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Report of the Radio Section of the 1932-1933
American Polar Year Expedition.

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DATE 6 March 1934

SUBJECT

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BY

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

6 March 1934 Report No. H-1032

NAVY DEPARTMENT

BUREAU OF ENGINEERING

REPORT OF

The Radio Section

of the

1932-1933 American Polar Year Expedition.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
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TABLE OF CONTENTS

SUBJECT		PAGE
	ABSTRACT	1
1.	INTRODUCTION	2
2.	AUTHORIZATION	2
3.	OBJECT	2
4.	IONOSPHERE INVESTIGATIONS	
	(a) Apparatus	2
	(b) Apparent Heights of the Ionosphere	2
	(c) Ionosphere Echoes and Magnetic Disturbance	5
5.	SPECTRA OF THE ARCTIC SKY	
	(a) Spectra of the Visible Light of the Sky	6
	(b) Spectra of the Ultra-Violet Light of the Sky	7
6.	INVESTIGATION OF THE AURORA BOREALIS	
	(a) The Aurora Display	7
	(b) Auroral and Magnetic Activity	10
	(c) Note on the Height of the Aurora	11
7.	RADIO METEORGRAPHS	11
8.	TEMPERATURE RADIATION FROM THE STRATOSPHERE	12

APPENDICES

Observations of Effective Ionosphere Heights	TABLE 1
Percent of time showing Measurable Radio Echoes	TABLE 2
Percentage of time Giving Measurable Photographic Records	TABLE 3
Data of the Spectra of Plate 6	TABLE 4
Data of the Spectra of Plate 7	TABLE 5
Synchronous Motor of Echo Reflection Recorder	PLATE 1
Schematic Diagram of Radio Echo Receiver	PLATE 2
Schematic Diagram of Transmitter Key	PLATE 3
Schematic Diagram of Transmitter	PLATE 4
Echo Reflection Records	PLATE 5
Spectrographs of Twilight	PLATE 6
Spectrographs of Ultra-Violet Radiation from the zenith sky	PLATE 7
Schematic Diagrams of Miniature Transmitter	PLATE 8
Auroral Photographs	PLATES 9, 10
Auroral Display of Wave Motion	PLATE 11
Auroral Display Showing Systematic Regularity of Stationary Light and Dark Spaces	PLATE 12
Coronal Auroral Display Showing Mutual Attraction or Repulsion of this Feature of the Display	PLATE 13
Auroral Arc Showing the Effect of Active and Inactive Regions of the Atmosphere	PLATE 14
Later Form of Plate 14 showing Characteristic Waves, Striae and Color of Active Curtain Display	PLATE 15

ABSTRACT

Ionosphere Investigations. Apparent heights of the ionosphere were measured by the radio echo reflection method. The apparent heights ranges from 130 to 700 km., the average increasing from 260 km in December, 1932, to 300 km in March, 1933. After April 1 the reception of echoes and the effective heights were progressively more erratic until August 24, 1933. Observations made during a Zenith auroral display indicated that the maximum ion density of the ionosphere may be 100 km or more above the position of maximum auroral brilliancy. Signals from distant stations during an active auroral display indicated that auroral activity may give a swinging Doppler shift to the frequency of a signal. Signal absorption was found to be much more important than maximum ion density in the reception of high frequency signals. This was found to be in agreement with the results of all attempts at commercial use of frequencies above 3000 kc. in Alaska.

Ionosphere Echoes and Magnetic Disturbances. A series of active magnetic disturbances of eight days each during January, February, March and April, obliterated nearly all echo signals. Another series of mild one day disturbances through April, May, June and July resulted in a great increase in efficiency of signal reception especially during daylight hours.

Spectra of the Arctic Sky. Spectra of the light of the twilight sky showed the presence of radiations in the yellow and red different from scattered sunlight which probable originate in the upper atmosphere. The radiation varied greatly in intensity, and somewhat in character from full daylight to complete night light. It is of special interest because it is of the same origin as the radiation from dark companion stars. The short wave limit of ultra-violet spectra of the daylight sky caried with the altitude of the sun. Qualitatively the variations indicated that the thickness of the ozone in the high atmosphere above Fairbanks was pretty much the same as that in temperate latitudes.

Aurora Observations of active and quiet auroral displays indicated a systematic regularity in the displays such as to suggest distinctly local changes in the property of the high atmosphere above Fairbanks. The displays favored certain regions of the sky for their appearance. Mass movements and mixing of active and inactive masses of atmosphere were observed in nearly all of the displays. Photographs and drawings of several displays are reproduced. A close correlation was observed between auroral activity and local earth current and magnetic activity.

Radio Meteorgraphs were sent up in free sounding balloons and seven successful records of stratospheric temperatures and pressures were obtained.

Stratospheric temperature radiation was observed with thermometers at ground level. The preliminary conclusion was that such a method in addition to the standard procedure at the Weather Bureau stations, may offer a way to observe conditions in the polar stratosphere which create storm centers and influence weather in temperature latitudes.

INTRODUCTION

1. The Radio Section of the American Polar Year Expedition was established at Fairbanks, Alaska, from September 1932 to September 1933. The work accomplished is described in detail in the following pages and dealt primarily with radio investigations of the ionosphere, with the spectroscopy of the arctic sky and with observations of the aurora, and to a slight extent with weather and conditions in the stratosphere. In common with most expeditions difficulties arose in adatping the apparatus to the conditions which were encountered. Certain of the results must be regarded only as a preliminary attack on the problems and of chief value in outlining the direction of future progress. Actually the information gained has led to a continuance of the ionosphere and sky spectra investigations under the direction of Professor Fuller at the Alaska School of Mines, Fairbanks.

AUTHORIZATION

2. SecNav letr of May 6, 1932.

OBJECT

3. Radio investigation under the Second International Polar Year Expedition, 1932-1933, at Fairbanks, Alaska.

IONOSPHERE INVESTIGATIONS.

4(a). Apparatus. The height of the ionosphere above Fairbanks was investigated by means of the radio echo method of Breit and Tuve. The receiver was installed at the Polar Year Radio Station and the transmitter was established about a mile away at the U.S. Signal Corps Cable Station. The Signal Corps offered material assistance and cooperation in the work throughout the entire year.

The receiver was designed according to a suggestion of Dr. G. W. Kenrick. The received radio echoes were recorded on a moving photographic paper automatically and continuously by means of a neon light actuated by the signal and focussed on the paper. A photograph of the neon light mounting is given in Plate 1, in which, a is a telescope barrel rotated by a synchronous motor d; b is the neon light which is focussed by lens c on the recording drum. Later the rotating telescope was replaced by a rotating mirror in order to avoid commutator troubles. This permitted the simultaneous recording of the ionosphere heights by two receivers working on different frequencies. This arrangement is shown in the schematic drawing of the receiver of Plate 2.

The transmitter (for schematic diagram see Plate 4) consisted of a 150 watt crystal controlled transmitter tuned to 2050 kilocycles and harmonics thereof. By means of a neon tube keying circuit, shown in Plate 3, a short sharp dot was emitted 60 times per second.

(b) Apparent Heights of the Ionosphere. A summary of the ionosphere height measurement work is given in Table 1 where column 2 gives the number of days visual observations were made during the months of column 1, column 3 is the number of days when at least one visual measurement was made, column 4 is the number of hours of photographic record, and column 5 is the number of hours showing measurable photographic records of echo delays. Columns 6 and 7 are the percents of photographic records obtained during the day and night, respectively; columns 8, 9 and 10 are the low, average and high apparent ionosphere heights measured for the different months from the photographic records. The measurements for August were taken from visual records.

Columns 3 and 5 of Table 1 show a gradual decrease in echo signals from March to August. The poor reception recorded for February is accidental. A magnetic storm which is discussed later stopped all echoes for eight days and since the station was in operation only twenty days very few echo records were obtained for the month.

Columns 6 and 7 show that the loss in signal strength with the approach of summer is greater for the day than for the night signals. Columns 8 and 9 show a gradual increase in effective heights from December to April and a decrease from April to July.

Plate 5 shows some typical records of echo reflection. a made December 11 shows unsteady signals which were very typical of conditions at Fairbanks. The time scale of these pictures is 16.8 Km per mm. b shows double reflections made simultaneously on the two frequencies 4100 kcs. and 6150 kcs. c shows multiple reflections of a type which were observed at several different times.

There were a number of items of the ionosphere measurements of interest which do not appear in the figures oftable 1. On January 27 steady signals were observed for several minutes at an apparent height 1970 km. The heights were checked by reception on two different receivers with different audio amplifiers and different neon light recording circuits. The transmitter was immediately checked and was found to be transmitting a normal signal.

It is of interest to note that these were the only strong steady signals measured optically during the period January 20 to February 3. During this time very unsteady echoes were recorded photographically for about two hours January 22 and again for about 6 hours January 26.

The apparent heights of 1970 km are not regarded as indicating that the radio wave was reflected from a region 1970 km overhead. It seems more conservative to believe that these are perhaps the "longer short-time echoes" which have been observed by Taylor and others in temperate latitudes. It has been suggested that these echoes are returned from the edge of the skip zone after arrival at the surface of the earth with one reflection from the ionosphere. Such echoes are uncertain and erratic in their appearance, and their true origin can not be said to be completely understood at the present time.

On one night during the period of poor reception of Janaury 20 to February 3 radio signals from a crystal controlled west coast station were observed to be swinging in frequency. The frequency of the station was about 7500 Kc and the swing which was quite rythmic amounted to one or two kilocycles over a period of two or three seconds. There was an active auroral display which reached some distance south of the zenith at the time and it was thought the swing in frequency was a Doppler effect caused by either a moving medium in the path of the signal or a reflection of the signal from a moving surface. A motion of forty kilometers per second would have been sufficient to cause the observed effect. Motions of greater velocity are quite common in pulsing auroral displays and the period of the pulsation is approximately the same as that of the frequency swing observed. Later observations during auroral displays showed no such effect. However, it seems quite probable that the frequency change observed was a Doppler shift resulting from a rapidly changing reflecting layer such as is indicated by a in Plate 5, which is a record made during a mild magnetic disturbance.

A check was made of echo reception during auroral displays and it was found that ordinarily no echoes could be observed during a display which was near the zenith. January 20 at 2:30 AM very faint echoes were observed visually at an effective height of 180 km while a good auroral display crossed the zenith. These signals were not photographed. January 30 at midnight strong echoes were observed both optically and photographically at heights varying from 400 to 550 mm while there was an active auroral display across the zenith. April 2 irregular echoes were observed visually at heights of 220 and 390 km while there was an active auroral display which did not cross the zenith.

These observations show that auroral displays result in high absorption of echo signal but are associated with great rather than small effective heights. Apparently short wave signals penetrate the aurora displays to a reflecting density which may be a hundred kilometers or more above the most brilliant part of the display.

Echo heights observed after April 1 generally fall into two different groups one of which show heights averaging well below 300 km and the other nearly 400 km. No echoes from the lower group of heights were obtained during August. The lowest height of 130 km was obtained June 10 and was the only "daylight" measurement obtained during the month. It is interesting to note that this low height was associated with a mild magnetic disturbance which is discussed in detail later.

A listening program was planned as a part of the ionosphere investigation but stations listed by the international committee for listening program transmission could not be heard. All attempts to establish a program of short wave communication with Point Barrow, 500 miles to the north, failed. Attempts to communicate by short waves with local amateurs failed. Pacific Alaska Airways repeatedly found short wave communication with radio equipped airplanes impossible except when the transmission was by a straight optical path. The Signal Corps in their operation of the Army Cable Stations had found short wave communication unsatisfactory north of the south coast of Alaska. The United States Forest Service has found that short wave equipment found satisfactory in the States was entirely unsatisfactory for Alaskan service although their operations have been confined to the southern coast. Commercial stations could always be heard but their reception was so erratic the attempts to obtain a systematic record of their signal strength was a failure. Signals received on an Adcock direction finder showed fading so persistent and universal that systematic measurements of direction were impractical.

(c) Ionosphere Echoes and Magnetic Disturbance. It was found that active magnetic disturbances prevented the return of the radio echo signals. This is brought out by a comparison of the percentage of the time during which echoes were received on magnetically disturbed days, shown in columns 2 and 3 of Table 2, and on days of magnetic calm, shown in columns 4 and 5. It is to be noted, as shown in column 4 of Table 1, that the photographic recorder was nearly in continuous operation after the first three months. Visual observations were made at noon and midnight every day, with some additional observations during morning and evening hours Each Wednesday visual observations were made every hour of the 24 hours.

It is interesting to note that during the thirty-two days of an eight day recurrent disturbance which started January 23 to 30 and ended April 16 to 23, visual records of echoes were obtained on only four days. Two of these days, February 19 and March 18, were each the first disturbed day for the groups and the echoes may have been measured before the disturbance reached the Fairbanks ionosphere. The signals measured on the other two days April 20 and 21 were observed only about 6 PM each day although nineteen unsuccessful attempts at observations were made during the two day interval.

Some magnetic disturbances had quite a different effect on echo signals from that shown by the eight day recurrent disturbance cited above. It is to be noted that the disturbance of December 14 to 16 had very little effect on signal strength. A mild disturbance was recorded at Mt. Wilson April 9, as a 0.5 magnetic storm. It was missed in May but reappeared June 8 and July 8. These disturbances were not reported by most stations, but they were associated by an increase in the efficiency of echo signal reception which is shown by Table 3. Column 1 gives the dates for the exceptionally good echo receptions, columns 2 and 4 the percent of time during which measurable photographic records were obtained during the slightly disturbed days and the remainder of the month respectively. The effect of the disturbance on daylight reception which is taken to be from 6 AM to 7 PM was more pronounced than during the night. Columns 3 and 5 were added to show this difference.

The groups of days for Table 3 included all adjacent days showing good reception for the different months. The sixteen day period included 48% of the measurable photographic records for the four months period and 66% of the records obtained between 6 AM and 7 PM.

The general conclusion from the ionosphere studies at Fairbanks was that although an active magnetic disturbance resulted in a high absorption for radio signals of all frequencies during the entire day, a mild disturbance may give decreased absorption with a low effective height for the ionosphere, especially during day-light hours.

5. (a) Spectra of the Visible Light of the Sky. A glass spectrograph consisting of the Littrow mounting of two glass prisms 4 inches high, one of 60° angle and one of 30° angle, was used to investigate the radiation from the sky in the visible region of the spectrum. A 4 inch f 4.5 glass lens was employed in the instrument. Spectra of the twilight sky were found to be quite different from the spectra of the daylight sky, although both spectra possessed in common the known absorption lines of the telluric atmosphere.

A series of spectra obtained at Fairbanks early in August during a period of couldless sky and a very clear atmosphere are reproduced in Plate 6; mountains 100 miles away were visible. The conditions under which the spectra were taken are given in Table 4. From about 9 p.m. to 3 a.m. the sun was below the horizon and in the case of spectra 3 to 11 the spectrograph was pointed toward the twilight sky above the sun. For spectra 1, 2, 11, 12 and 13 the spectrograph was pointed toward the zenith. In the case of spectrum 13 the conditions were those of full daylight.

The two broad absorption lines or bands in the yellow, marked by a and b, on spectrum 1, are visible on all of the twilight sky spectra 1 to 12, but do not appear on the full daylight sky spectrum 13. The broader absorption lines, H, K, G, etc., of the solar spectrum are visible on spectrum 13, but the dispersion of the spectrograph was too small to permit the sodium doublet at 5890 to 5896A to appear clearly.

On the twilight spectra 1 to 12, Plate 6, certain changes occurred during the night, namely, the absorption band b becomes gradually less prominent from 8 p.m. until about 12 midnight and from then until sunrise it increases in prominence again.

It is further to be noted that the shorter wave-length portion of the spectrum from 5000 to 4000A is practically absent from the twilight spectra 3 to 11, and is present strongly on the daylight spectra, even on such a weakly exposed spectrogram as spectrum 13.

It is seen that the twilight sky spectra were quite different from the full daylight sky spectra, and therefore the foregoing facts lead forcibly to the conclusion that a large portion, or perhaps all, of the light of the twilight sky, under cloudless conditions, is not sunlight scattered by the atmosphere. It is mainly fluorescent light emitted from the high atmosphere, the fluorescence being stimulated by the short ultra-violet radiations of sunlight.

To test this conclusion the spectrograph was taken to the top of an 8000 foot mountain and in an airplane to about 18000 feet. Spectra at these altitudes were in agreement with those taken at ground level. This was further evidence that the twilight sky radiations are emitted from very high levels of the sky.

Recent experiments at this Laboratory yielded twilight sky spectra which were practically the same as the day or solar spectra. It was concluded that this was due to the smoke and haze in the atmosphere, so that the twilight sky radiation was almost entirely sunlight scattered by the impurities of the atmosphere, the scattered light being intense enough to conceal the fluorescent light from the high atmosphere.

The facts of the spectra of the twilight sky at Fairbanks are in keeping with the idea that the twilight sky radiations were similar in origin to radiation from dark comparion stars which has been of such great interest to astromoners in recent years. Certain of the spectrum lines agreed, within the error of identification, with those observed by Slipher at the Lowell Observatory, Flagstaff, Arizona, in his spectra of the night sky.

(b) Spectra of the Ultra-Violet Light of the Sky. To obtain spectra in the ultra-violet region of wave-lengths a Littrow quartz spectrograph was used containing a 3 inch 60° quartz prism and an f 6.5 quartz lens. A series of exposures were made morning, noon and evening each day from March 8 to August 26, 1933. On Wednesdays exposures were made hourly throughout the daylight portion of the day. In Plate 7 is given the spectrograms of August 23, the line 3143 being marked on each plate. The spectrum is the usual solar spectrum scattered by the sky, the ultra-violet cut-off being due to the ozone in the high atmosphere. The data of the spectra of Plate 7 are given in Table 5.

The spectra of Plate 7 show that the ultra-violet limit of the spectrum reached the shortest wave-length at the highest altitude of the sun and marches toward longer wave-lengths with decreasing altitude of the sun. This is in qualitative agreement with the fact that the ultra-violet limit of the solar spectrum is due to ozone in the high atmosphere. A complete analysis of the entire series of spectra, over 500 in number, is contemplated.

The visible and ultra-violet spectrographs were left at Fairbanks in charge of Professor Fuller who planned to continue the spectrographic investigations.

INVESTIGATION OF THE AURORA BOREALIS

6. (a) The Aurora Display. Throughout the year visual and photographic observations were made of the aurora and notes and sketches were recorded of the different types of display and of the development, progress and decay of the luminosity. Nearly all displays started with a homogeneous quiet arc which developed about 30° each of north and about 10° up from the horizon. In no case was a display seen which was initiated below the horizon. Almost invariably the display moved upward in the sky, and hence toward the southwest. Generally as one display moved up, another developed below or to the northeast of it. The arc form was approximately a section of a circle of magnetic latitude, the arc toward the west being usually curved to the northward of the magnetic parallel. The particular part of the sky which was illuminated by the display at any one instant of time seemed to depend on some property of the atmosphere which was much more persistent than the luminosity itself.

The arc as it moved southwest or upward in the sky generally became active. The activity seldom started before an altitude of 20° was reached and it was very seldom that an arc reached the zenith before its activity developed. The first sign of activity was generally the appearance of rays shooting upward. These were often followed by a ray which shot downward and then rapidly spread sidewise under the arc into a curtain or drapery. The velocity of spread of the curtain was about 2 to 20 miles per second. The ray shooting upward was never as active. It generally did not shift its position on the arc, but sometimes moved with a velocity of one to two miles per second. The rate of motion of the inactive arc up the sky was of the order of one mile per minute, but this motion was often greatly increased as the arc became active.

Pictures 1, 2, 3, 4 and 5 of Plate 9, and pictures 16, 21 and 22 of Plate 10 were different types of arcs. 1 was a section of a typical arc very slightly divided. 2 and 3 were patchy sections of an arc. 4 and 5 were multiple arcs sometimes formed by a division of the original arc as suggested by 1 and 5, but more often the additional arcs developed within or behind the original arc and progressed outward to take its place when it was broken up by certain activity. 16 shows a remarkably brilliant arc which had a curvature quite independent of the arc of magnetic latitude. 21 shows an arc curved in by some peculiar feature of the atmosphere which evidently placed some limit on the part of the atmosphere which would become illuminated. The peculiar feature of the atmosphere shown in 21 was often persistent for many hours, during which time the display might brighten and disappear many times or might be moved outward toward the zenith without affecting the distribution of the specially active regions. Picture 22, Plate 10, was of a very brilliant and very uniform arc display. Pictures 25 to 30 are of an exceptionally quiet arc which crossed the zenith. 25, 26, 27 and 28 show the arc to the southeast, 29 in the zenith, and 30 to the northwest. When the display was first observed the striations were vertical as shown in 28. Later they were distorted by a slow drift to the north of the portion next to the horizon. The fact that the fine striations were distorted uniformly is considered good evidence that the striations were outlines by peculiar properties of the atmosphere and were distorted by mass movements of the atmosphere. 11, 12 and 13, Plate 9, were types often called bands, but which might be more appropriately called distorted arcs. The remaining pictures are of different forms of curtain.

Plate 11 shows a sketch of a very regular arc which was disturbed at the lower boundry by a very regular series of waves which ran under the arc from east to west and then reversed and ran from west to east with a velocity of about twenty miles per second. These waves did not disturb the upper part of the display or the second arc which appeared lower, but was probably a hundred miles or more back of the active arc. This display seemed to be entirely different from the pulsating displays to be described later.

Plate 12 shows a sketch of a very striking arc seen near the zenith (marked X). When this display was first observed it showed two uniform bands very sharply outlined and extending from horizon to horizon across the zenith. The south band very rapidly developed the barred appearance shown throughout its entire length. The display was very sharply outlined, very regular, and quite inactive throughout its entire length.

The two displays described above give strong evidence of a distinctly local mechanism for determining the nature of the displays.

Curtains generally developed from a quiet arc display, but occasionally appeared quite independent of any arc. Their luminosity was confined to a wavy surface at all points approximately parallel to the earth's magnetic field as shown in pictures 10, 14, and 15, Plate 9. Observed edgewise, at right angle to the earth's magnetic field, they have the appearance of rays, and observed near the zenith in the direction of the earth's magnetic field, they may show the peculiar perspective known as corona, as shown in Plate 13.

Plate 13 shows a sketch of the final appearance of a curtain which, when first formed, reached all the way across the sky from an altitude of about 60°. It became violently agitated by transverse waves, the ends near each horizon began to roll up as shown at the top of the sketch, and the whole curtain moved rapidly up toward the zenith (marked by a cross in the sketch). When the display first occupied the position shown in the sketch, there was no luminosity in the region between the two sections of curtain, but a luminous filament appeared to the south and rapidly spread through the dark space separating the curtain displays. During its progress the new display gave the appearance of being repelled by the curtain display. The sketch illustrates the rolling action of the curtains, the apparent repulsion of one part of the curtain by another part, and the development of a secondary display which was apparently repelled from the original display.

Curtains occasionally became active within themselves. In these cases they were generally striated. The striae appeared vertical, but were probably following the direction of the earth's magnetic field. The striae often developed rapidly moving light and dark spaces similar to those seen in a vacuum tube. The movement was along the striae. The sketches of Plates 14 and 15 illustrate the appearance of the striae with their light and dark spaces and also the transverse waves, which gave the display the appearance of a curtain or flag blown in a wind. These waves ran along the curtain with a velocity of approximately 50 miles per second. Generally, the waving curtain, within a few seconds of the beginning of its activity, began to fold or to roll up and, within three or four seconds time, would disappear across the entire sky. The development of an active curtain generally dissipated the arc from which it came, and the development of activity within a curtain always dissipated or broke up the curtain. Colors were not, at any time, seen in the auroral displays except in the active curtains. The strong appearance of light and dark spaces along the striae of a curtain was generally but not always a fore-runner of color display. When colors developed, red was always on the lower side and on the front of any activity such as a running wave or forming curtain. The sketch of Plate 15 was made to illustrate this. No color display was seen which lasted as long as ten s seconds.

Plates 14 and 15 are sketches of a peculiar form of arc and curtain which was persistent from 7 p.m. until 1 a.m., November 1. The whole display covered an angle of about 90° along the horizon. The section b had the shape of the average arc, but the sections a and c had the appearance of wind distortions in a non-homogeneous atmosphere. They were gradually distorted and lost their sharpness as the display grew older. During the night the display faded out to complete invisibility several times, only to reappear with the original form. This type of fading, which covered periods of many minutes and was quite irregular, should not be confused with pulsations which are distinctly rhythmic with periods of a few seconds at most. Distortions such as a and c were quite common in the arc displays. They may have almost any form, but were seldom as regular as the ones sketched.

Nearly every auroral display became pulsating at some time during its development. The typical pulsation took the form of waves of increasing and decreasing brilliancy of display. Often an individual wave could be seen across more than 90° of the sky, probably over two hundred miles in extent. It was about one hundred miles from one crest of brilliancy to the next. The velocity of advance of these waves was about one hundred miles per second. The motion of these waves was generally, but not always, in the direction of the magnetic field. This type of display should not be confused with the wave forms shown in Plates 11, 14 and 15, which have the appearance of mass motions in space, whereas the waves of the pulsating aurora are rhythmic changes in luminosity which may repeatedly pass over sharply outlined displays, such as are sketched in Plate 12 and shown in photographs 24 to 30, Plate 10, without affecting the outline of the display. The pulsations did not affect all parts of the visible display but only certain ones. Some displays were observed to pulsate for nearly an hour without much change in the rythm.

A second form of pulsation often seen had very much the appearance of searchlight beams that were flashed on and off. These were faint displays which passed near the zenith and seemed to radiate from a point below the horizon. Light along these beams spread across the entire sky in less than a second, probably with a velocity greater than five hundred miles per second.

The descriptions given above are for a typical display, and the velocities should be considered as only descriptive terms. Many displays were seen which approximated the ones described quite closely and others seemed to offer variations of the types described rather than new types.

(b) Auroral and Magnetic Activity. The auroral observations gave strong evidence that the average auroral display at Fairbanks followed a local system of development. This was not invariably the case, but applied to about nine tenths of the displays. The slow development and final approach to a short period of intense activity which terminated the display suggested that the display was activated by the storing up and release of of energy supplied from some outside source, such as the chaging magnetic field of the earth. Earth currents are known to exhibit marked activity during magnetic disturbance and therefore it was of interest to see whether auroral activity was correlated with magnetic activity as indicated by earth current variations.

Many comparisons of the auroral records with the rapid earth current recorder at Fairbanks showed that there was a close connection between the two activities, there being no observable time delay between the two phenomena. A delay of 30 minutes could have been detected. The conclusion was reached by comparing notebook records of the times of occurrence of details of the auroral display with the curves of the earth current recorder.

It is believed that a closer study of the time relations between auroral and magnetic activity would be of value. The time interval of correlation should be reduced below 10 seconds. To achieve this the auroral observer should be provided with a magnetic instrument by means of which he could watch the changes in the earth's magnetic field at the same time that he was viewing the aurora. Such an instrument might be constructed of two crossed permalloy bars set perpendicular to the earth's magnetic field, each carrying a pickup coil, the output of which is amplified by a vacuum tube amplifier to actuate the plates of a cathode ray oscillograph. The instrument would be satisfactory for the observation of correlations between magnetic field activity and auroral displays and also would indicate the nature od any correlation which might be found, since at any instant the position of the cathode spot would be a direct measure of the magnitude and direction of the deflecting vector in the earth's magnetic field.

(c) Note on the Height of the Aurora. Plans were made for simultaneous auroral photographs between Fairbanks, Point Barrow and Nome, three stations about 500 miles apart, in order to determine the height of the aurora. The Signal Corps arranged very satisfactory communication between the stations by means of long wave radio. Professor Fuller was in charge of the photographic work. Preliminary experiments yielded good auroral photographs, but it turned out that no satisfactory heights could be determined from the pictures because of the difficulty in identifying the auroral features of the pictures taken from the different stations. To obtain satisfactory results would require a more systematic series of experiments with trained personnel than were possible at the time.

Previous investigations of the height of the aurora have been made from stations not more than 40 miles apart, and the heights obtained have been chiefly of the lower limits of the displays. Experiments from stations 500 miles apart would serve primarily to locate the upper limits and the total volume of the auroral activity. If work of this kind is contemplated, it is believed that the best results can be obtained by arranging the cameras at the different stations in fixed positions. The pictures made at each station would then always show the same part of the sky, which would make the identification of displays more certain.

RADIO METEORGRAPHS

7. In cooperation with the Weather Bureau arrangements were made to send up radio meteorgraphs attached to free sounding balloons in order to obtain records of the pressures and temperatures at high altitudes. Successful records were obtained from seven flights, two in which German meteorgraphs were used and five with Russian meteorgraphs. The records were retained by the Weather Bureau for analysis.

In view of the fact that the radio meteorgraphs as received were unreliable and had to be remodeled before they could be used, the following description of the Russian instrument and a suggested improved instrument may be of value in future work of this sort. The construction of the Russian instrument, Molchinoff type, was satisfactory, but the design could be improved. In the instrument the pressure and temperature records were transmitted by keying discs a, Fig. 1, Plate 8, attached to shaft b which was driven by windmill c. Contact with the different discs was made by means of the fingers f and the moving arms d and e, which were actuated by the pressure and temperature devices, respectively. A chopper g was placed in the circuit for the purpose of identifying the signal. This was not needed for an isolated station like Fairbanks and was removed from all of the sets. The design placed five loose contacts in the radio circuit, each one of which was a source of trouble Contacts for the fingers had to be adjusted very lightly because of the small energy available to drive shaft b and the contacts of the moving arms d and e had to be made light to avoid lag in the pressure and temperature measurements. Of course, the failure of one of the contacts meant loss of the signal. As these sets were received, the fans of windmill c were too small and the shaft of the first set quit turning at thirty-five thousand feet. Larger and lighter fans were substituted and this trouble was avoided for the other sets.

The eight sets sent up were heavy, weighing about four pounds, and elaborate, making them cost about eighty dollars. The tubes used required four volts filament voltage. Tubes are now available which will give as good service with two volts on the filament. Figure 2, Plate 8, shows a simplified design of mechanism for the transmission of pressure and temperature records. Windmill a drives gears b and c. The axis of c carries pointers d and d_1 which are rotated on their axes by thermal and pressure elements. The point of d is adjusted for a close approach, but no contact with arm f on gear c as c rotates. Notch g in base h is adjusted for approximately the same capacity change with a close approach of f as that given by d. Elements d, f, and g are connected to tune a simple Hartley circuit radio set which consists of a single type 230 tube. The shift in frequency with each close approach of f to d or g will detune the signal at the receiver sufficiently to operate a relay, and mark an automatic receiving tape whose uniform motion will give an accurate measure of the time interval between successive close approaches. The relative times between successive approaches to g and the included approach to d will then give an accurate measure of the temperature if the rotation of a is constant. All of these operations are completed with a very low friction drag for both the recording element and the timing mechanism and without introducing a poor contact into the radio circuit. The whole set is so extremely simple that its cost should be relatively low, perhaps less than ten dollars.

TEMPERATURE RADIATION FROM THE STRATOSPHERE

8. Preliminary observations with a heliometer and with ordinary thermometers exposed to the sky gave abundant proof of the fact that there were sudden and radical changes in the radiation received from the clear sky. During cold weather there was almost no wind at Fairbanks. Occasionally during the morning while the radiation from the sun was increasing the temperatures, at ground level indicated by thermometers exposed to sky radiation, would be decreasing. During the night there was often an increase in temperature when there were no winds and no clouds in the sky. The observations indicated that during the winter the surface temperature of the earth was oftentimes entirely dependent on equilibrium with the stratosphere radiation.

Changes in sky radiation at Fairbanks may be associated with the development of storms which move south. For example, the lowest temperature, about -60°F, recorded in twenty years occurred while one of the worst blizzards of the decade was developing along the Pacific coast. Again, early in April, 1933, the weather became exceptionally warm. There were no clouds or winds to explain the change. The high temperatures must have been the result of exceptional sky radiation, which prevented night cooling as a frost is often prevented by a blanket of clouds, except that in this case the blanket was invisible in the clear sky. A pilot balloon, April 12, showed a strong east wind, eighty-five miles per hour, at elevations from ten to twenty-five thousand feet. On April 13 an exceptionally intense barometric low developed along the Aleutian Islands which, April 14, divided and started a new storm center south down the Pacific coast. The exceptionally strong east wind probably was the result of stratosphere conditions and was probably the result of a southward movement of air away from polar regions, caused by the movement northward of warm air at high altitudes into polar regions.

It was concluded that a better understanding of stratosphere conditions and of the air circulation in polar regions might be of value in understanding the development of weather in temperate regions. Recording thermometers exposed to the sky radiation, and protected from ground level temperature effects, might yield important data in addition to the other standard equipment of the stations of the Weather Bureau.

TABLE 1.

Observations of Effective Ionosphere Heights.

	VISUAL		PHOTOGRAPHIC				Measurements of effective ionosphere height in kilometers.		
					Percent of Measurable records.				
Month	Total Days	Records	Total Hours	Measurable Records	Day	Night	Low	Average	High
December	14	14	110	95	56	44	160	260	700
January	30	21	390	84	54	46	180	270	480
February	20	10	181	19	53	47	270	300	420
March	31	23	725	226	69	31	260	300	670
April	30	23	635	85	57	43	260	320	690
May	31	22	609	60	24	76	270	290	550
June	30	21	634	46	11	89	130	290	500
July	31	14	728	33	18	82	230	280	390
August	24	5	524	00	0	0	370	390	420
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

TABLE 2

Percent of time showing measurable radio echoes.

Period of Active Magnetic Disturbance	Disturbed Day Photographic Record hours	Disturbed Day Visual Record days	Remainder of Month Photographic Record hours	Remainder of Month Visual Record days
December 14-16	70	100	96	100
January 23-30	0	0	31	96
February 19-26	0	12	31	69
March 18-25	5.5	12	40	100
April 16-23	1.3	25	17	100
May 18-19	0	0	11	82
June 13-15	0	33	8	74
July 22-25	0	33	5	46

TABLE 3.

Percentage of time giving measurable photographic records.

Period of Good Reception	Good Period Total	Good Period 6AM to 7 PM	Remainder of month Total	Remainder of month 6AM to 7 PM
April 8-12	41%	60%	7.1%	5.6%
May 8-11	29	26	6.4	1.8
June 6-10	22	9.2	3.9	0.7
July 7-8	13	12	4.0	1.1
Total 16 days	28	31	5.3	2.4

TABLE 4

Data of the Spectra of Plate 6.

Spectrum	Altitude of Sun	Time of Day	Time of Exposure
1	$+3^{\circ}$	7:45 p.m.	30 sec.
2	Sunset	8	40 sec.
3	-3°	10	4 min.
4	-5°	11	5 min.
5	-8°	11:30	30 min.
6	-10°	12	1 hour
7	-10°	1 a.m.	1 hour
8	-8°	2	1 hour
9	-5°	2:30	5 min.
10	-3°	3	4 min.
11	Sunrise	4	40 sec.
12	$+3^{\circ}$	5	40 sec.
13	+15	8	5 sec.

TABLE 5

Data of the Spectra of Plate 7.

Spectrum	Time of Day	Time of Exposure
1	Midnight to 6 a.m.	6 hours
2	6 a.m.	20 min.
3	7	15 min.
4	8	15 min.
[illegible]	9	10 min.
6	10	10 min.
7	11	10 min.
8	Noon	10 min.
9	2 p.m.	10 min.
10	4	15 min.
11	5	20 min.
12	6 to 8	2 hours.

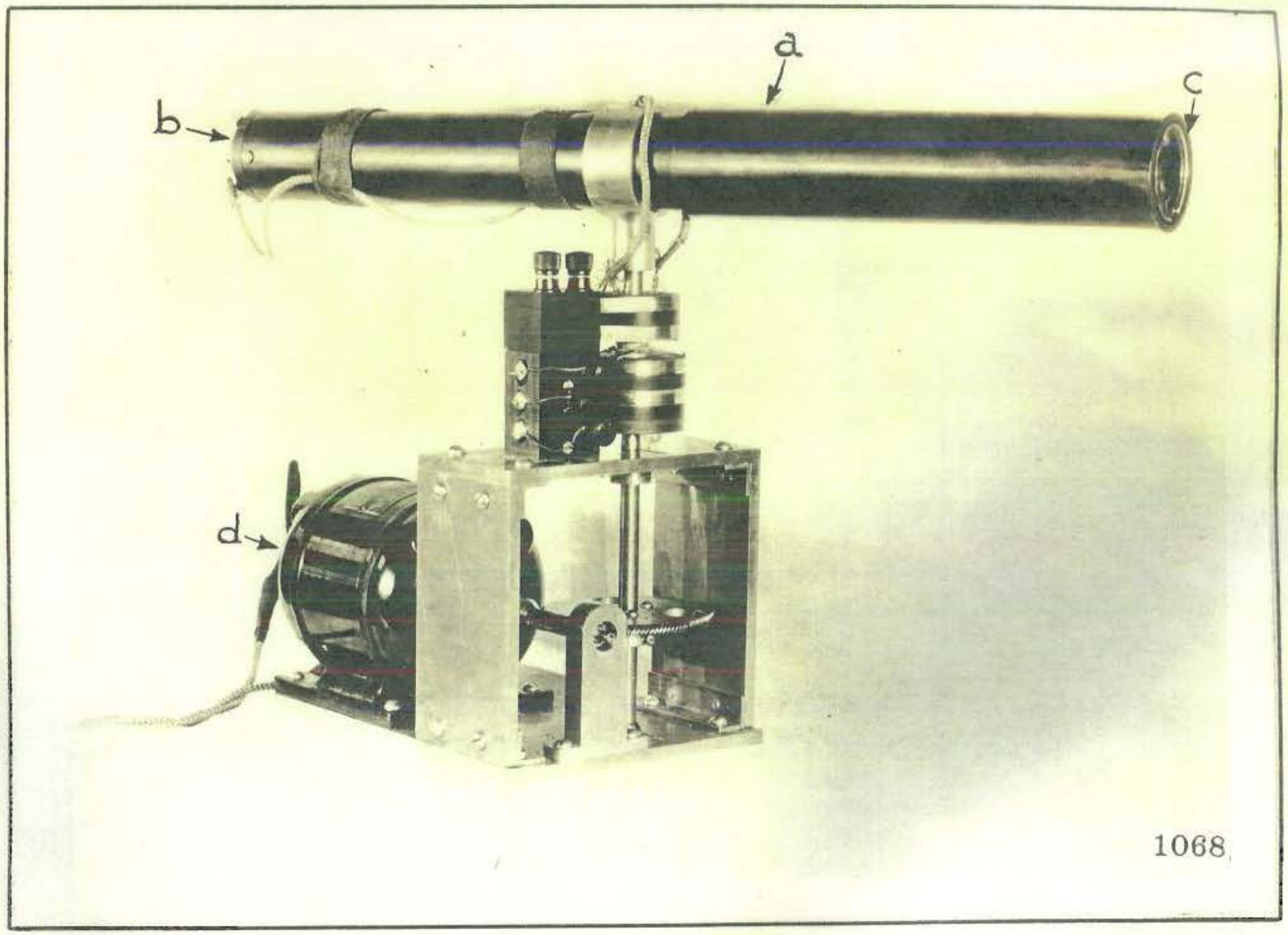


PLATE I

SCHEMATIC DIAGRAM
OF RECEIVING EQUIPMENT
USED IN MEASURING HEIGHT
OF HEAVISIDE LAYER AT
FAIRBANKS, ALASKA.
1932 - 1933

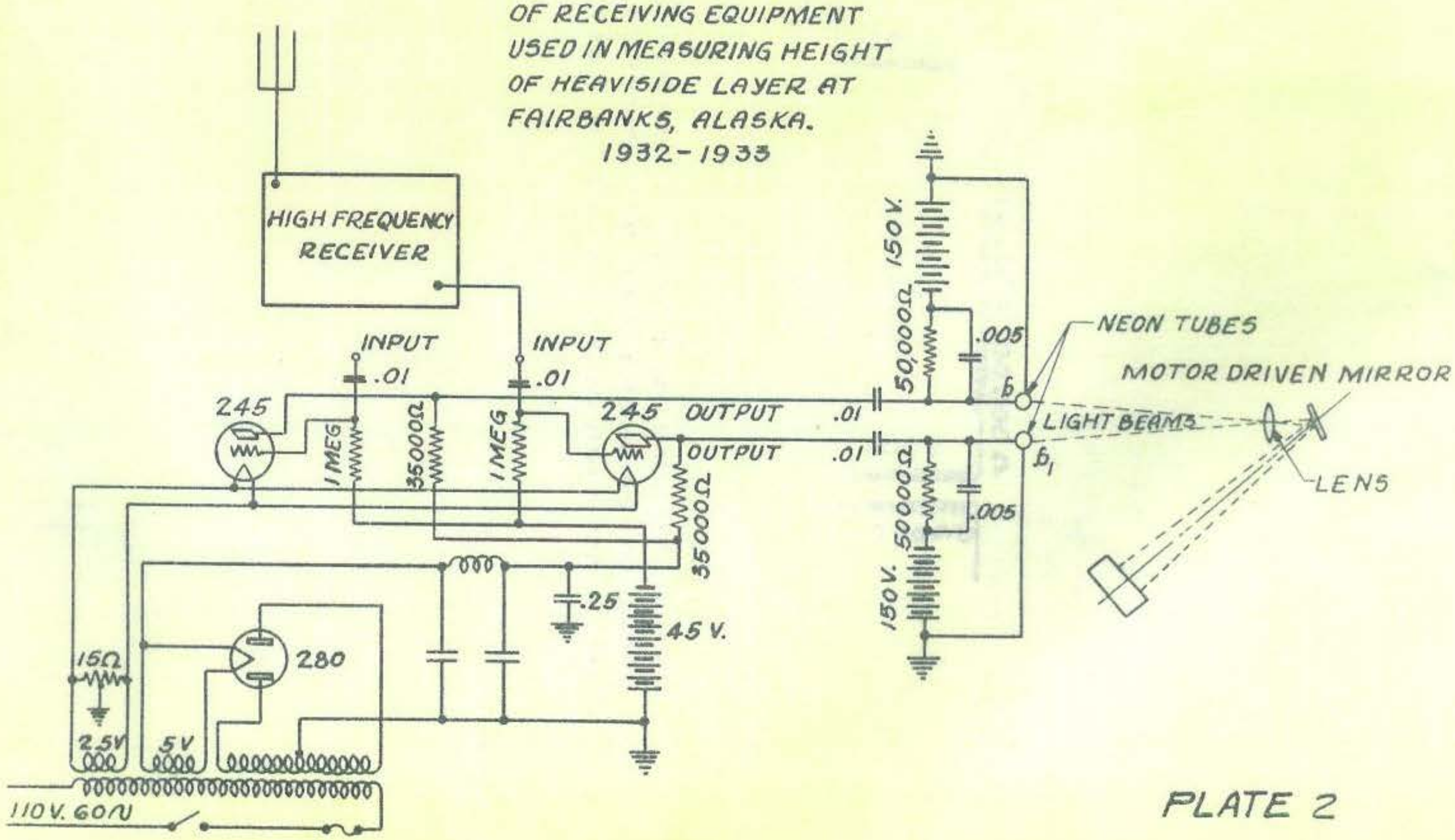
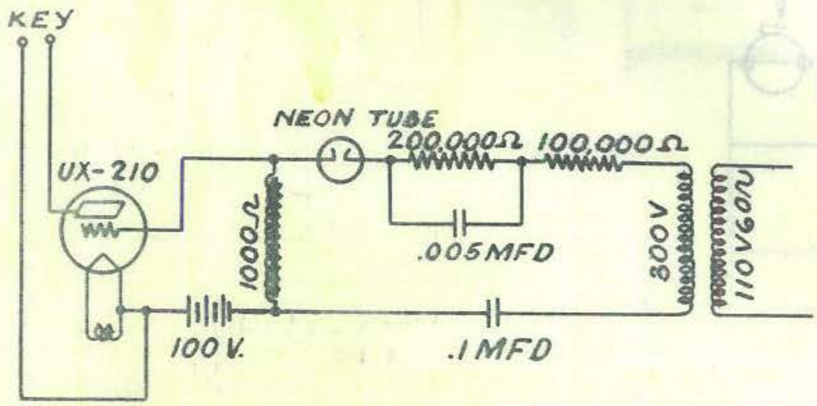
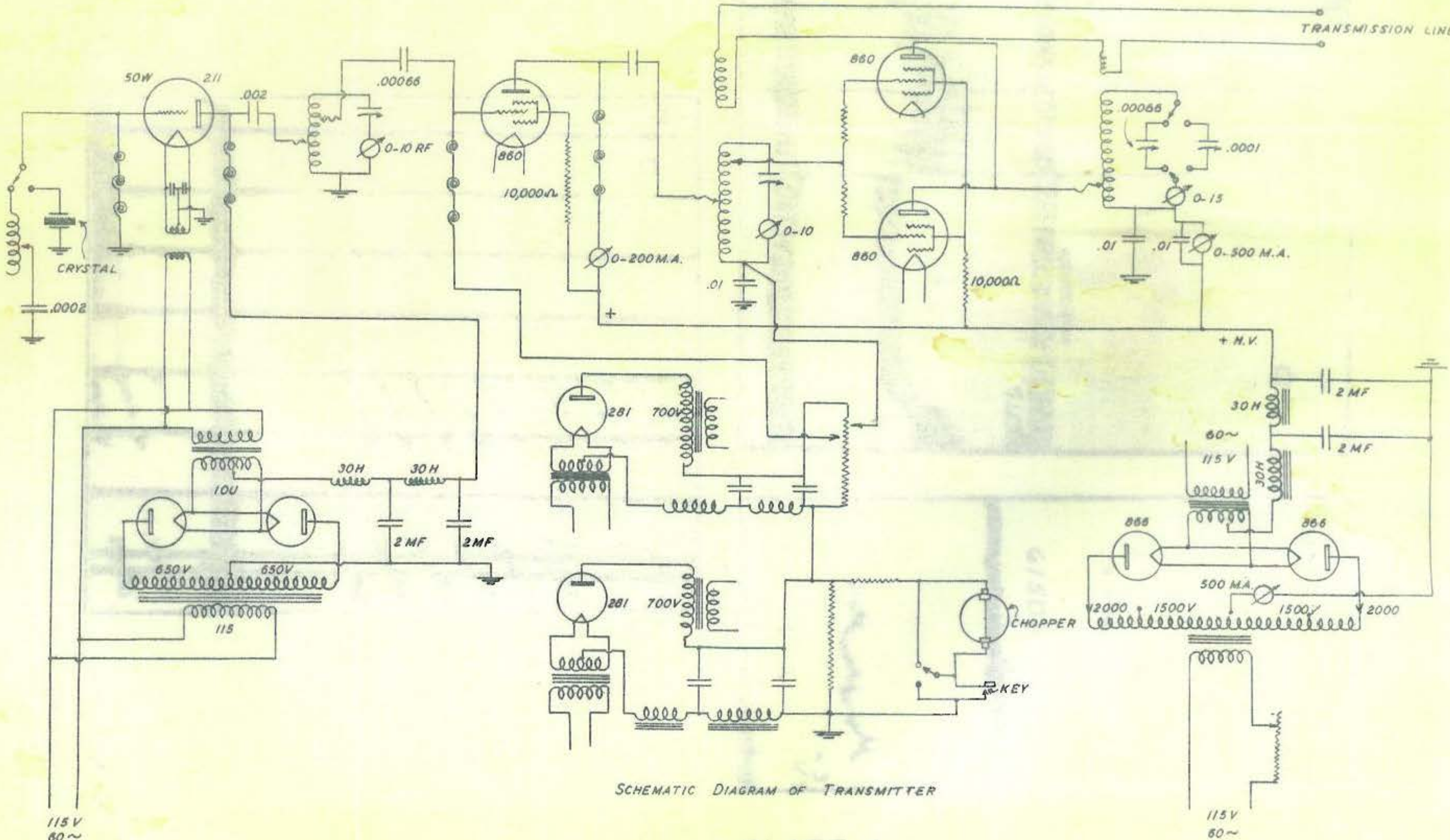


PLATE 2



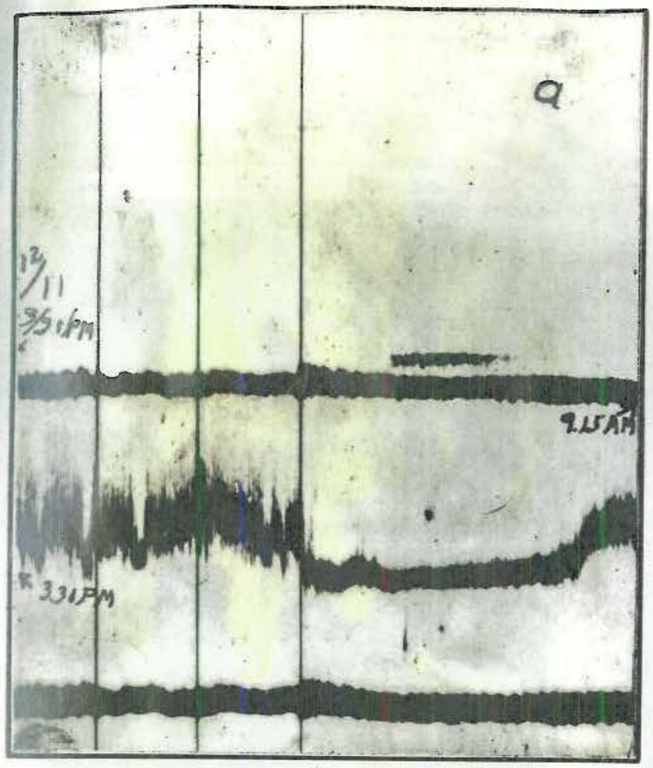
SCHEMATIC DIAGRAM OF KEYING SYSTEM USED ON HIGH FREQUENCY TRANSMITTER FOR MEASURING HEIGHT OF HEAVISIDE LAYER AT FAIRBANKS, ALASKA 1932-1933

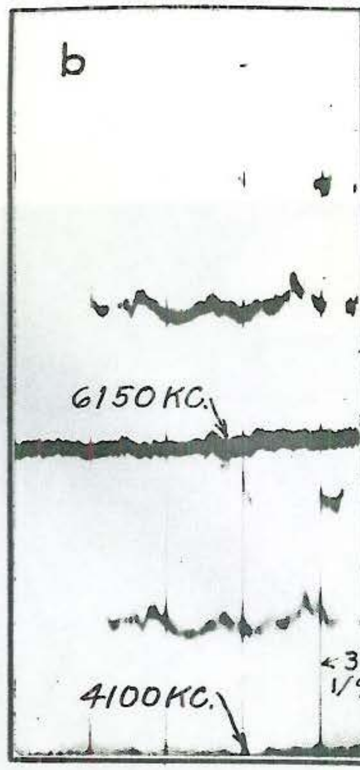
PLATE 3



SCHEMATIC DIAGRAM OF TRANSMITTER

PLATE 4





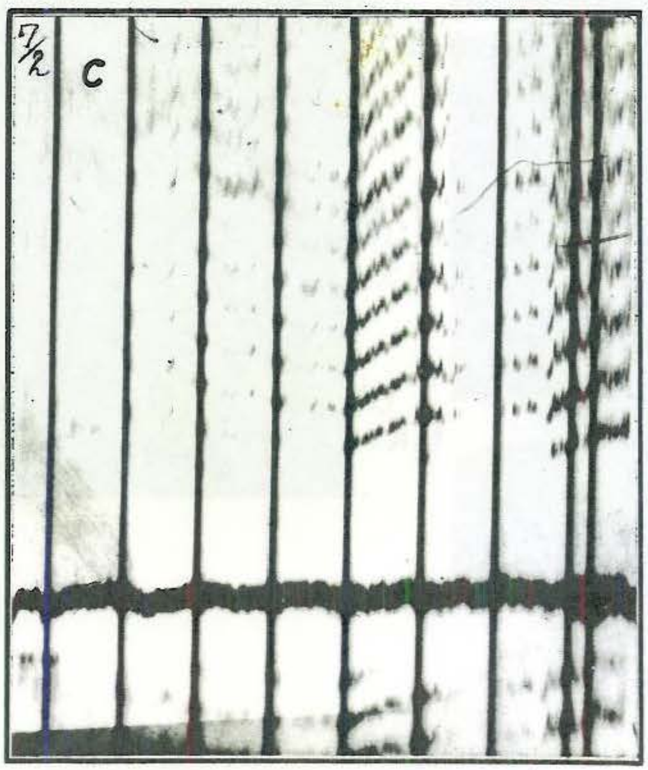


PLATE 5

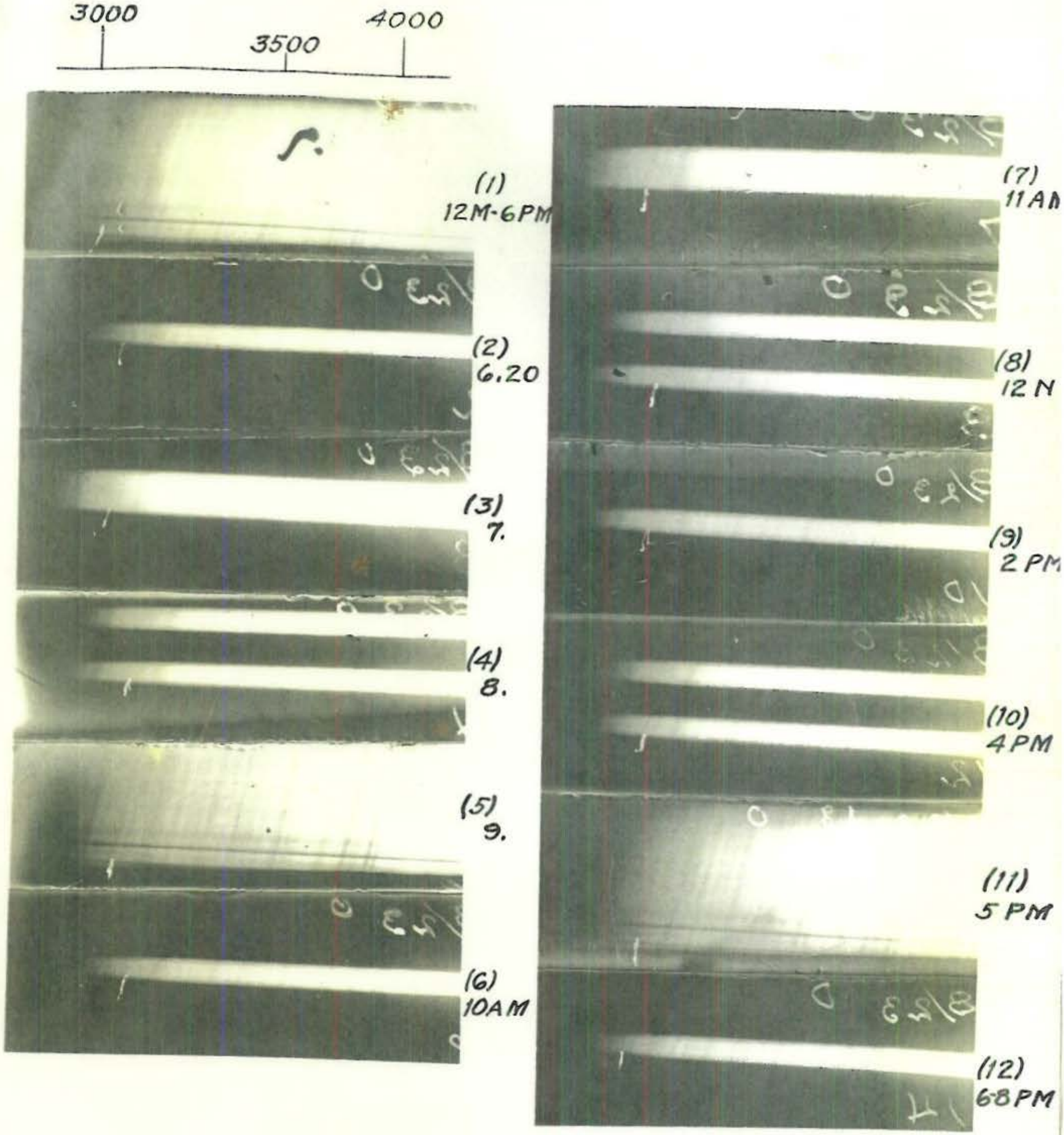

3000
3500
4000
(1) 12M-6PM
(2) 6.20
(3) 7.
(4) 8.
(5) 9.
(6) 10AM
(7) 11AM
(8) 12 N
(9) 2 PM
(10) 4PM
(11) 5 PM
(12) 6-8PM

PLATE 7

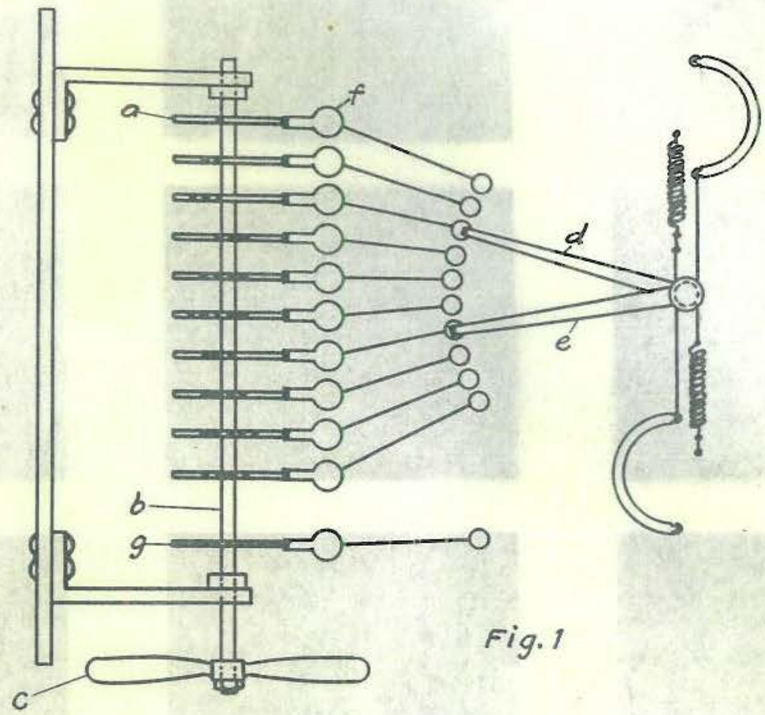


Fig. 1

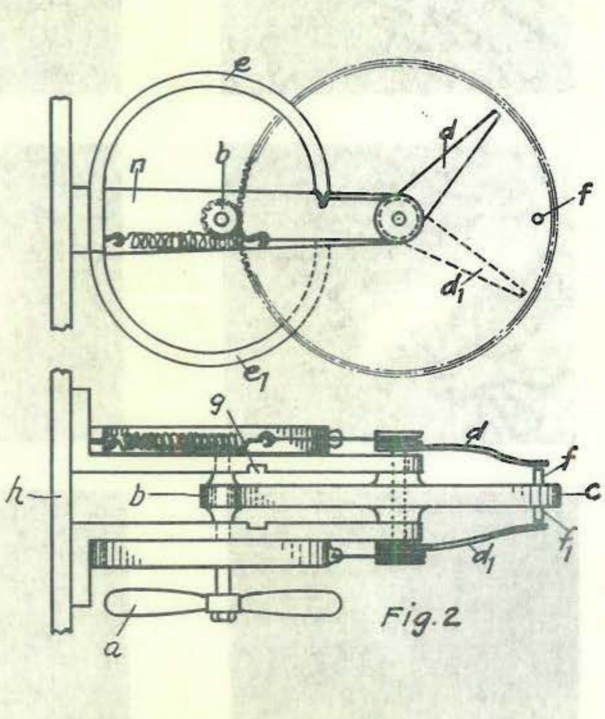


Fig. 2

PLATE 8

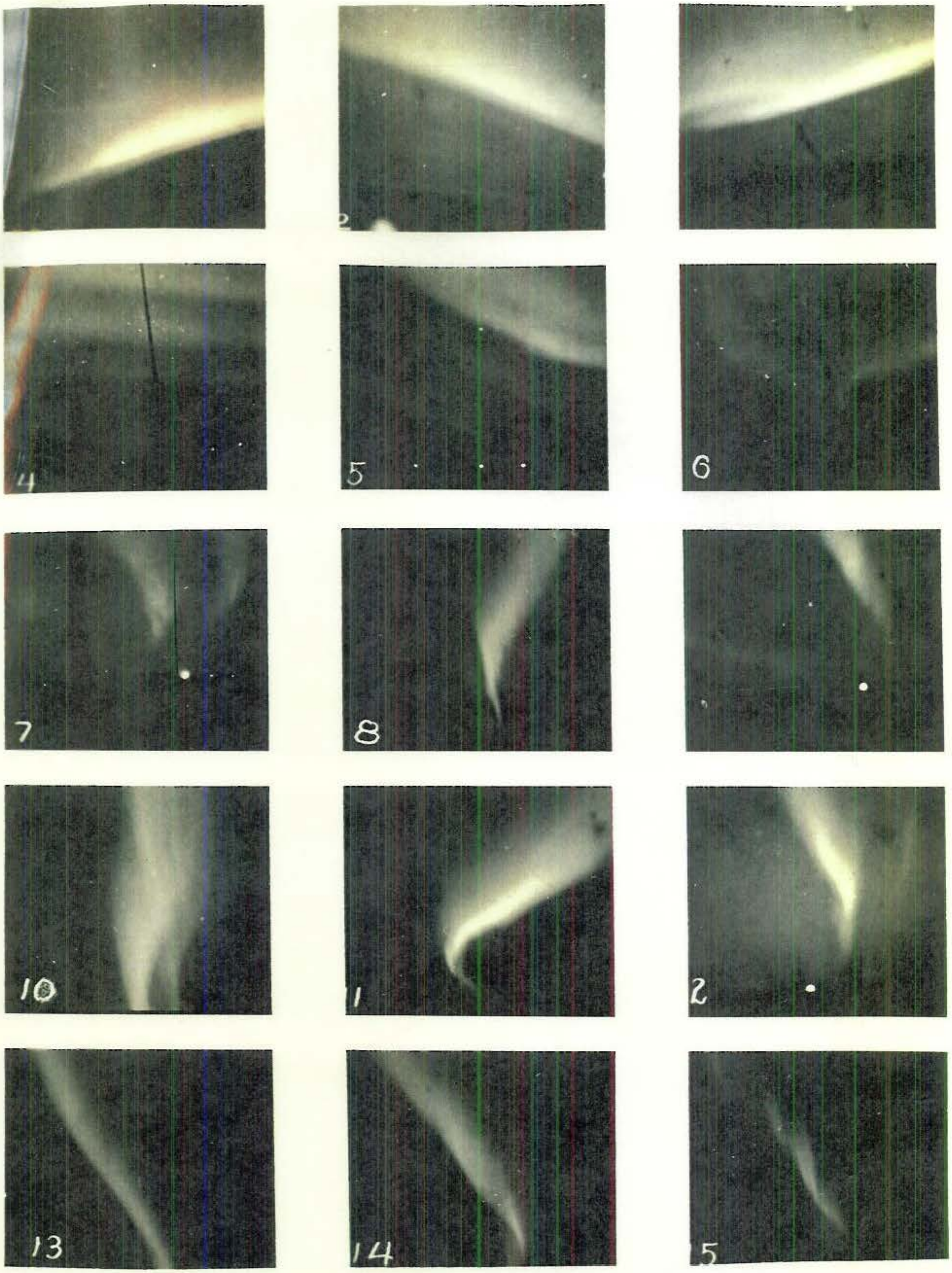


PLATE 9

PLATE 10

PLATE II

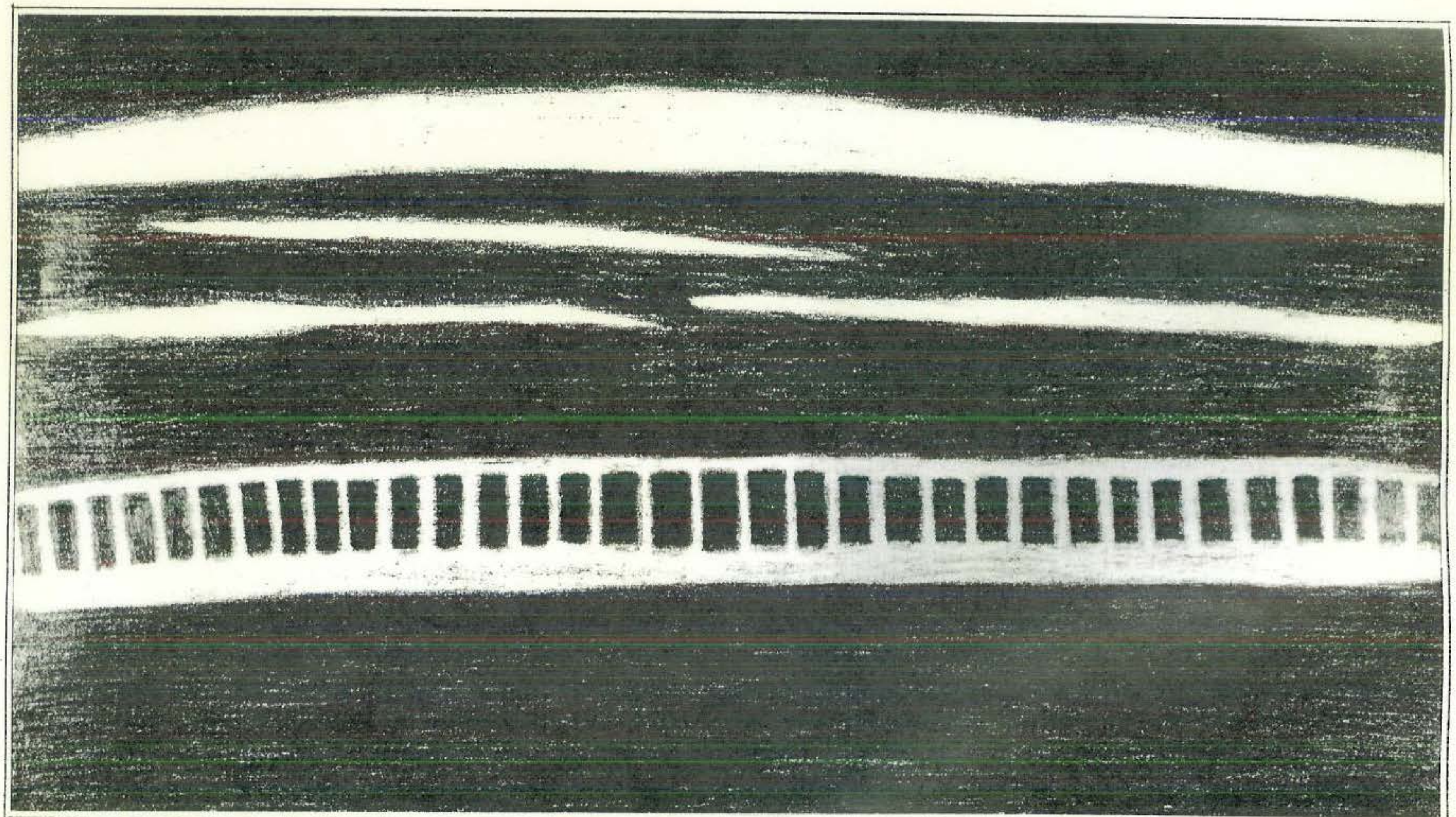


PLATE 12

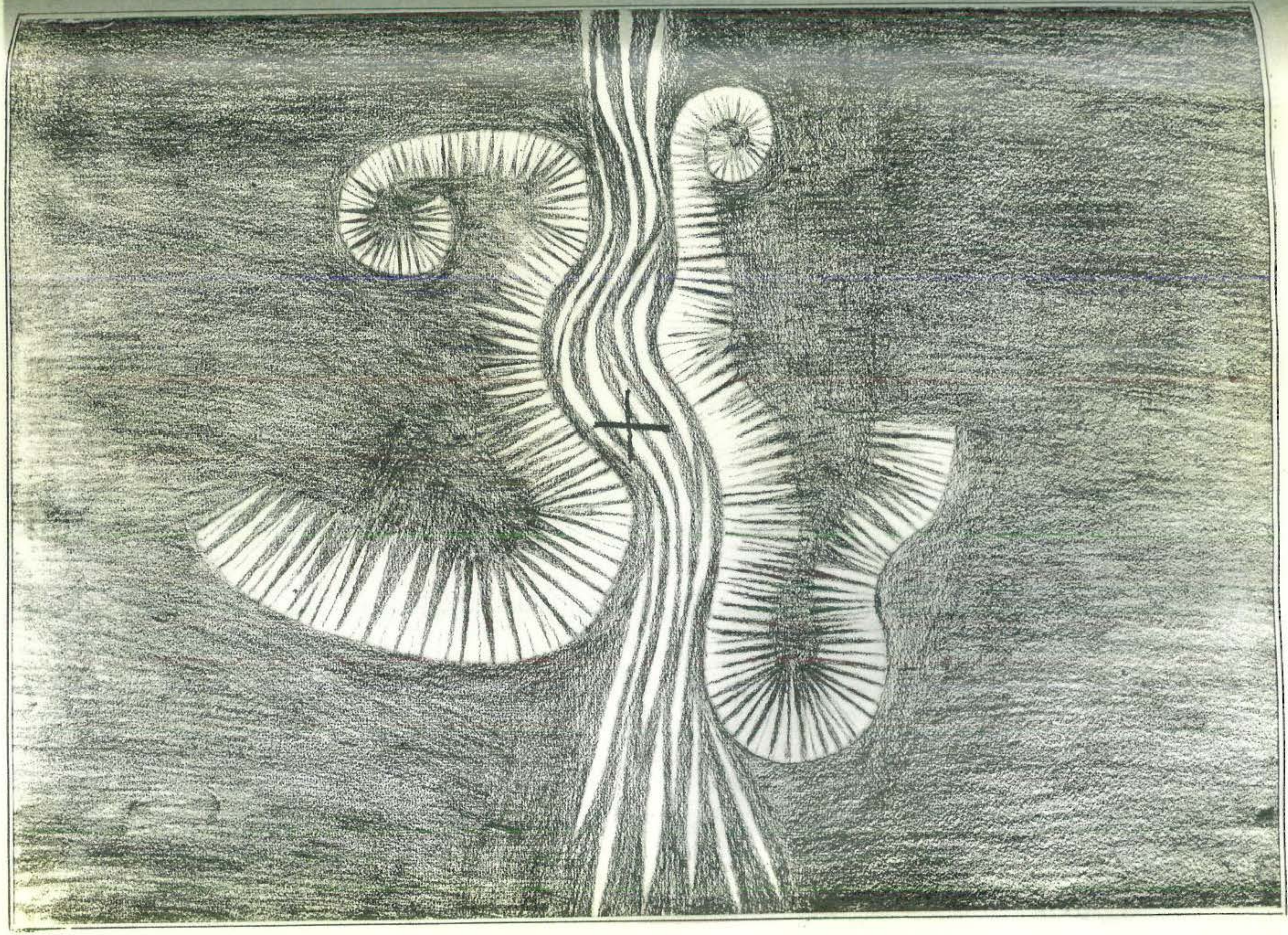


PLATE 13

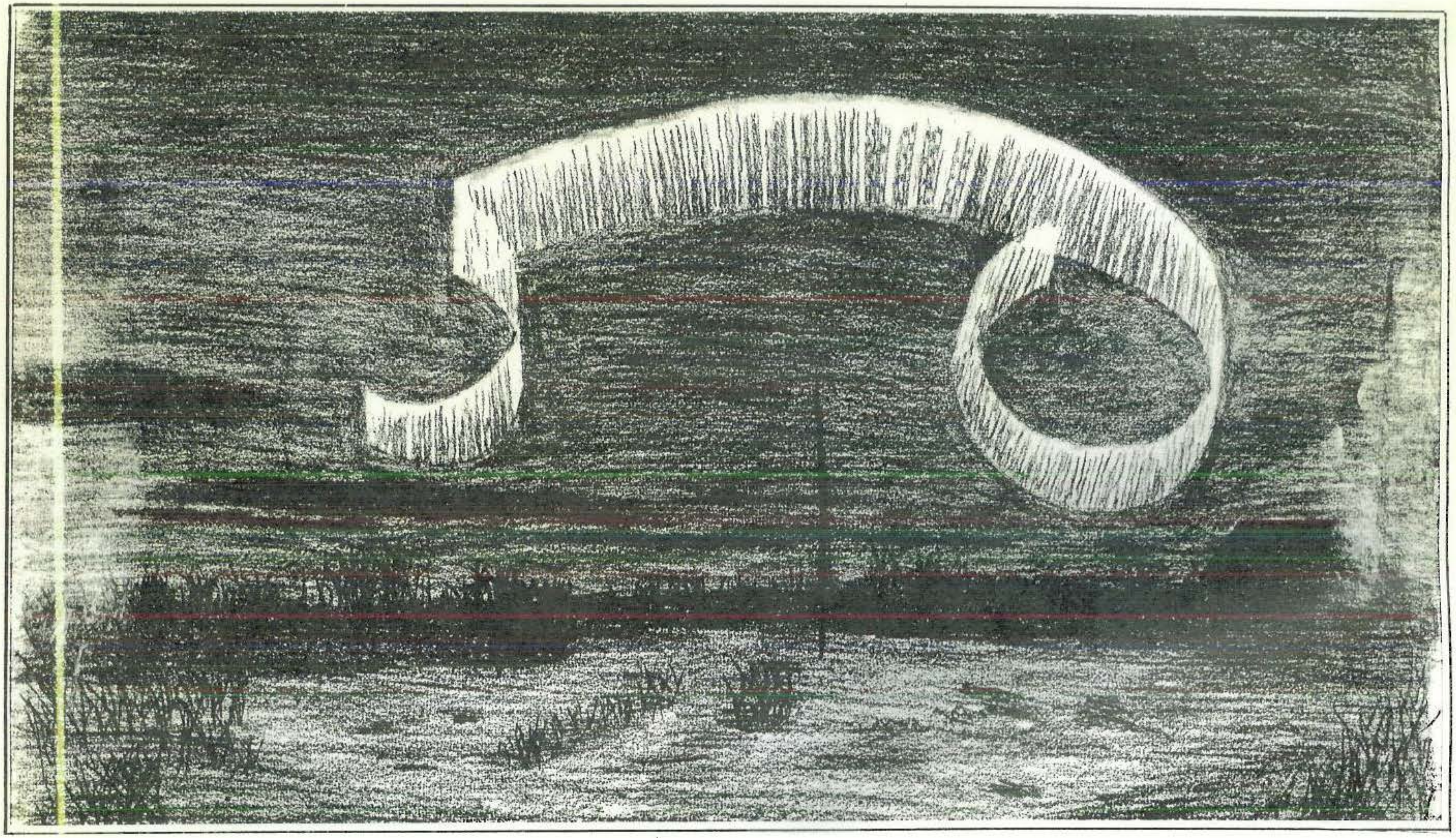


PLATE 14

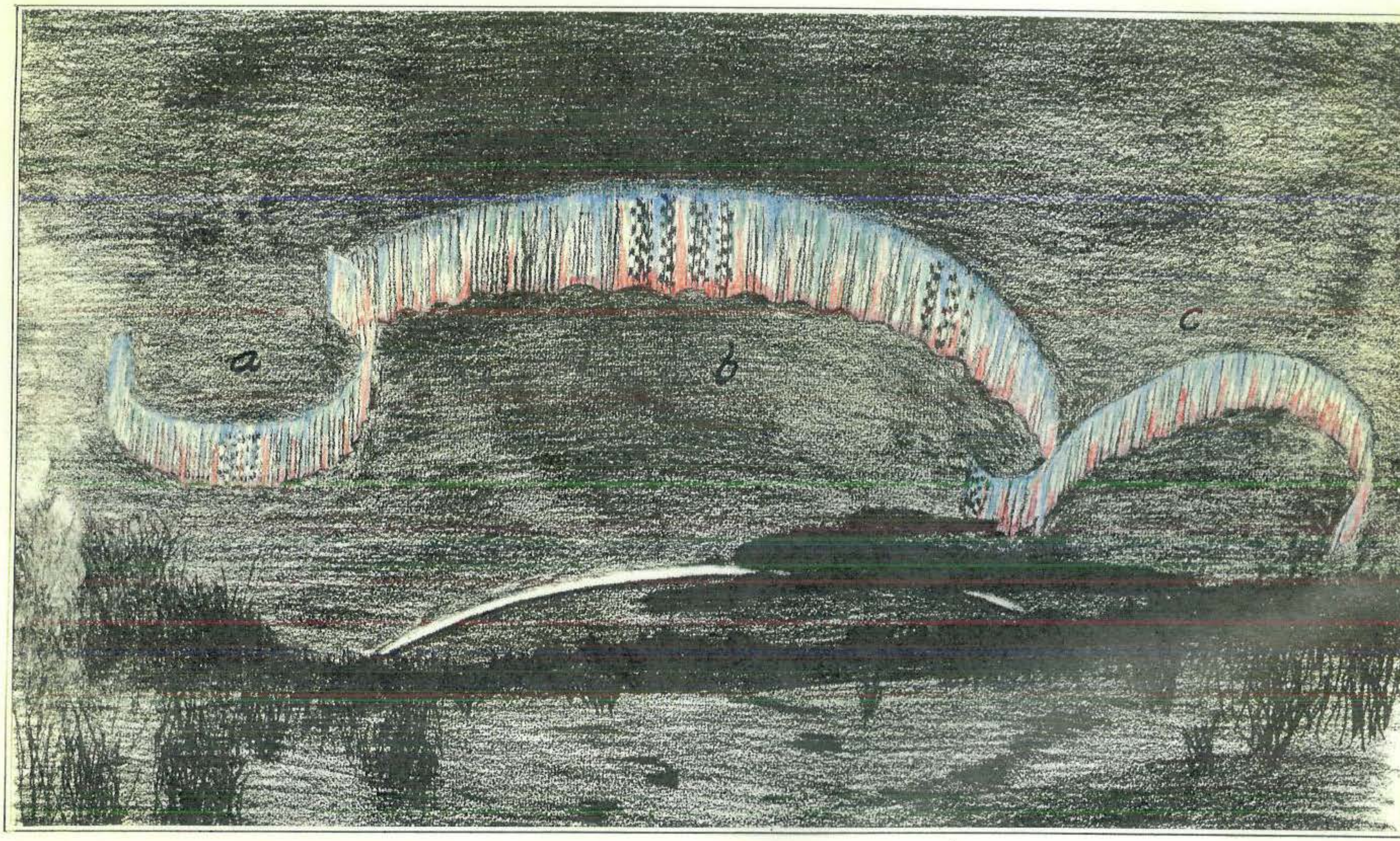


PLATE 15