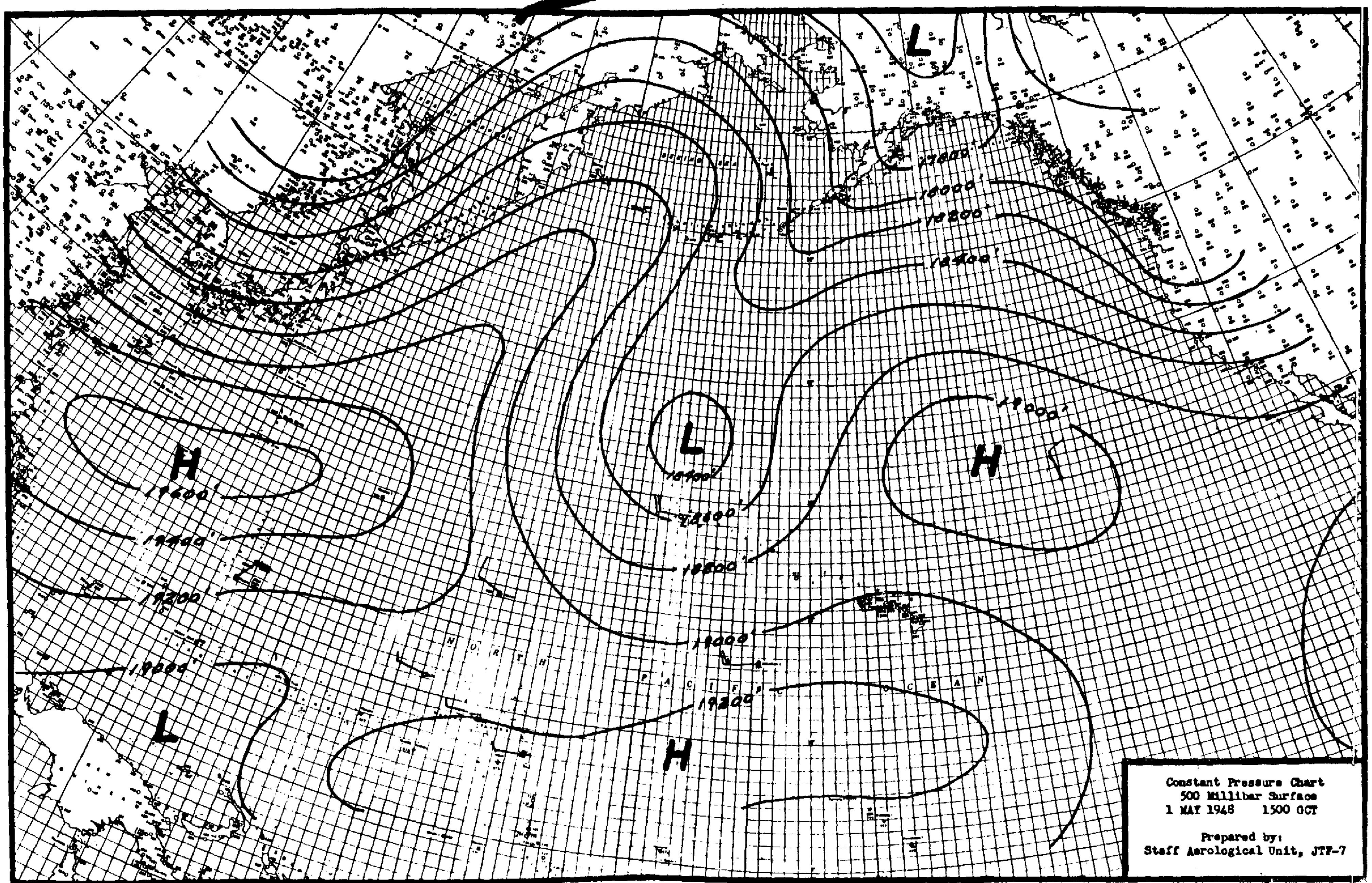

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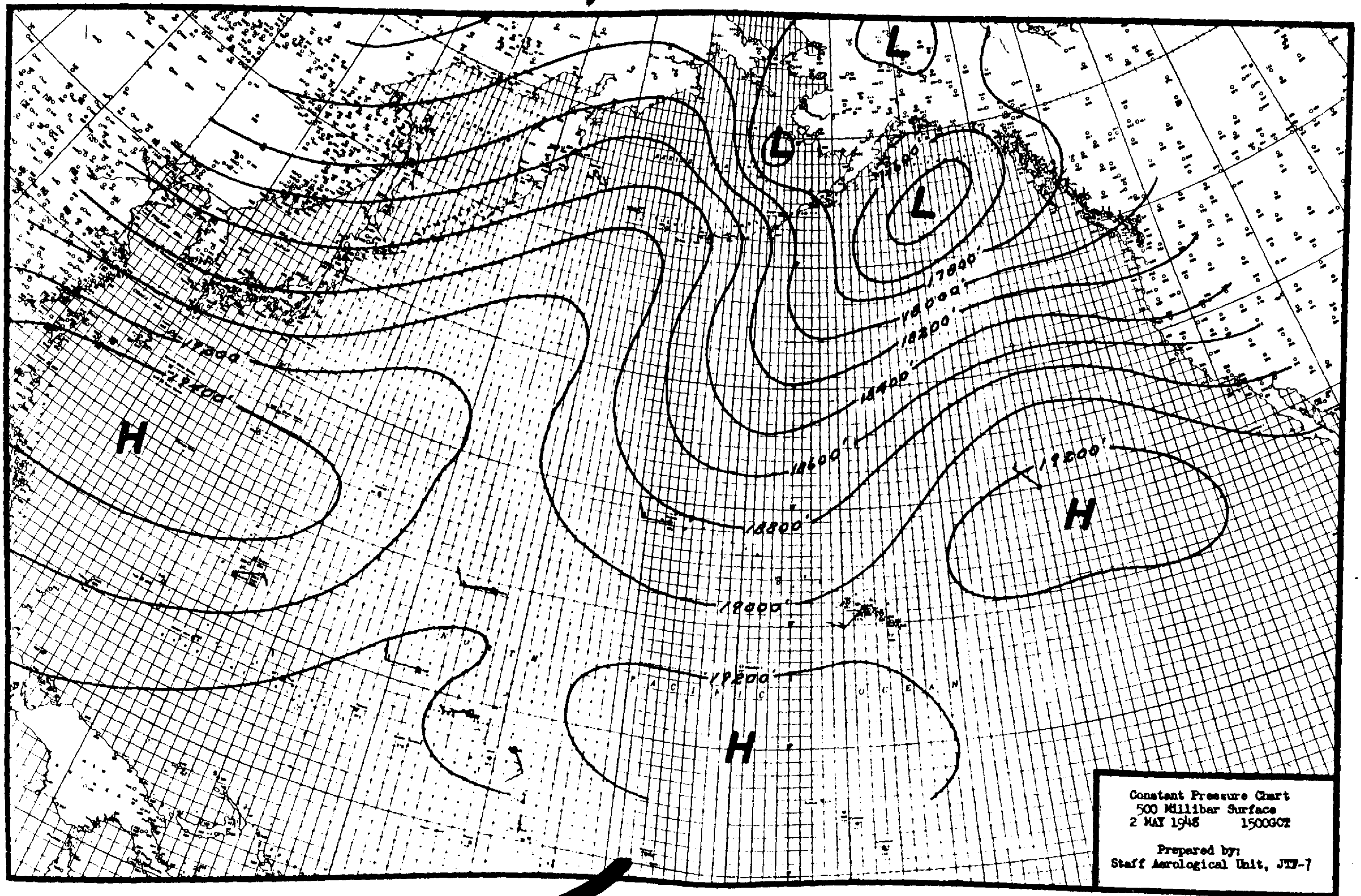

Constant Pressure Chart
500 Millibar Surface
2 MAY 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

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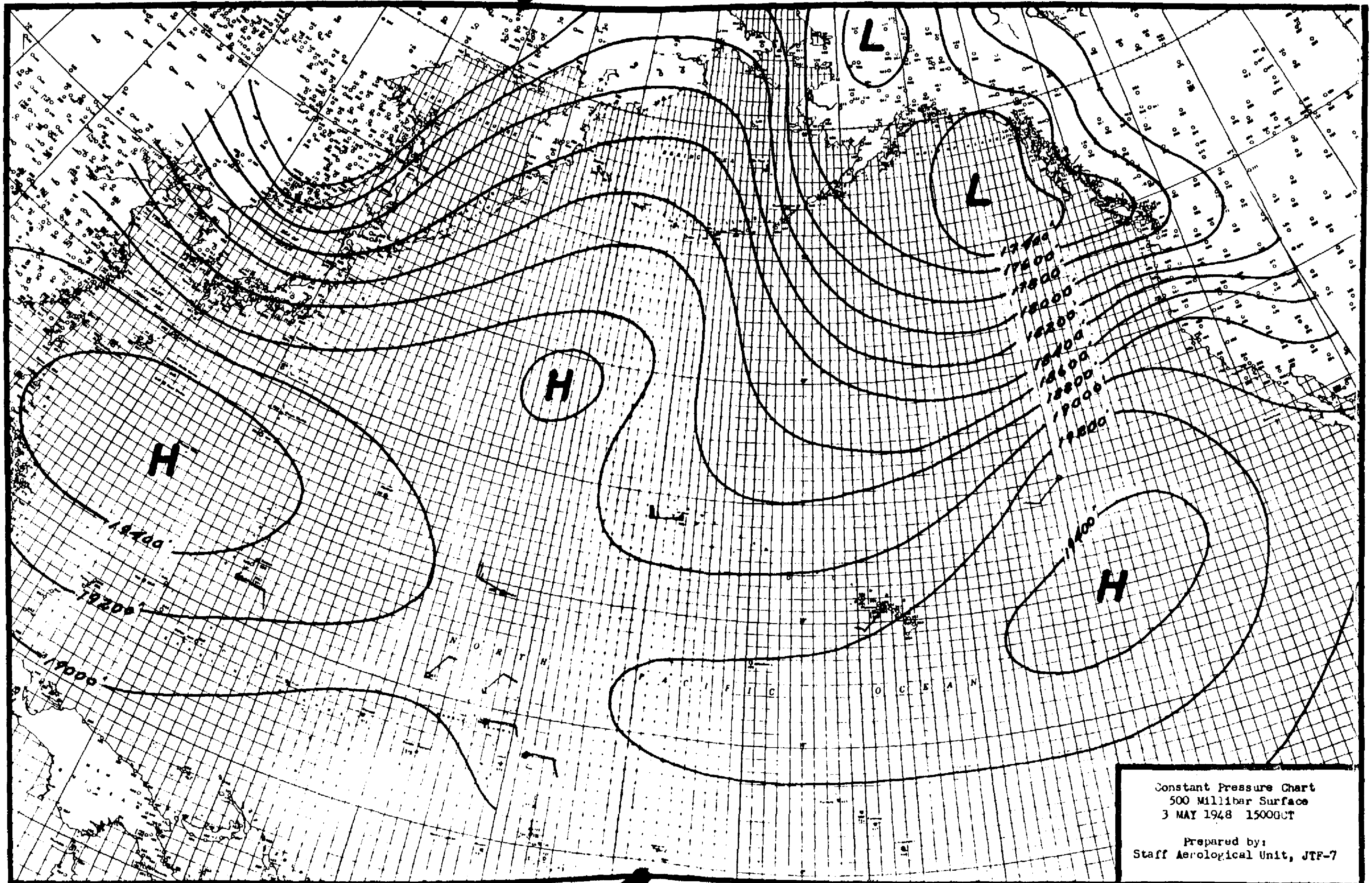

Constant Pressure Chart
500 Millibar Surface
3 MAY 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

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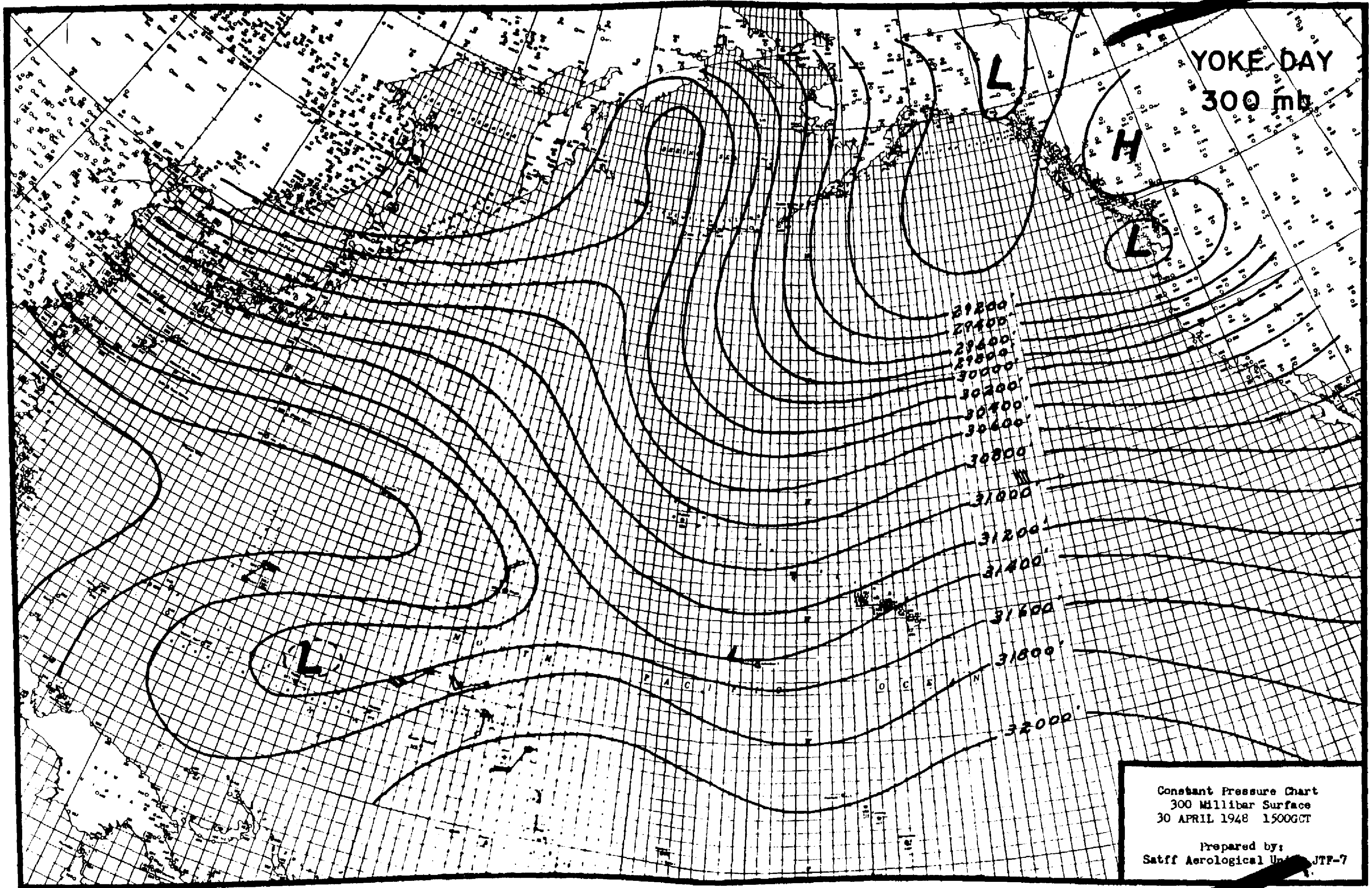

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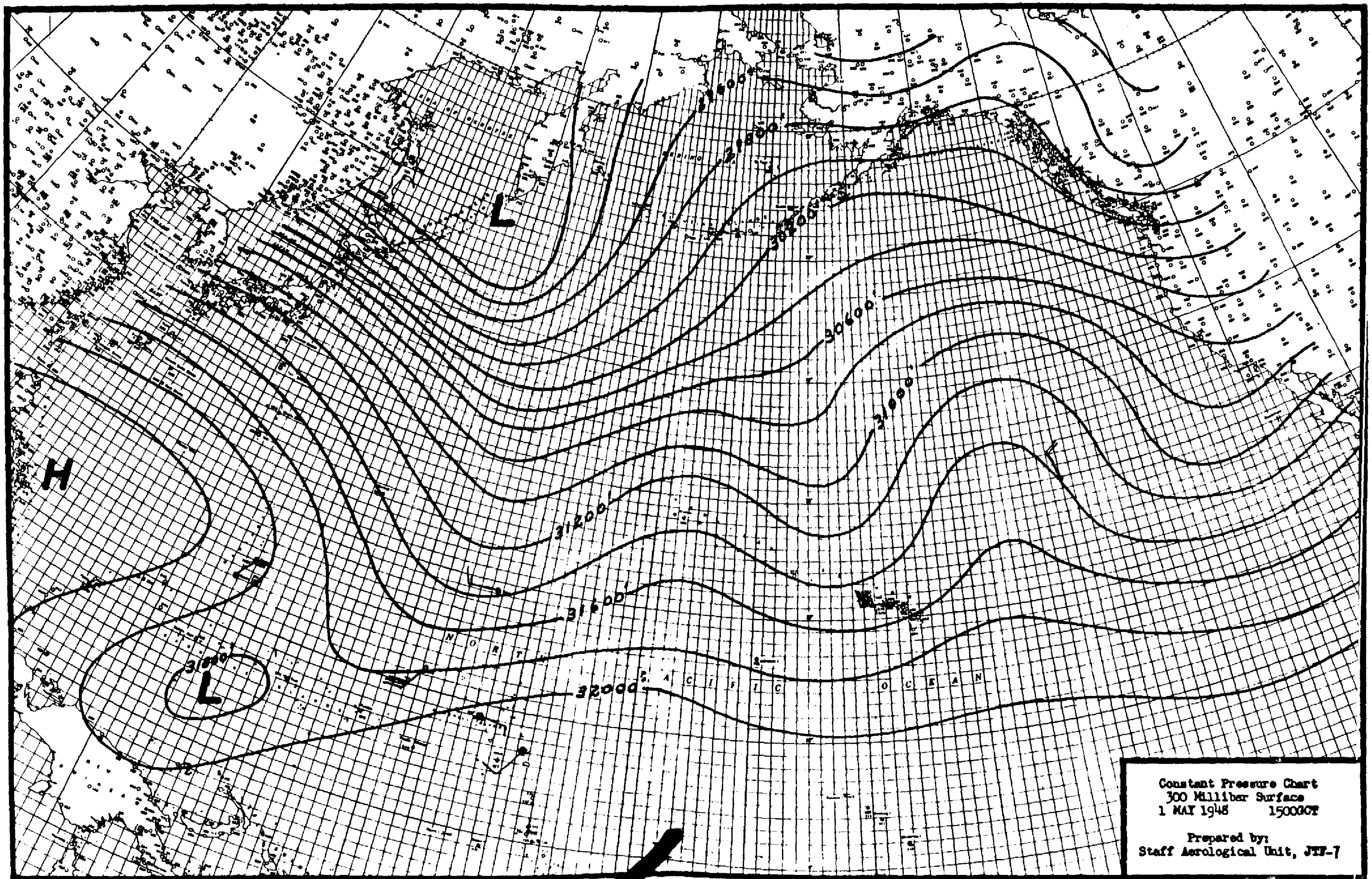
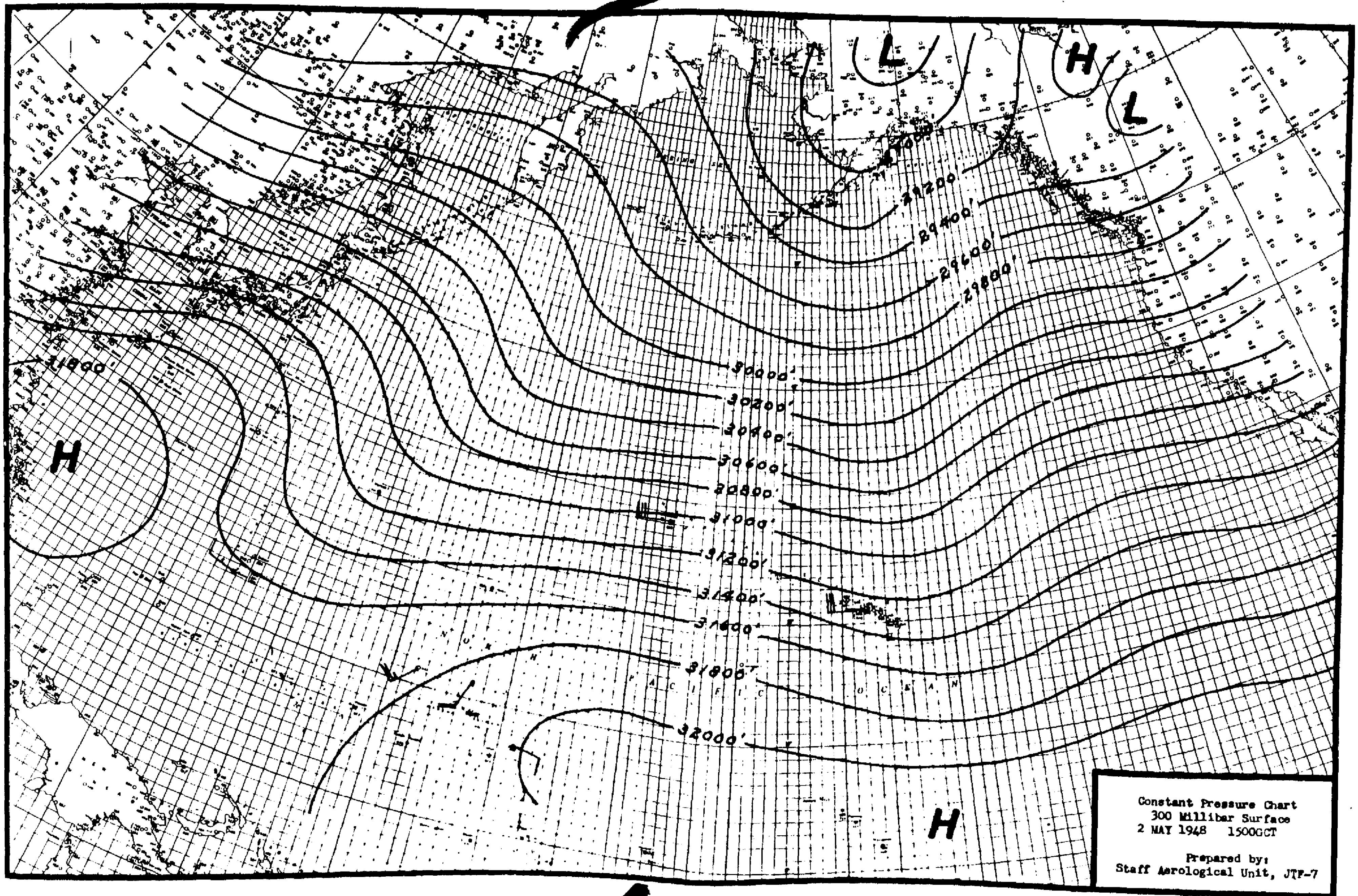


Constant Pressure Chart
300 Millibar Surface
1 MAY 1948   1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

SECRET



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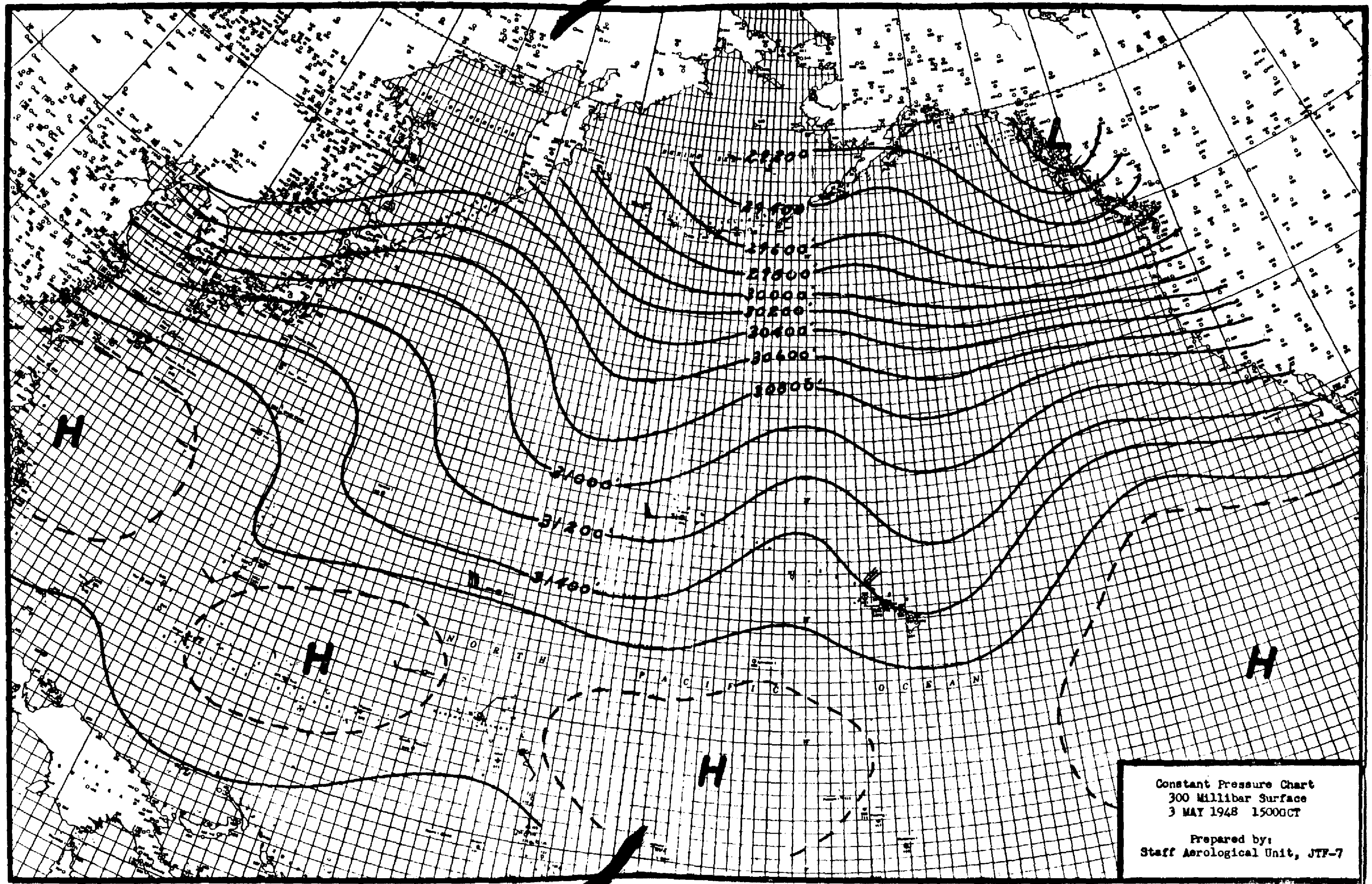
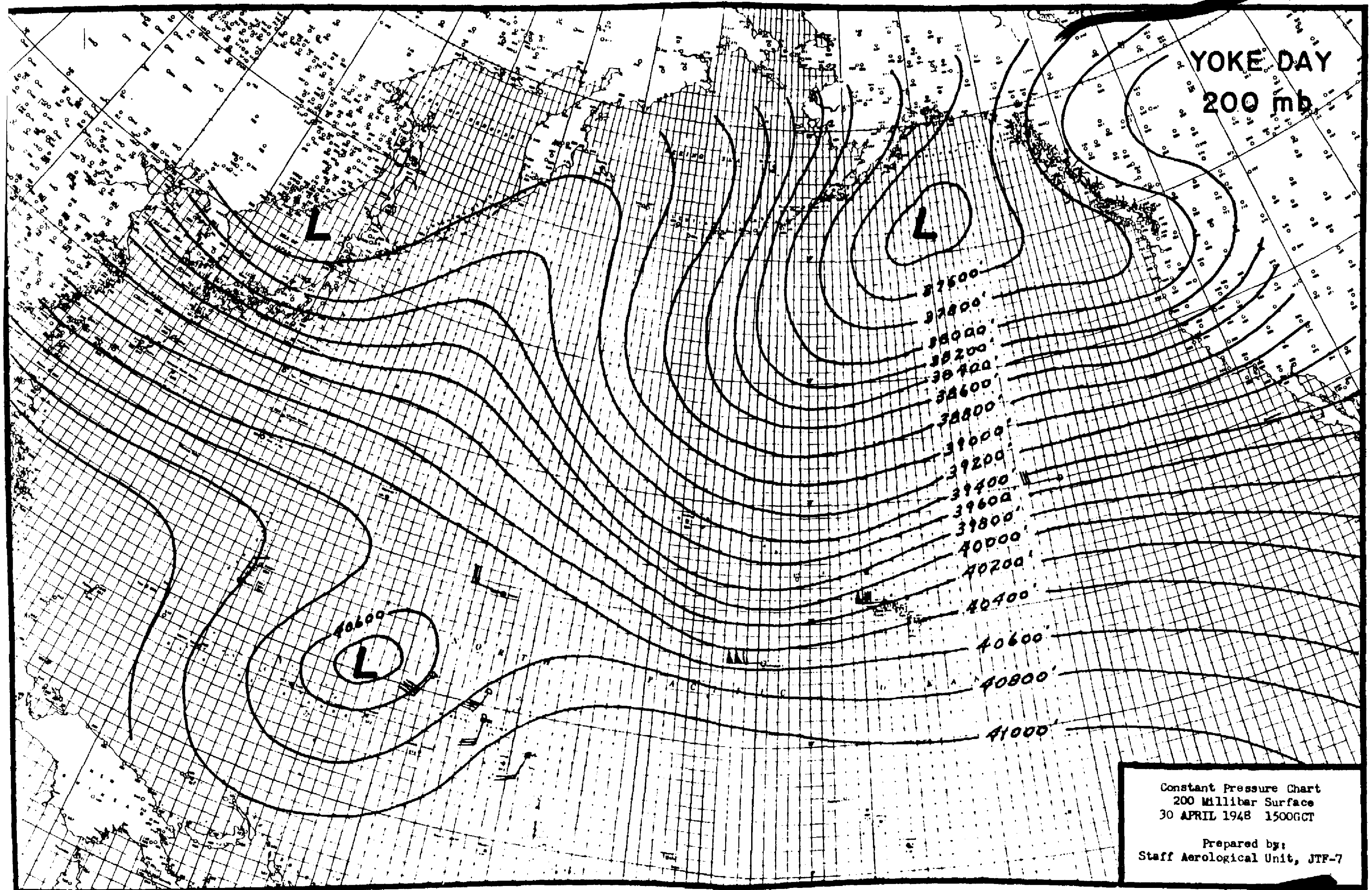


Constant Pressure Chart
300 Millibar Surface
3 MAY 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7


YOKE DAY
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40200'
40400'
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40600'
Constant Pressure Chart
200 Millibar Surface
30 APRIL 1948 1500GCT
Prepared by:
Staff Aerological Unit, JTF-7

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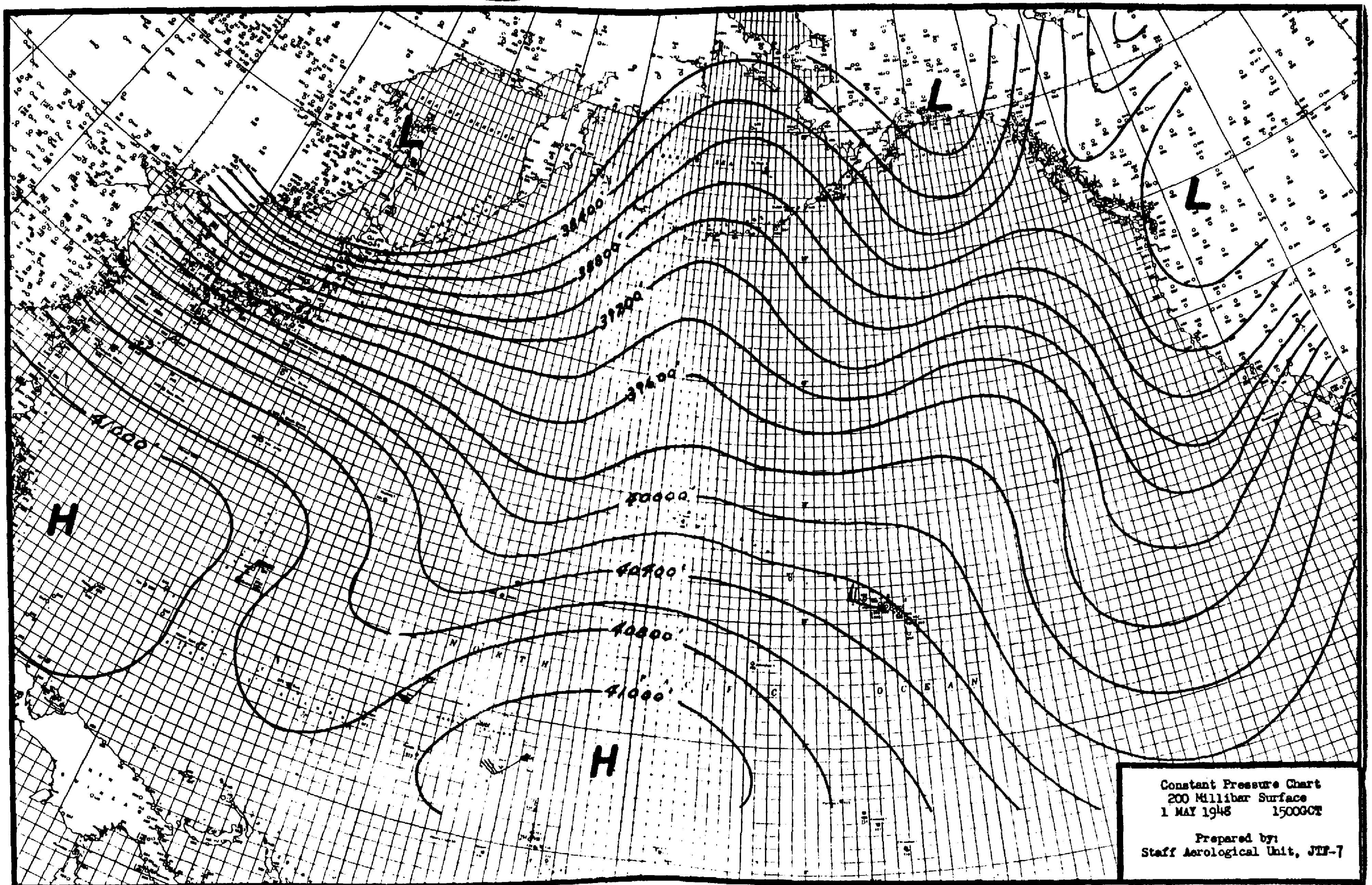

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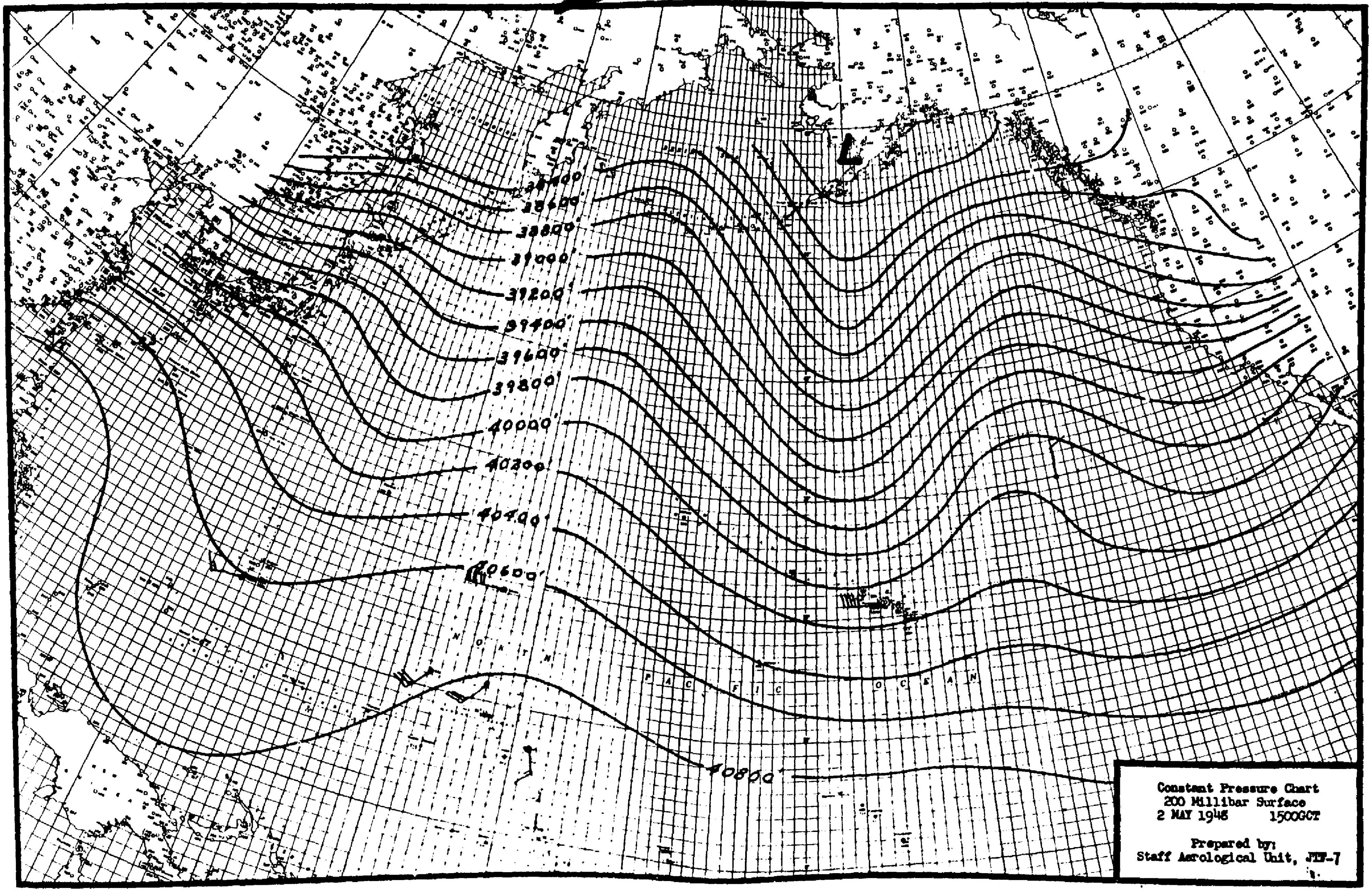

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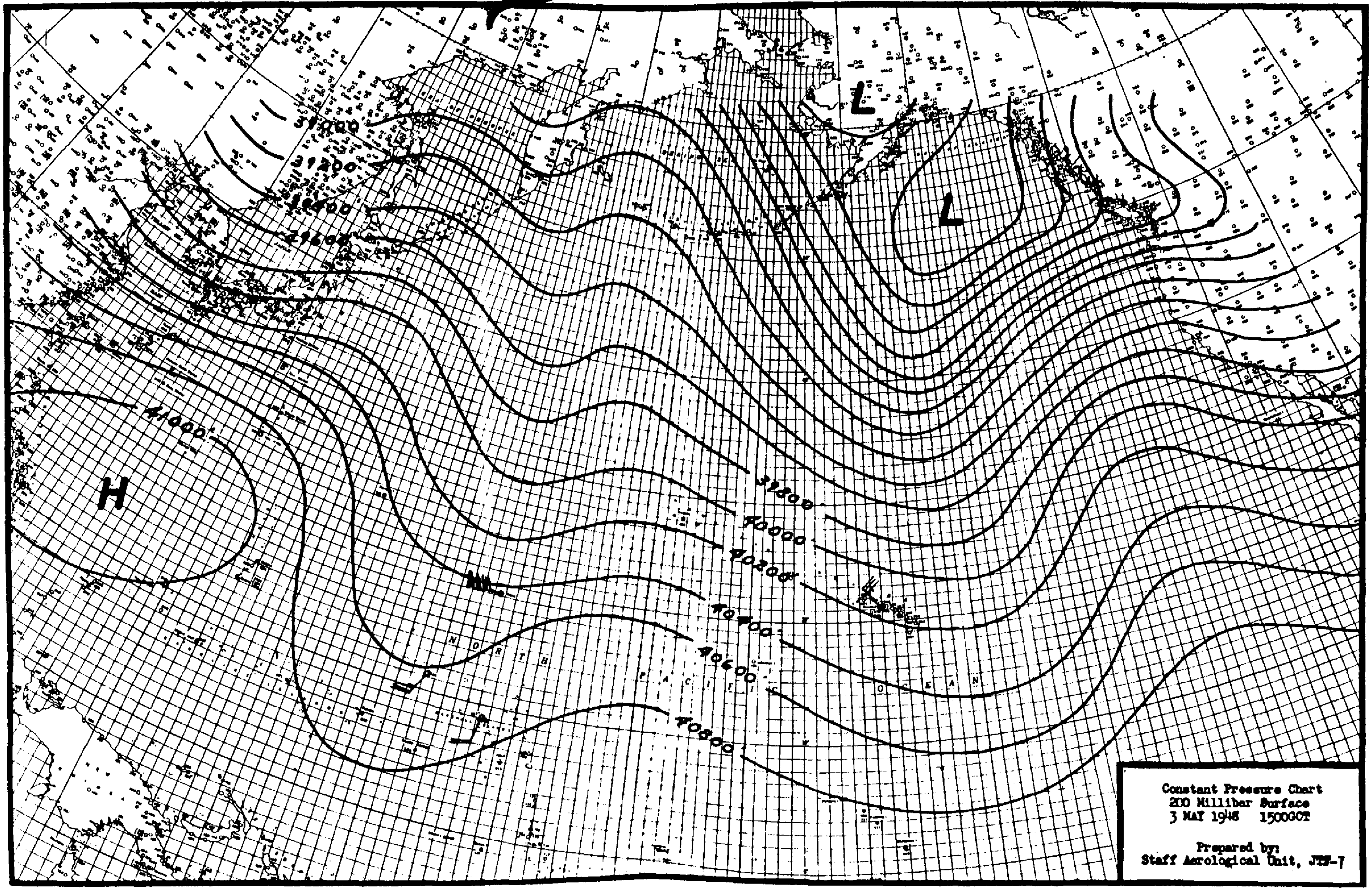

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ZEBRA DAY

850, 700, 500, 300 and 200 Millibar Surfaces

14, 15, and 16 May 1948

1500 GCT

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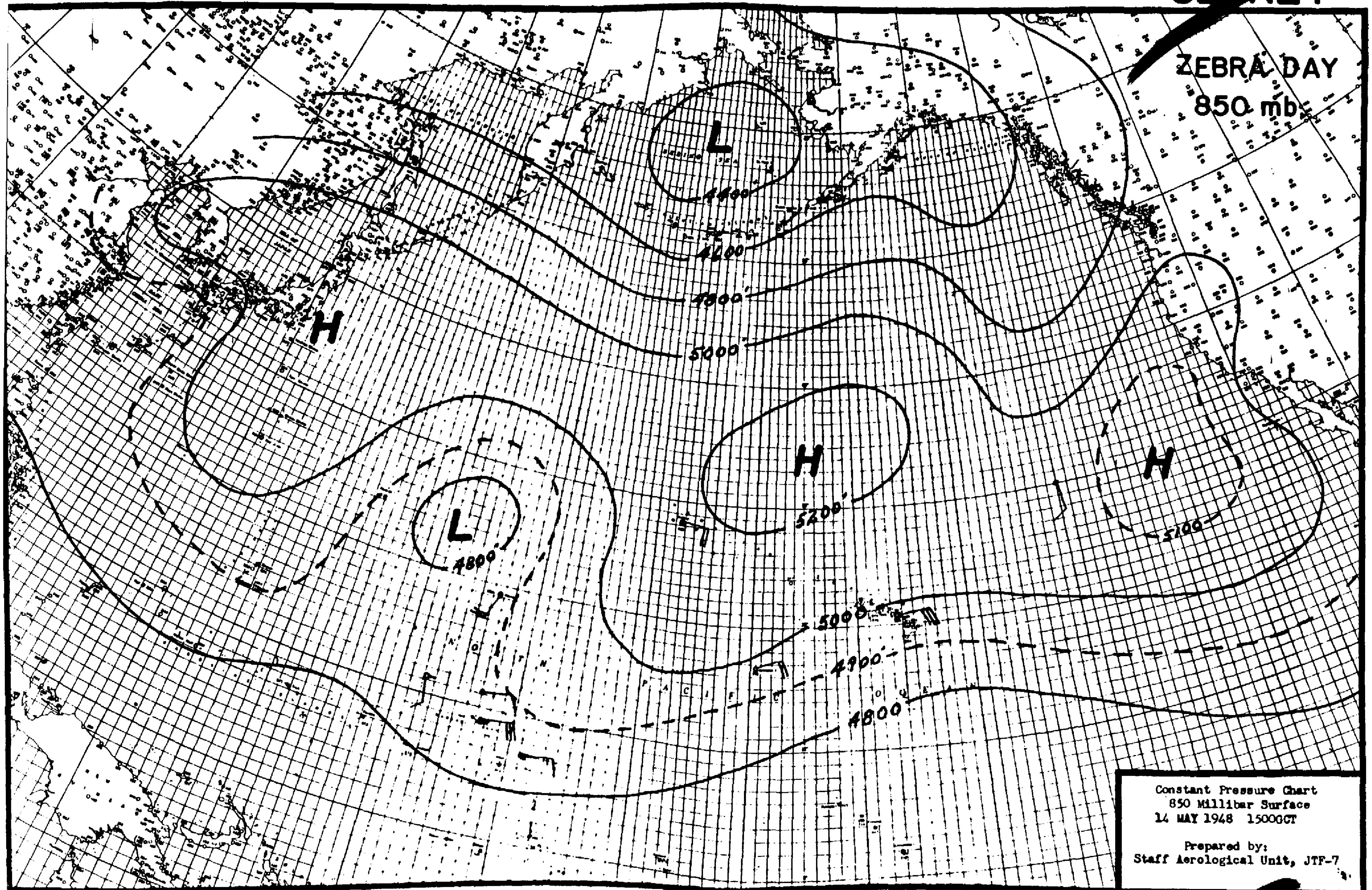

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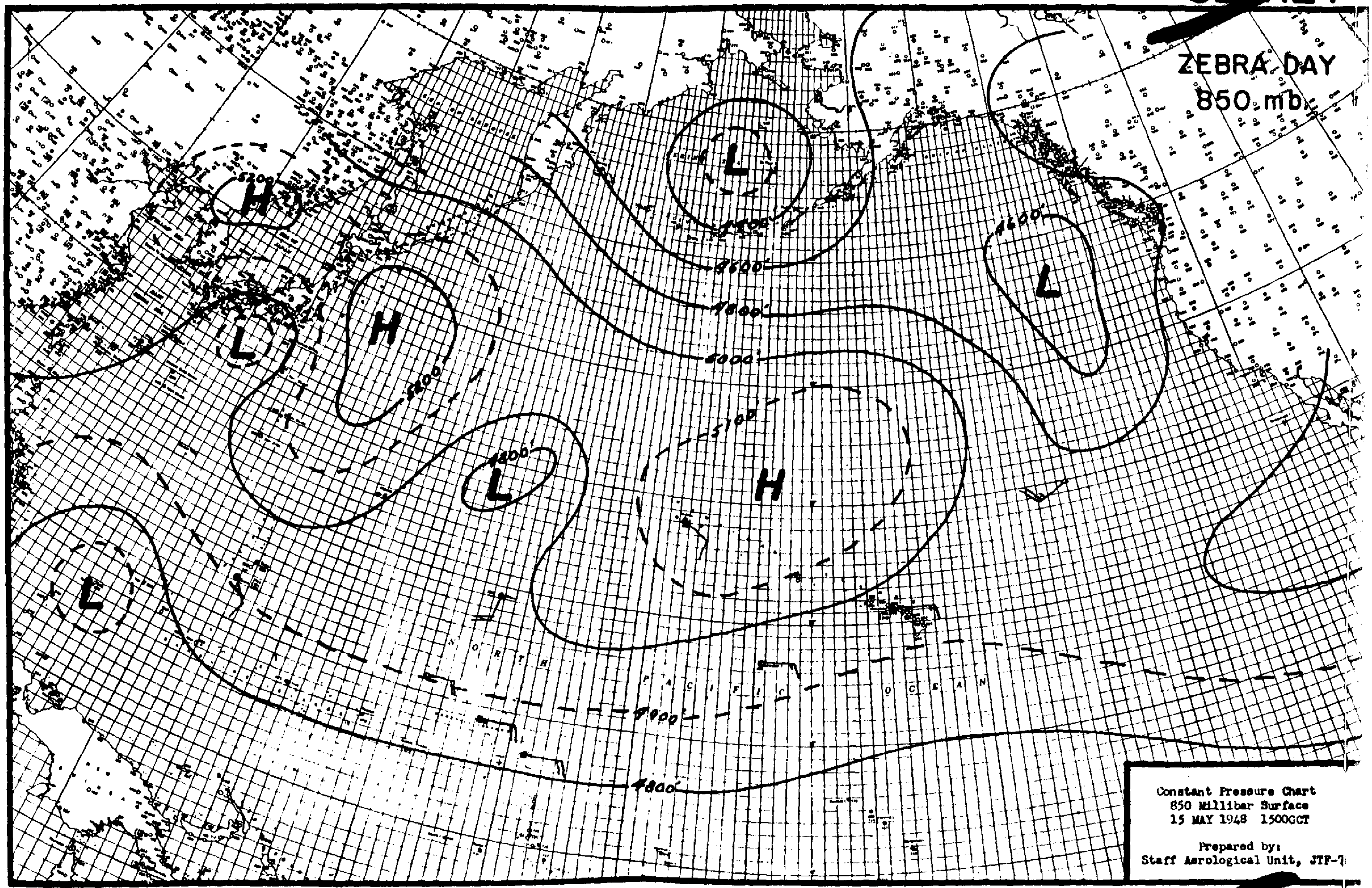

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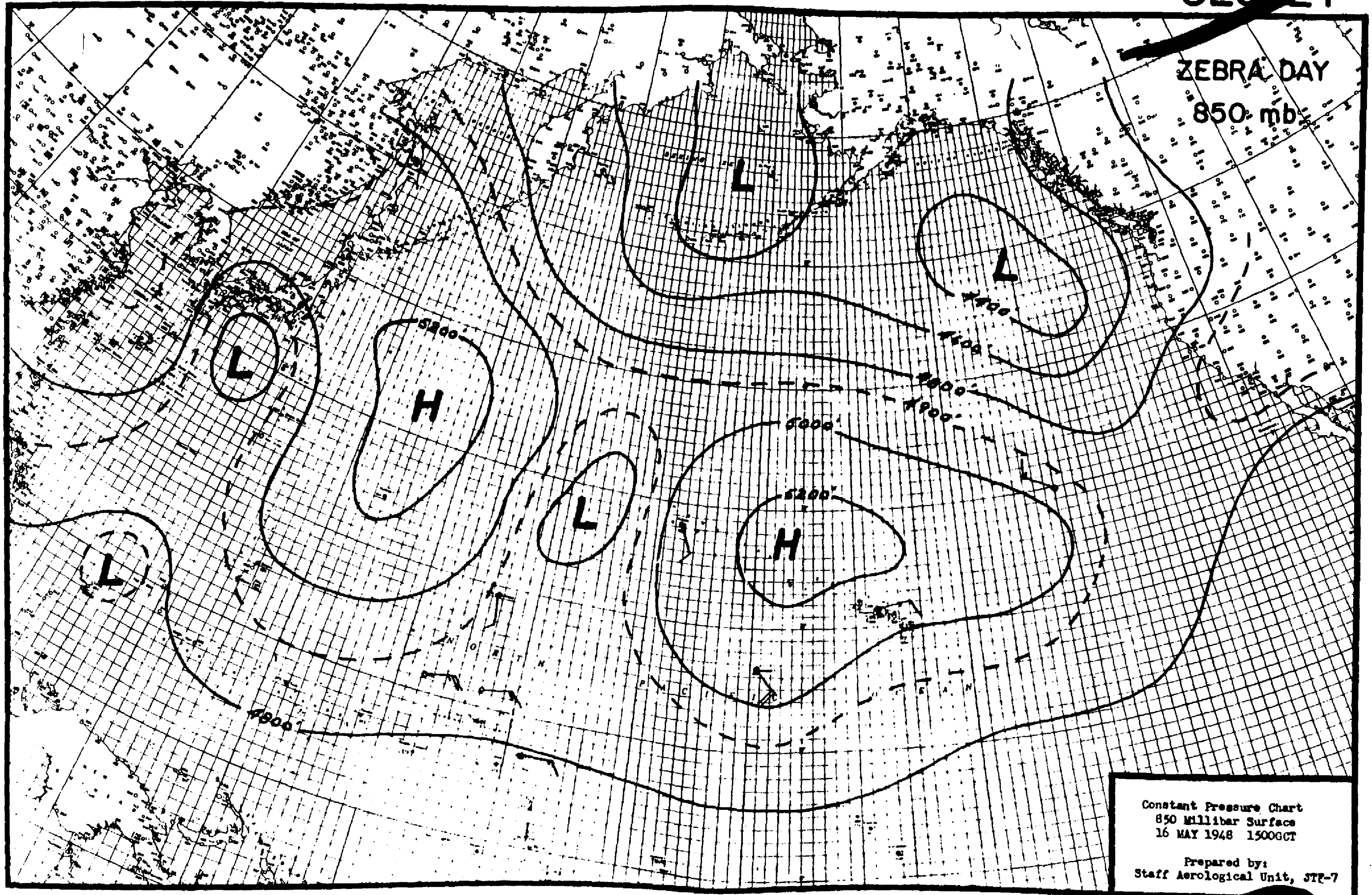

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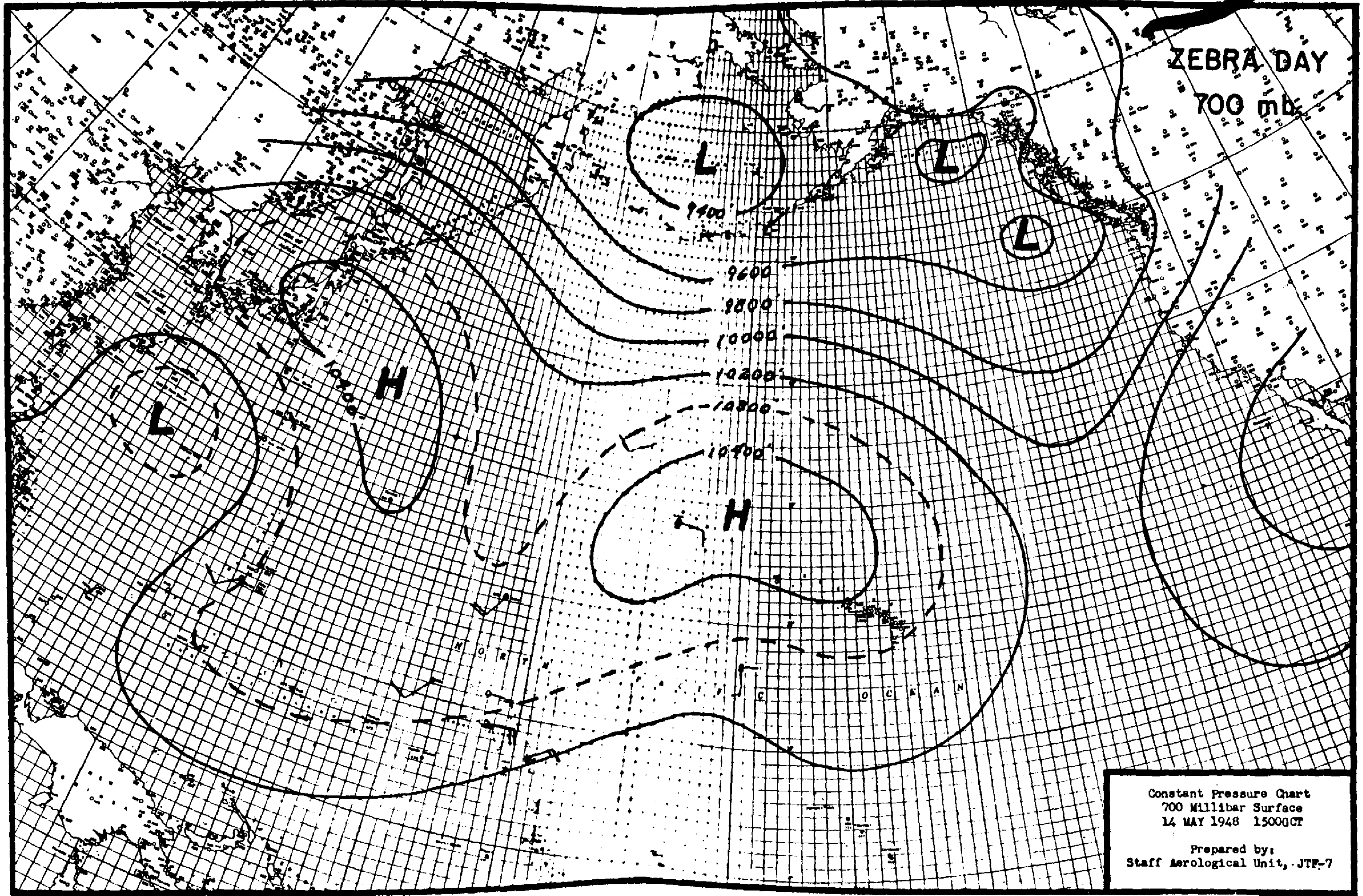

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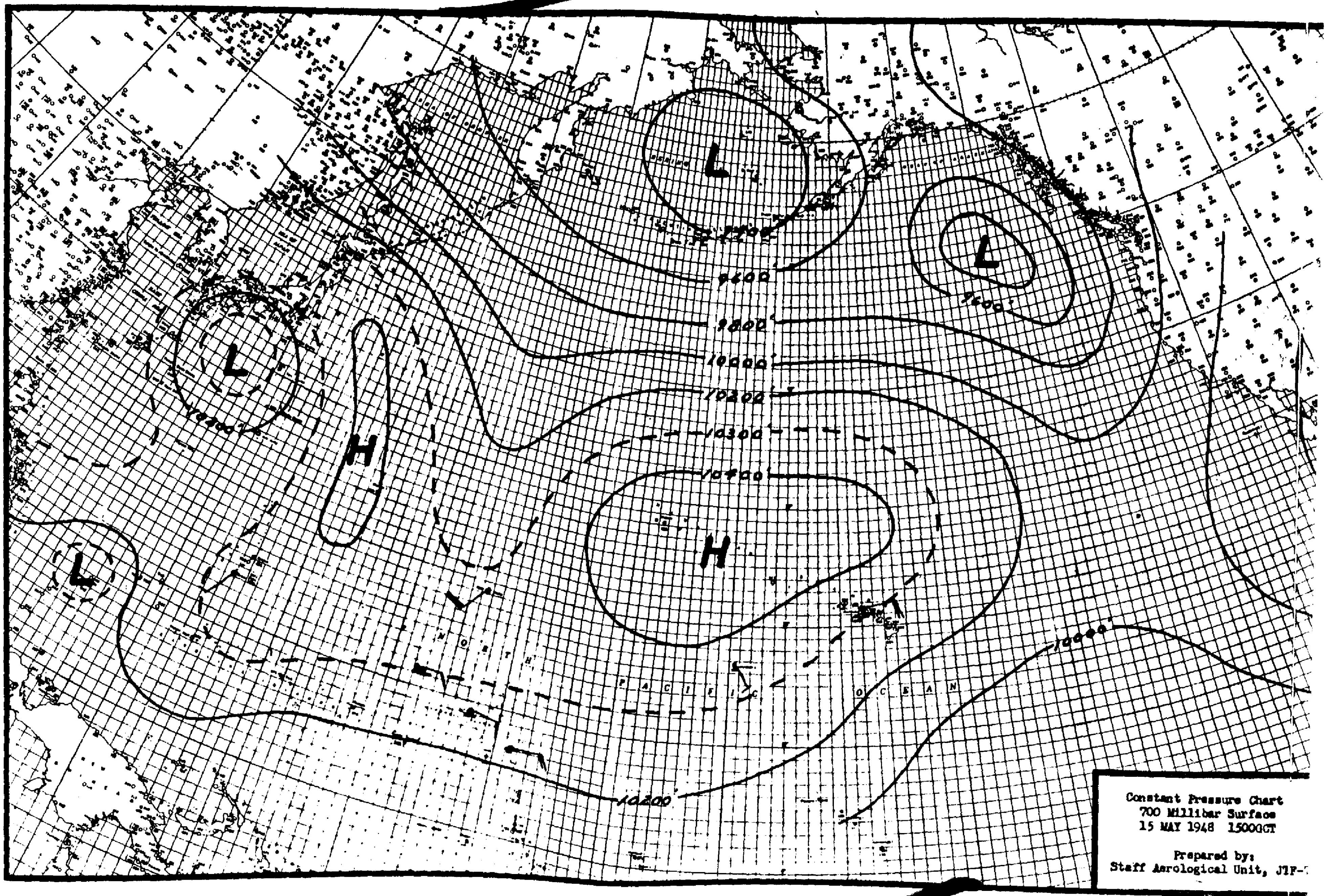
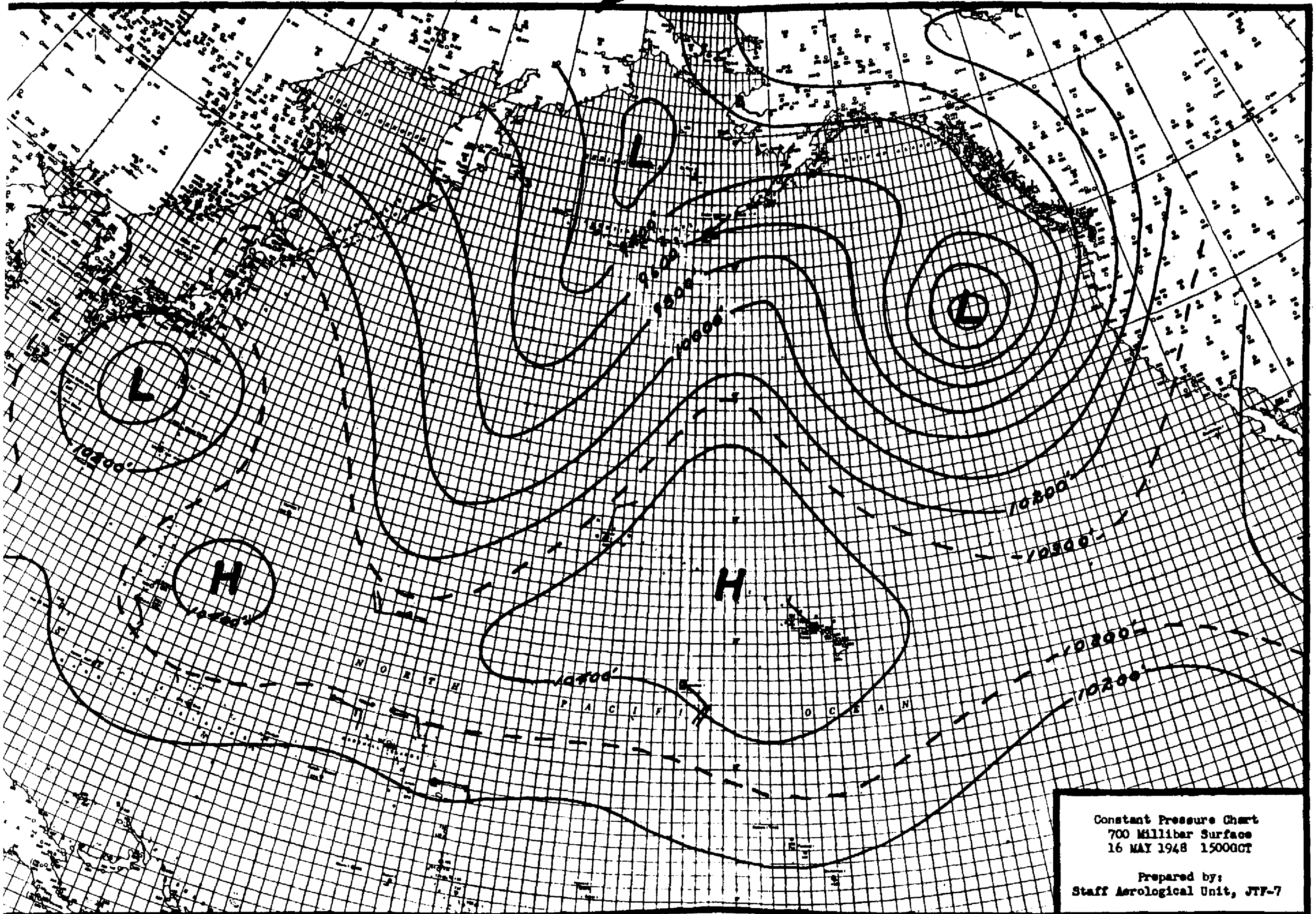


Constant Pressure Chart
700 Millibar Surface
15 MAY 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-

SECRET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9500
9600
10000
10200
10300
10400
NORTH PACIFIC OCEAN
Constant Pressure Chart
700 Millibar Surface
16 MAY 1948 1500GCT
Prepared by:
Staff Aerological Unit, JTF-7

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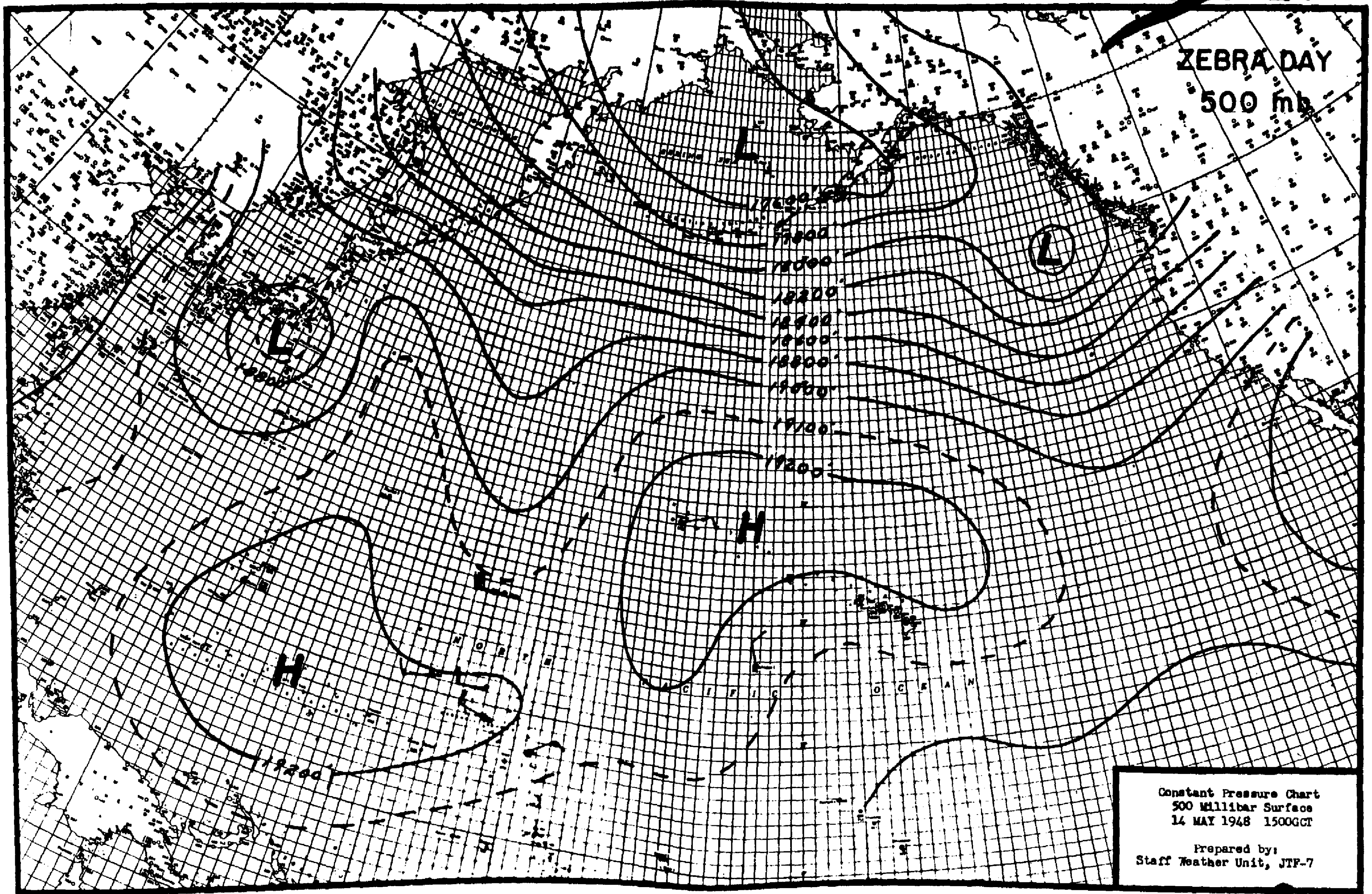

Constant Pressure Chart
500 Millibar Surface
14 MAY 1948 1500GCT

Prepared by:
Staff Weather Unit, JTF-7

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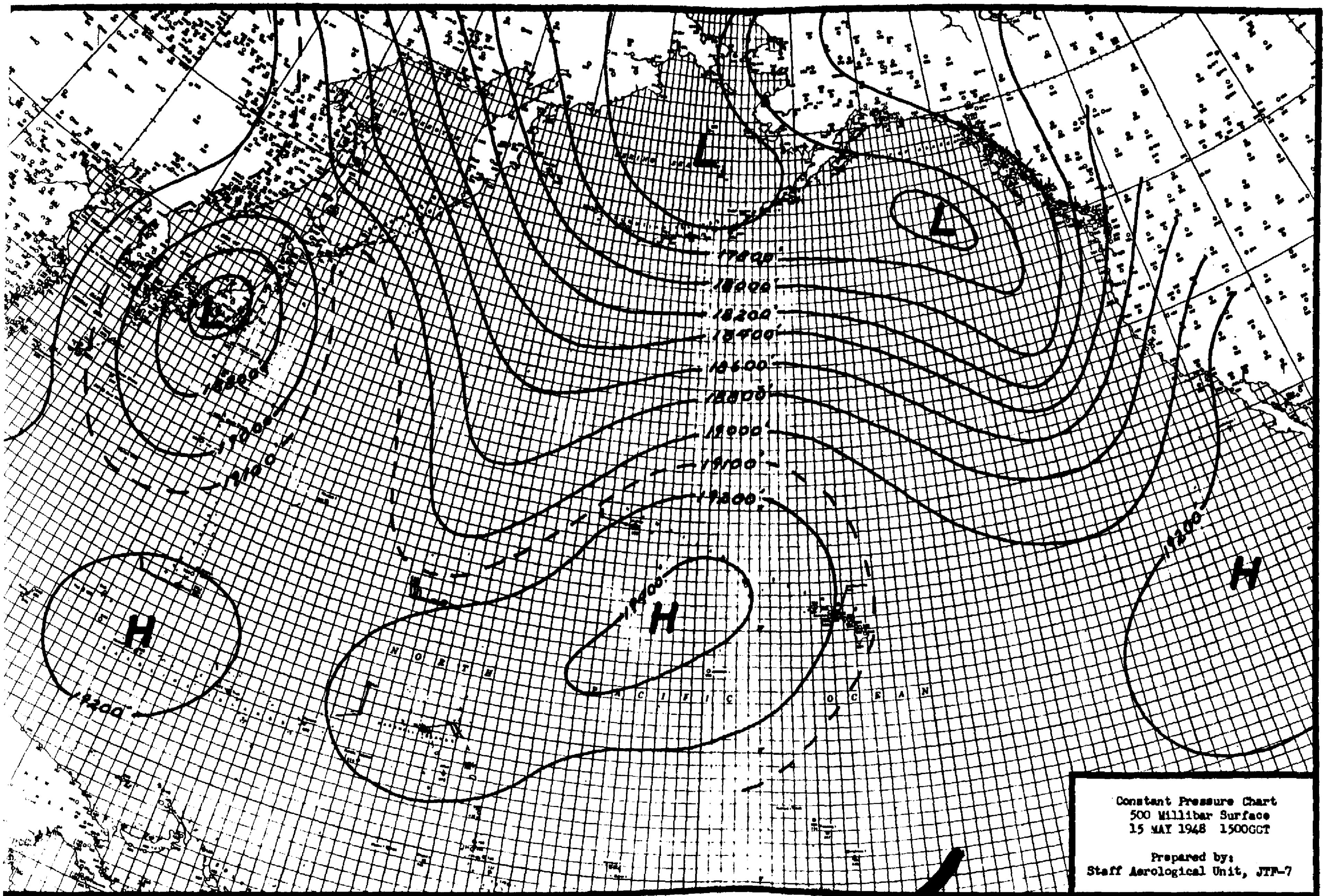

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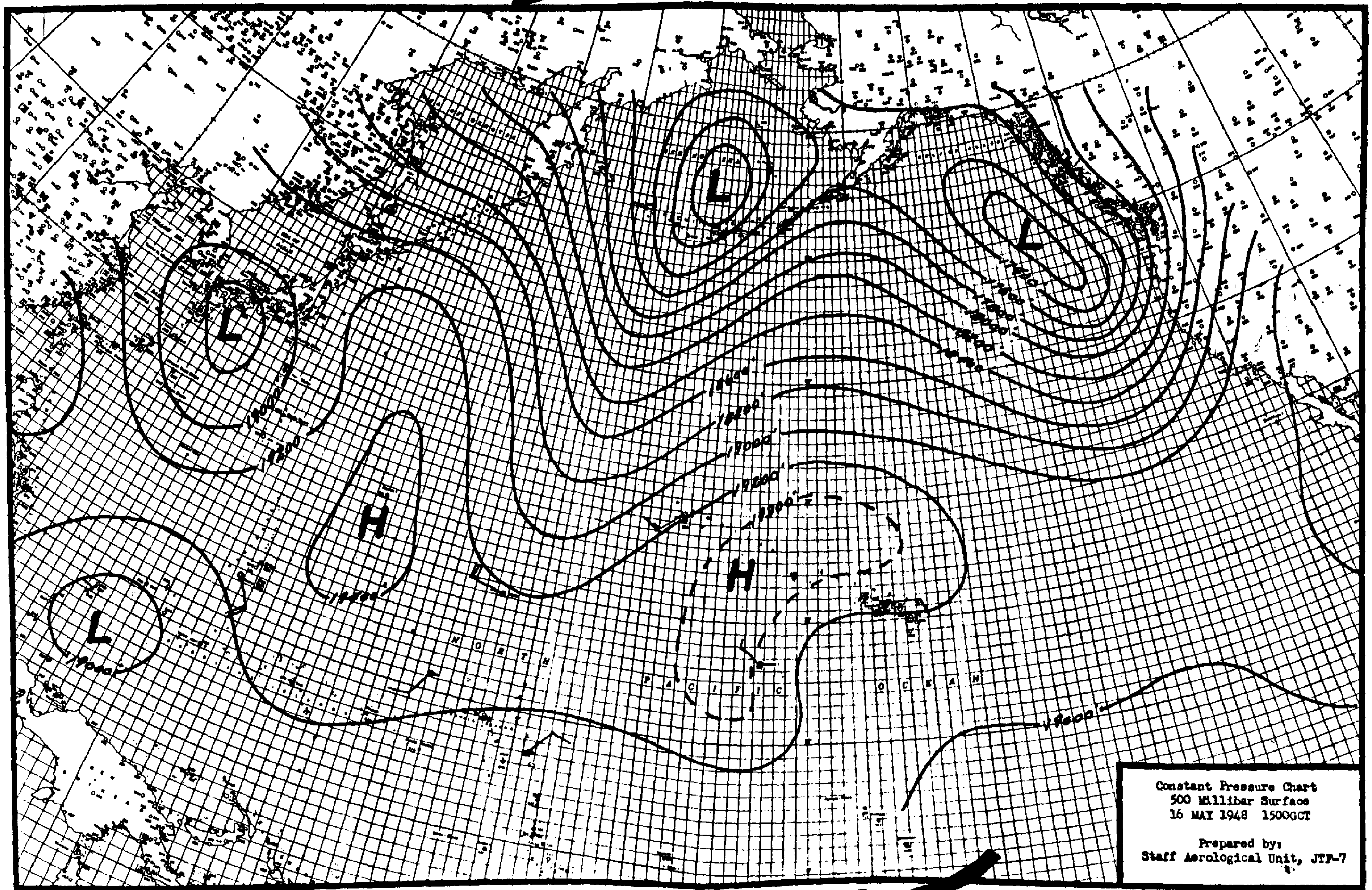

Constant Pressure Chart
500 Millibar Surface
16 MAY 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

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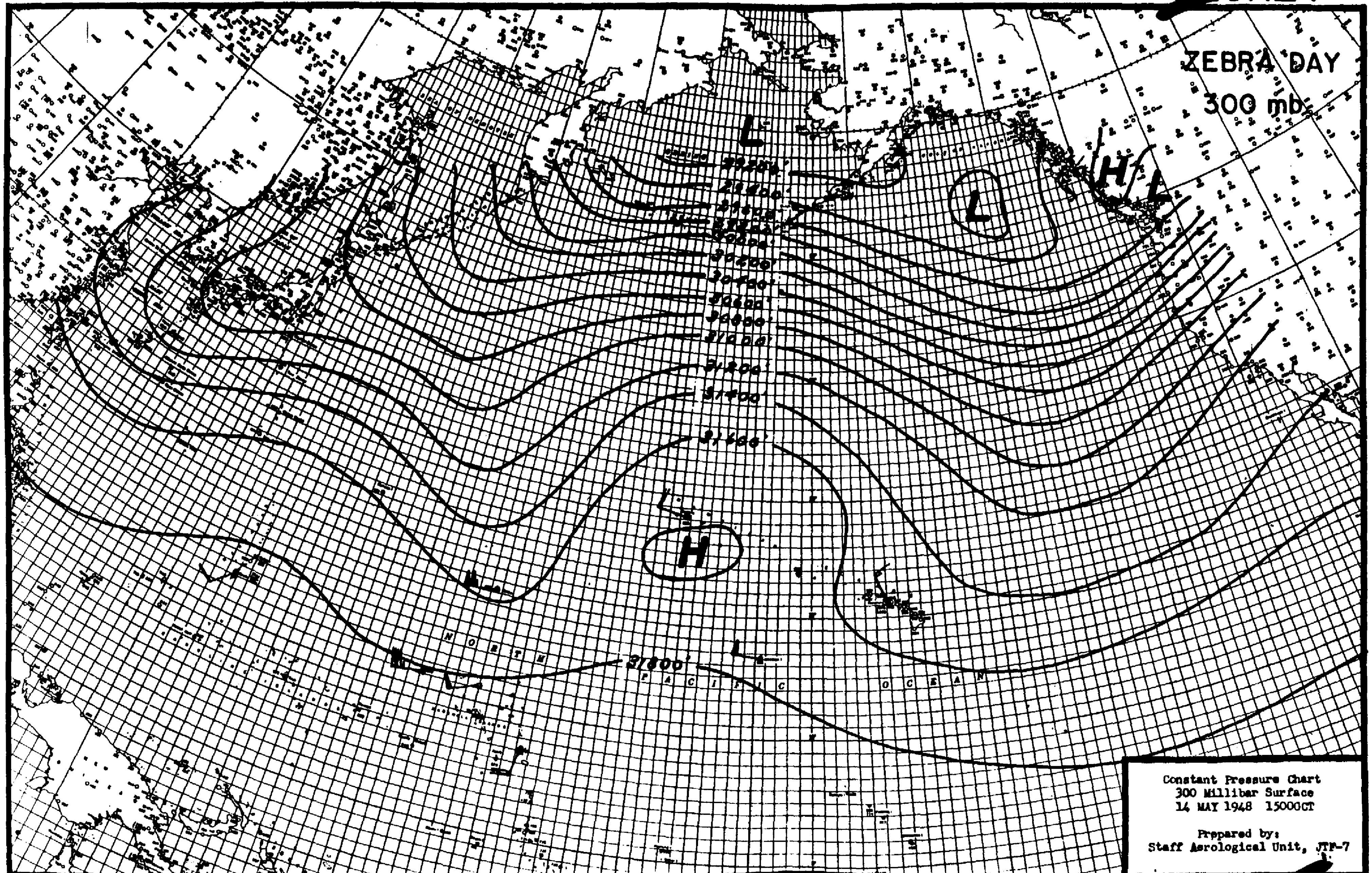

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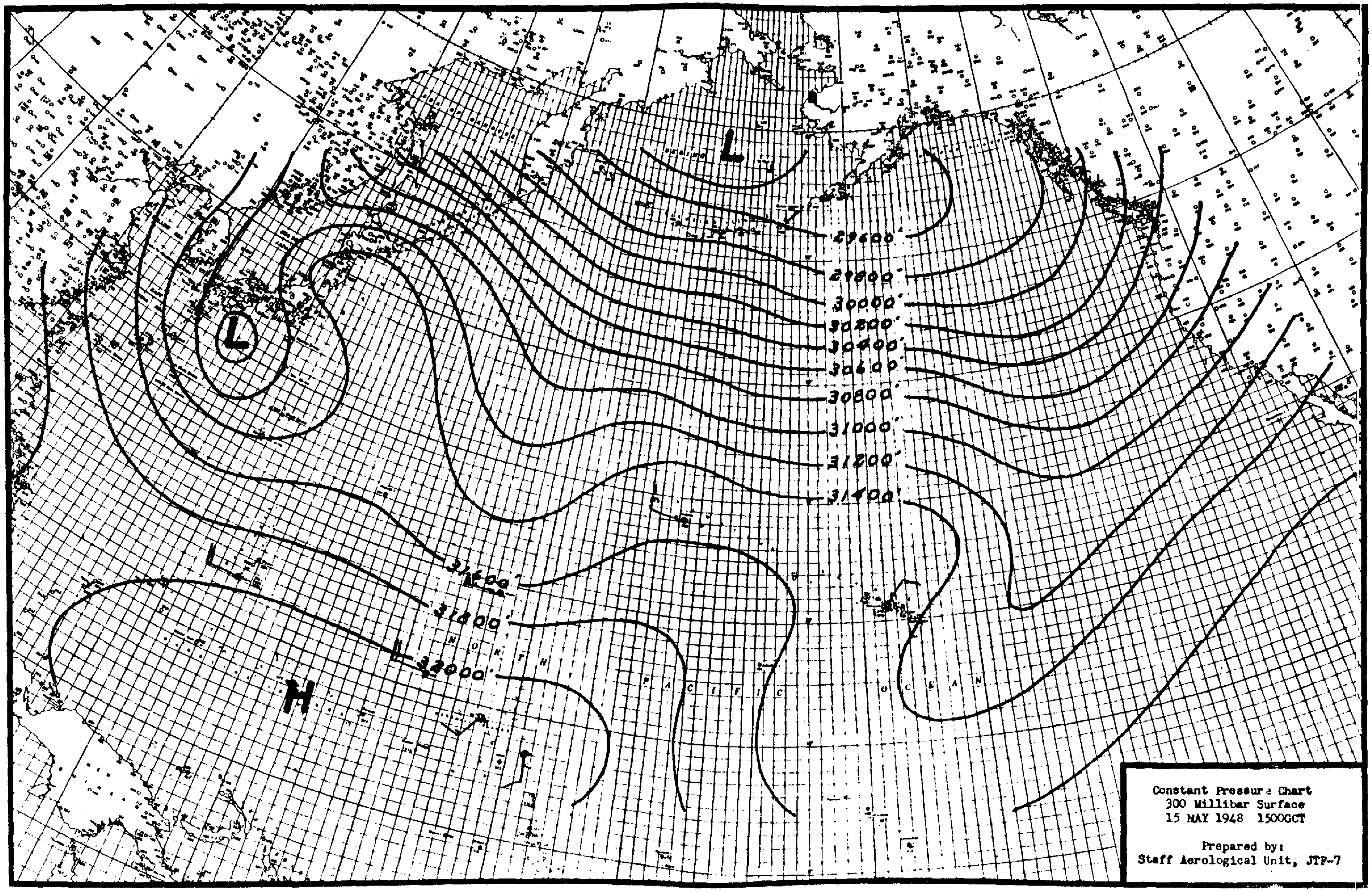

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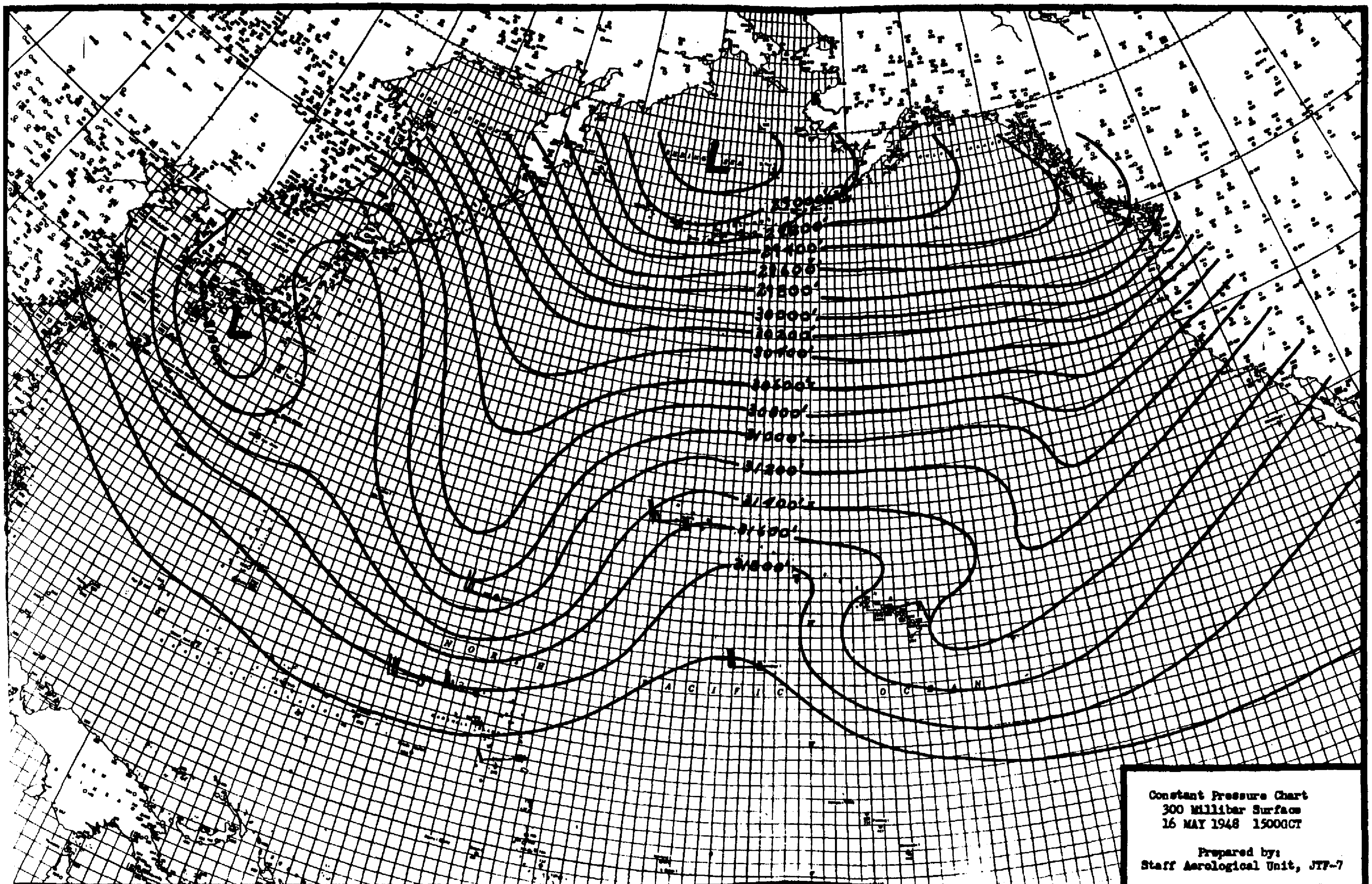

Constant Pressure Chart
300 Millibar Surface
16 MAY 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

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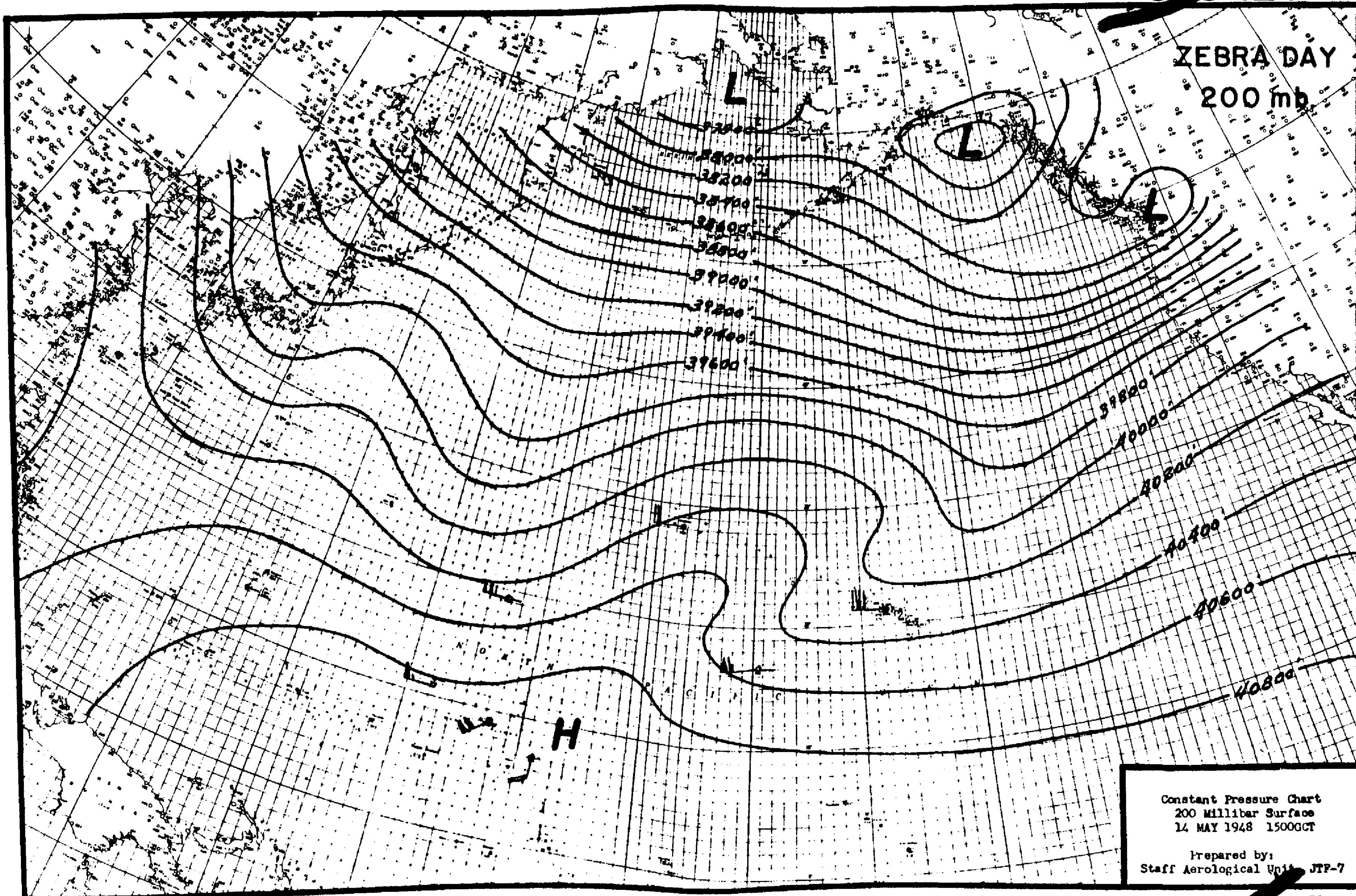

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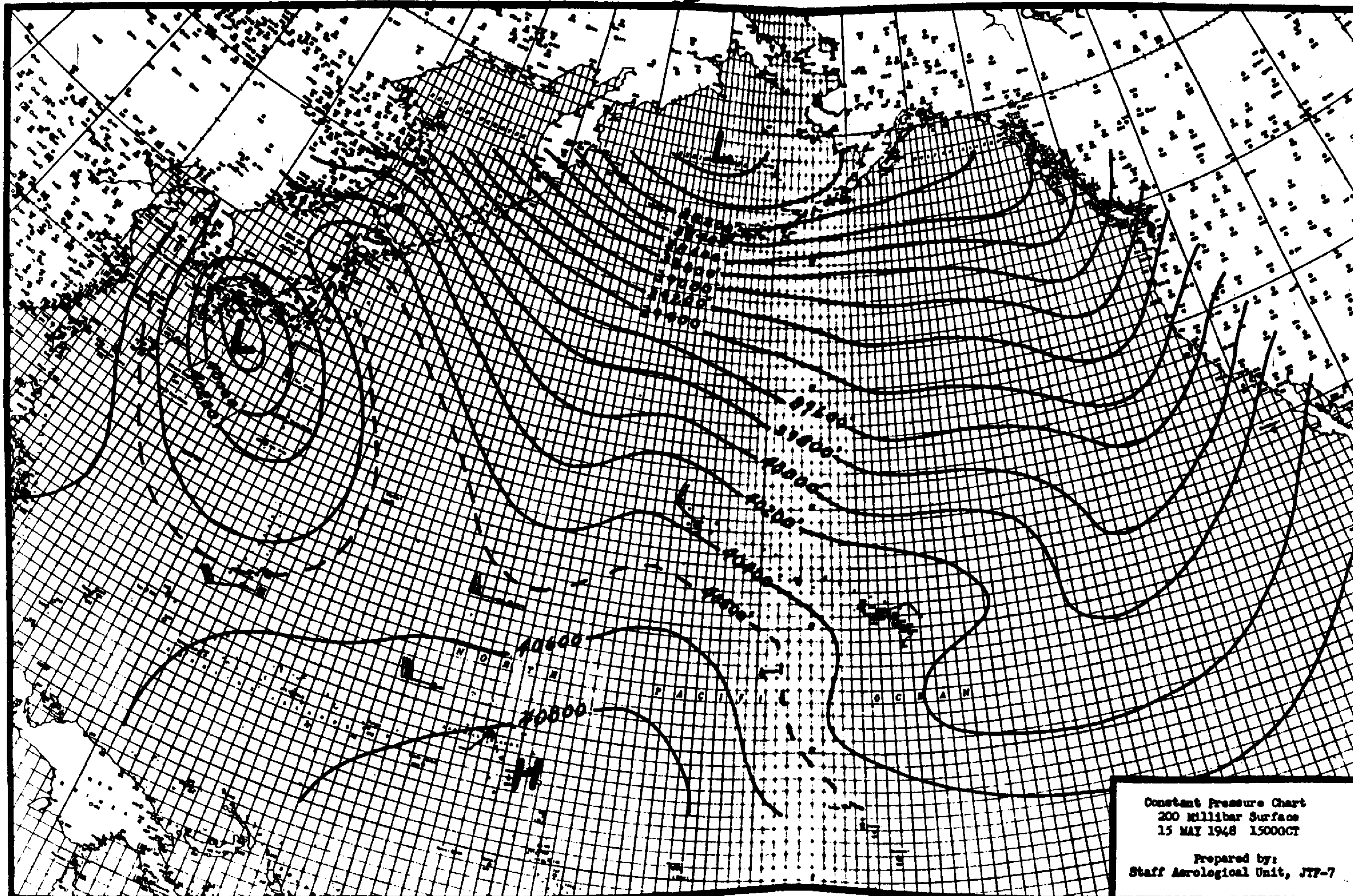

Constant Pressure Chart
200 Millibar Surface
15 MAY 1948 1500GCT

Prepared by:
Staff Aerological Unit, JTF-7

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