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A DETAILED INVESTIGATION OF AN ILLINOIS HAILSTORM ON AUGUST 8, 1963

by

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INTRODUCTION

During the afternoon of August 8, 1963, scattered air mass thunderstorms occurred in portions of central and northern Illinois. A few of these thunderstorms produced hail which in turn inflicted damage to crops and property.

One of these hailstorms occurred near Weldon, Illinois (fig. 1), and an exhaustive study has been made of this storm. The detailed study of this storm was performed to add to our knowledge of the causes, structure, and rainfall production of hailstorms, and the relationship of these factors with crop damages. Information on the relationship between radar-depicted storm echoes and damaging hail incidence was also desired.

The hailstorm under investigation occurred between 1601 and 1625 CST and produced hail over an area of approximately 17 square miles. Light damage to both corn and soybean crops was produced in about 50 percent of this incidence area. The largest hailstones measured were slightly more than one inch in diameter and most stones were spherical in shape. The hail cell moved from the NNE, which is an unusual direction of movement for Illinois hailstorms, and produced a swath about seven miles long and two miles wide.

This particular hailstorm was selected for detailed investigation for several reasons. Primary reasons were: 1) the storm occurred entirely within the confines of one of the Water Survey's dense raingage networks, and 2) the storm was observed (and photographed) by two Water Survey radar sets located about 25 miles from the storm area. The storm also occurred in a highly-productive agricultural area which was accessible for a field survey of the storm. Furthermore, crops were at growth stages which clearly revealed any damage from hail.

In this report all findings and data concerning this hailstorm are presented. These include synoptic weather data, field survey data, radar data, rainfall data, and crop loss data from member insurance companies.

DESCRIPTION OF DATA

A wide variety of scientific data were collected during and immediately after the storm occurred.

Synoptic weather data were obtained from U. S. Weather Bureau maps and stations in Illinois and vicinity. Additional wind and pressure data in the storm area were obtained from equipment of the State Water Survey. Three recording microbarographs within a few miles of the storm site served as a source of pressure data.

On August 9, the day after the storm, a field survey was conducted by Water Survey personnel. This survey team interviewed 12 farmers in the storm area to obtain information on the time of beginning and ending of the hail, the maximum and minimum hailstone sizes, occurrence of other forms of severe weather (high winds, lightning, heavy rainfall), number of stones on the ground, and shape and color of the hailstones. In addition to the data gained from these interviews, traverses were made along all section roads in the area to determine 1) the general extent of the damage area and 2) the direction from which the damaging hailstones fell.

During the storm, two of the Water Survey's 3-cm radar sets located at the University of Illinois Willard Airport were in operation. The hailstorm cell was located from 20 to 30 nautical miles away from the radar sets, and these distances are optimum distances for detailed radar portrayal of precipitation echoes. One of these radar sets was a CPS-9 which furnishes a PPI (horizontal) portrayal of precipitation echoes. The other set was a TPS-10 which furnishes a RHI (vertical) portrayal of echoes. The scope presentations of these two radars were photographed, but camera malfunctioning on the TPS-10 scope eliminated a portion of that data. Data from these two radar sets furnished an excellent 3-dimensional portrayal of the storm and revealed the above-surface characteristics of the storm's development.

The hailstorm occurred near the center of a dense raingage network operated by the State Water Survey. In a 400-square-mile rural area in central Illinois centered around Weldon (fig. 1) there are 49 standard recording raingages which have been located to form an even grid pattern. The gages are separated by distances of approximately three miles. All but five of the gages were recording rainfall on relatively fast time speeds (one chart revolution per 24 hours), which enabled an accurate determination of 5-minute rainfall amounts from 44 raingages.

From various crop insurance companies, information concerning the percent of adjusted crop loss by crop types was collected. These data applied to insured acreage in the immediate area of study.

SYNOPTIC WEATHER CONDITIONS

The surface weather maps for August 8 show a very flat pressure gradient over the entire Midwest, somewhat like a typical August weather map. For example, at 1200 CST the pressure in the Illinois area varied from 1015mb in a low pressure area in Wisconsin to a high pressure area of 1017mb in Missouri. During the day, pressures fell throughout the Midwest, dropping up to 5mb with no major frontal systems influencing these drops.

The printed U. S. Weather Bureau surface map also shows an east-west oriented stationary front extending from Lake Superior to northern Wyoming. This front separated the Canadian air from the maritime tropical air which covered much of the central United States.

Careful re-analysis of the surface weather conditions indicated that in the Illinois area there was a remnant of a frontal system which separated the maritime tropical air from the modified mp air. This demarcation line ran southeastward from Minnesota through the southwest corner of Lake Michigan, thence southward through extreme western Indiana to Kentucky, and then eastward to the Atlantic Coast.

Maximum temperatures on August 8 were in the mid-80's in Ohio, the low 90's in Iowa, and the high 90's in Kansas. Low temperatures during the morning of August 8 were in the mid-50's in Indiana, the mid-60's in Illinois, and the low 70's in Kansas.

The printed surface map indicated precipitation at the first-order stations in the Illinois-Iowa-Missouri-Indiana-Ohio area on the 8th. Rain was also shown in an area from California to Minnesota.

The 500-mb maps (20,000-foot level) indicated generally light winds throughout the country and a low pressure system east of Hudson Bay with a trough extending southward into the Atlantic Ocean. A large anticyclone existed over the southwestern states with a ridge line extending northward to Alberta. At 1900 CST a 35-knot northwest wind existed over Peoria, and 500-mb winds of 25 knots were within 200 miles east and west of this area. Therefore, there appears to have been a minor wind maximum over central Illinois at this level.

The winds-aloft charts for August 8 indicated light northerly winds over most of the upper Mississippi River Valley and the area eastward, and light southerly winds west of this area. Most of the winds reported from the surface up to 20, 000 feet ranged from 5 to 15 knots with some approaching 25 knots. The tropopause was located at 45, 000 feet.

From the published 24-hour rainfall maps, which are based upon first-order weather station data, it was found that rains on August 6 occurred in Ohio and on westward through Illinois with large amounts in Illinois and Iowa. On August 7 rainfall was reported in an area from California to Kansas and in another area which extended northeastward from Texas through Indiana, and then eastward to the Atlantic Coast.

The total rainfall in Illinois for August 6-7 (fig. 2a), which was derived from all U. S. Weather Bureau stations in Illinois, shows that rainfall covered the northern two-thirds of Illinois with a maximum point amount of 3.98 inches occurring southeast of Springfield. As shown on figure 2a, a belt of heavy rainfall extends southeastward across the state to Paris where amounts of one inch or greater are common. The Paris rainfall occurred on the 7th.

Selected rainfall amounts and the boundary of the rainfall area in Illinois based on August 8 data from all Weather Bureau stations in Illinois are plotted on figure 2b. Rain occurred generally within an elongated north-south area in the eastern portion of the state. The highest known point rainfall amount in Illinois on August 8 was 1. 42 inches measured at raingage 39 (fig. 4) in the Water Survey's central Illinois raingage network. This and the other heavier rainfall amounts in Illinois on August 8 occurred in the immediate area where the hailstorm under study occurred. The locations of the 32 townships where claims of hail losses to insured c rops were reported are also shown in figure 2b. These townships are all located relatively near to moderately large (greater than 0.5 inch) point rainfall amounts.

A portion of the rain on August 8 fell during the morning hours. An area of light nocturnal showers developed east of Moline (fig. 2b) at 0400 CST and moved southeastward passing north of Peoria into central Illinois. Its position is portrayed in figures 3a and 3b, and rain from this system terminated in the general position shown on figure 3b at 10 30 CST.

At 1215 CST light thundershowers began developing west of Kankakee (where the morning rain had ended) and by 1300 CST these showers were occurring at several isolated locations in and south of the area of formation. Around 1500 CST second group of thunder-storms began developing in the area between Urbana and Chenoa (fig. 26) and also in the area between Ottawa and Paw Paw. These storms produced most of the damaging hail which occurred on August 8. These more severe thunderstorms moved generally southward, as had the earlier thundershowers, and by 1630 CST (after the Weldon hailstorm ended) thunderstorms were occurring as far south as Charleston (fig. 2b). The heavy hail near Pana began just before 1700 CST= and the most southerly thunderstorm reached Flora at 1800 CST and ended there at 1915 CST.

A study of the detailed hourly weather maps for the Illinois area between 0600 and 1800 CST on August 8 revealed marked regional differences in the dew point temperatures and the afternoon air temperatures. As shown in figure 3a, the pattern of dew points at 0600 CST shows only a gradual decrease from 70 in the western portion of the state to 60 F in the eastern portion. Fog was reported at many of the locations with light rain showers in a small area north-west of Peoria, These showers had developed in the extremely moist air located in eastern Iowa and northwestern Illinois during the night of August 7-8.

Around 0800 CST, due point temperatures rose rapidly at some stations in central Illinois as reflected by the pattern at 0900 CST (fig. 3b). Between 0700 and 0900 CST, a 10-degree rise in the dew point occurred at Springfield, a 6-degree rise at Peoria, a 4-degree rise at Champaign, and none at Rantoul. However, these locations were not in the rain area in Illinois (fig. 3a and 3b).

The gradient of the dew points continued to increase markedly. By-noontime (fig. 3c) the dew point temperatures had risen 9° at Rantoul and 5° at Champaign. A definite moist tongue of air extended from Cedar Rapids, Iowa, into the central Illinois area, just south of the eventual hailstorm area. Also shown on the map for 1200 CST are the isotherms of air temperatures. Their pattern indicated a sharp temperature gradient across east-central Illinois with temperatures differing as much as 6 between Peoria and Champaign. Sky cover throughout the area was not markedly different and could not explain this variation. Scattered thunder-showers developed during the next hour west of Kankakee.

As indicated on the 1500 CST map (fig. 3d), large temperature drops had occurred in the rain area with a drop of 14° at Champaign. At this time there was a tongue of hot, dry air moving into the state as indicated by a 97° temperature at Quincy. The moisture pocket is highest in the Decatur area which is just southwest of the forthcoming formations of hailstorms. At 1600, temperatures at Champaign and Decatur were 13 lower than at Springfield and 23° cooler than at Quincy as downdrafts from the showers created a pocket of cold air throughout the east-central Illinois area. A thunderstorm high pressure area of 3mb was created by the downdraft and the rainfall.

The large increases in the dew point temperatures, as convection from solar heating began around 0800 CST, indicated that considerable evaporation and transpiration was taking place from the ground surface. Since the dew points remained high throughout the morning and afternoon of August 8, the evapotranspiration of the maturing crops with very moist soil conditions would have been at a maximum rate. Assuming an evapotranspiration rate of 0.2 inch/day, the resultant increase in dew points would be 11°F. Since the surface winds were light, the moist air was not transported away from the area.

This localized high atmospheric moisture content over central Illinois and eastern Iowa, a remanant of the heavy antecedent rains on August 6-7, first led to the early morning (August 8) development in northwestern Illinois of light showers which moved into central Illinois. The subsequent diurnal increase of moisture due to evapotranspiration, the rain-produced eastward spread of moist air into central and eastern Illinois during the morning hours, and the diurnal increase in heating combined to create the conditions which led to the development of air mass thunder showers in the early afternoon. The presence of an old north-south oriented warm front along the eastern Illinois boundary added to the locally unstable conditions and helped delineate the area of storm development.

The eventual development of the hail-producing thunderstorms was largely the result of two factors. Foremost was the localized presence on a very warm summer day of extremely moist air which had been produced by 1) the area's heavy antecedent rainfall on August 6-7, 2) the early morning showers on August 8, and 3) the light thundershowers in the early afternoon of August 8. The second factor in their development was the presence of strong low-level winds which produced shear. Many of the thunderstorm RHI echoes in the middle and late afternoon had pronounced shear near the 10,000-foot level, and as shown by Browning (1), such shear materially aids the convective processes and helps lead to the development of hail within a storm.

DESCRIPTION OF SURFACE HAIL PATTERN

From the information collected on the field survey, the area where hail fell and the area where crop damage was inflicted by hail were defined (fig. 4). As shown in figure 4, the area of damage to crops determined visually was almost half as large as the total area of surface hail. This condition had not been noted in previously-surveyed hailstorms where the damage areas were much smaller than the hailfall areas (2).

Exact times of the beginning and ending of hail were available from only- three sites. The hail fell first in the northeastern portion of the hail area (point A on fig. 4), and lasted 5 minutes there. The hail cell moved southward and began to produce crop damages one to two miles south of the point of hail initiation. The stones at point A (fig. 4) ranged from 1/4 to 1/2 inch in diameter, and those at the rain drop camera site were from 1/4 to 3/16 inch in diameter. Throughout the damage area, spherical stones ranging from 1-1/4 to 1/2 inches in diameter fell, and their directions of fall (azimuth of incidence noted on corn stalks, buildings, and poles) were from the E and ESE. At point B (fig. 4) hail began at 1610 CST and persisted for 11 minutes. Damage in the area of maximum crop damage was not too severe because only 3 to 4 stones pere square foot were noted to have fallen. In the southern portion of the hail area, 1/2-inch diameter spherical-shape stones were common. The hail cell continued to move towards the south, and hail at the surface ended at 1625 CST at point C (fig. 4) after lasting 7 minutes at that location. Wind damage to trees was also common in the southern portion of the hail area, and the direction of their fall (generally towards the SSW) and their locations are noted on figure 4. The apparently higher surface wind speeds in this portion of the hail area were partially responsible for the crop damage in the region where the stone diameters were generally smaller than those which fell in the central and northern portions of the hail area.

The hail area shown on figure 4 had a generally oblate shape which is similar to those noted in other carefully studied hailstorms (2, 3, 4). The total hail area of about 17 square miles is much smaller than that measured for several frontal hailstorm cells (3). This August 8 hailstorm area, as opposed to others investigated in Illinois, was a result of a single cell (shaft), and was not a composit of several hail cells. This hail cell's lifetime was 24 minutes which is considerable less than the 36-minute average obtained for six hail cells in a 1960 frontal hailstorm complex near Decatur (3). However, this 24-minute duration was identical with that associated with a 1962 air mass thunderstorm in central Illinois (4). Point durations of the hail fall near Weldon varied from 5-11 minutes which compares favorably with duration data from the previous storms studied in similar detail.

The direction of cell movement (from the NNE) is uncommon in Illinois hailstorms. However, the forward speed of the hail cell was about 25 mph, which is equivalent to speeds previously measured for other hail cells. The direction from which the hailstones fell (ESE) was at right angles to the direction of cell movement. This condition was noted in the air mass hailstorm studied in 1962 (4), but was not common condition in the cells with frontal hailstorms.

In general, it appears that except for direction of movement, the August 8 surface hail pattern and many of the various other storm characteristics were almost identical with those measured in a 1962 central Illinois hailstorm which was also associated with an air mass thunderstorm.

RADAR FINDINGS

The first TPS-10 photograph of the echo which produced the hailstorm was taken at 1544 CST with the echo extending from 29, 000 to 41, 000 feet (figs. 5-7). At this time, the nearest other radar echo was approximately eight miles north. No echo was visible at 1541 CST, and thus the "first echo" of the hailstorm developed between 1541 and 1544 CST. The high level of first echo formation is quite uncommon for thunderstorms, although Browning (5) noted similar heights of formation for first echoes of hail-producing thunderstorms in Oklahoma. Photographs of models prepared from the TPS-10 data are shown in figures 5-7, and these models furnish excellent 3-dimensional portrayals of the size, shape, and variation in the echo during its developmental stage.

By 1550 CST there was a second echo forming alongside the original echo which now extended from 9, 000 to 41, 000 feet. Note how the views of the models at 1550 CST reveal the decent of the precipitation shafts. By 1550 CST, and in all succeeding portrayals of the echo, at least three turrets (cells) extended above the main echo mass.

At 1554 CST the first rain (echo) was reaching the ground, and the echo was showing development of shear at the 12, 000-foot level. This shear was also apparent in several echoes (storms) occurring about this time elsewhere in central Illinois. This shear and the small rain shaft are quite evident on the 1554 model shown in figure 7. At 1558 and 1602 CST horizontal enlargement of the echo had occurred at all levels (fig. 8). No TPS-10 data were available after 1602 CST.- The developing shear at the 12, 000-foot level is well shown in the 1558 and 1602 models on figure 7.

At the 30,000-foot level (fig. 8a) the enlargement of the echo area between 1550 and 1554 CST was a result of the new cell which had formed alongside (to the ESE) the old cell at 1550 CST (fig. 6). Between 1554 and 1558 CST considerable change occurred in the echo depicted at the 30,000-foot level as the northern portion of the echo appeared to pivot to the ESE. Furthermore, by 1558 CST another new cell adjacent to the major cell (and to the ESE) had developed and is shown in figure 6. Between 1558 and 1602 CST, the echo area at 30,000 feet had diminished. The new cell apparent at 1558 had been incorporated into the older cell by 1602.

The sequence of echo areas at the 20, 000-foot level (fig. 8b) reveals continual enlargement from first appearance at 1550 until 1602 CST. Rapid forward movement between 1558 and 1602 is attributable to the incorporation of the second new cell into the older echo between these two times.

The sequence of echo areas at the 10, 000-foot level helps to illustrate the rapid development of shear near this level between 1554 and 1558 CST (fig. '8c). Note how the echo area at 1558 CST has moved rapidly to the ESE from its position at 1554 CST. The two new cells which developed and joined the original cell (echo) formed considerably above this level. The second new echo was an integral part of the echo at this level at 1602 CST.

The pertinent aspects of the hailstorm echo in its development stages were: 1) the "first" echo development at unusually high levels, 2) the extremely diverse cellular structure, and 3) the extreme shear at the 12,000-foot level.

During the period of the hailstorm development and duration there were no step 1 (maximum radar sensitivity) data obtained for the CPS-9 PPI. However, the echo portrayals on step 2 (reduced gain) were available and these were analyzed (fig. 9). The first such detection of the storm echo came at 1549 CST with detection of a small, 4-square-mile echo. As shown on figure 9, the echo moved from NNW, which is in agreement with the wind directions at all upper levels. The echo was also enlarging rapidly between 1551 CST and 1555 CST. Its forward motion in the development stage (1551 to 1601 CST) was at a speed of 54 mph.

After 1601 CST, the forward speed of the PPI echo diminished to less than 25 mph and continued thusly until the step 2 echo dissipated by 1619 CST. The PPI echo size remained approximately the same from 1555 until 1609 CST. Thereafter, the echo size began to decrease slowly until 1611 when it rapidly became smaller. The rainfall data, which is discussed later, reveals that the hailstorm rain cell persisted after 1619 CST, but by 1615 other rain moved between the radar station and the hailstorm echo causing echo attenuation thereafter. During the period of rapid movement and enlargement, which lasted from 1549 until about 1601 CST, the echo movement was from 330° (NNW). However, as s hown on figure 8d, after 1607 the echo movement was from the north. Movement of the echo from the north was not a result of steerage by any upper level wind since the winds at all levels were either from the NW or NNW. Convective storms developing in a warm air environment, such as this August 8 storm, usually travel in the direction of the winds at some middle level while the storm is young and developing. However, as Newton (6) and Browning (1) have noted, intensive convective storms can and will move to the right of winds in the mid-troposphere.

Direction of echo movement from the TPS-10 data was more difficult to determine because of the shorter period of available data. The centroids of the echo portrayals at three levels were plotted to obtain a measure of the RHI-echo movement (fig. 8d). Although the echo areas (fig. 8a-c) at the three levels differed considerably in shape and size, their direction of movement was much the same. The direction of movement of the upper-level echo areas was in agreement with that of the surface echo (CPS-9), although at any given time the centroids of the upper level echoes were in more easterly locations. The great echo shear at 12, 000 feet with precipitation at the surface located 1 to 3 miles west of its horizontal location at 12, 000 feet accounts for much of this displacement. Examination of the time sequence of TPS-10 echo models (figs. 5-7) reveals the great amount of change that was occurring in the storm cells at all levels. The RHI data revealed that during the storm formation two major cells formed ahead (to the ESE) and in line with the direction of movement of the original cell. These new cells, rather than any basic change in the wind fields at the variou|s levels, were largely responsible for certain observed unusual changes up to 1601 CST in echo speed and direction of movement revealed by the data from both radar sets.

RAINFALL RELATIONSHIPS

The 49 recording raingages of the Water Survey located in the storm area furnished excellent portrayals of the rainfall patterns associated with the hailstorm. In figure 4 the total rainfall amounts produced by the hailstorm are shown for the individual raingages in the storm area. Using the rainfall amounts for 5-minute intervals, rainfall maps were plotted (fig. 10). These 5-minute maps furnish useful detailed information about the behavior of the storm. Such information could not be as accurately portrayed by the CPS-9 data because of radar signal attenuation and the lack of maximum sensitivity data.

The rainfall maps revealed that rain from the hailstorm was first detected at 1556 CST at gage 17 (fig. 4), which is in the north-central portion of the network. In the first five minutes of rainfall, 0.4 inch fell at gage 25 (fig. 10b), and this amount is a once in five year, 5-minute frequency amount. Several excessive rainfall amounts for durations of 5 to 30 minutes were produced by this storm, and these will be discussed later in this section of the report.

The rainfall core (0.4-inch area 5 minutes) moved rapidly from the north until 1610 CST (fig. 11), and was also enlarging during this 15=minute period. After 1610, the core began to move more slowly (20 mph), and to move from the NNE. The core became stationary at gage 39, producing 1.05 inches in the 10-minute period ending at 1630 (a once in 30-year point event). Gage 39 is located where wind damages were produced by the storm. The rainfall core exhibited the same general tendencies for motion shown by the PPI echo (fig. 9). However, the time-space comparisons of the positions of the echo (fig. 9) and rainfall core (fig. 11) reveal that the westerly portion of the rainfall core was not being detected by the radar signal, probably due to signal attenuation.

The rainfall from the hail-producing storm continued until the storm passed from the southern edge of the network at 1640 CST. The heavy rainfall rates ended by 1630 CST. The maximum 5-minute rainfall rates in the 1630-1640 period were 0. 2 inch.

There was a close relationship between the hailfall and the rainfall from this thunderstorm. The hail began within 5 minutes after the heavy rainfall rates began, and the hail cessated 5 minutes before the heavy rainfall terminated. The hail fell from the western half of the rainfall core (fig. 10b-g), and at any given instant the hail cell was about one-half the size of the rainfall c ore (0.4-inch area). The direction and speed of movement of the rainfall core was apparently closely aligned with the movement of the hail cell. The tendency for the hail to fall to the "right" (in relation to direction of movement) of the rainfall core has been noted in other Illinois hailstorms moving from westerly and southwesterly directions (2, 3, 4). The location where the speed of the rainfall core was reduced was associated with the area of increased crop damage from the hail and the occurrence of wind damages.

The rainfall rates produced by this storm were excessive. Seven network raingages recorded 5, 10, 15, and 30-minute rates in excess of the 2-year frequency values for these durations. For 5-minute durations, heavier measured amounts ranged from 0. 32 inch (2-year value) to 0. 61 inch (25-year value). For 10-minute durations, large amounts ranged from 0. 55 inch (6-year value) to 1.05 inches (30-year value). For 15-minute durations, amounts ranged from 0.6 inch (2-year value) to 1.25 inches (25-year value). Five raingages had 2-year or greater values (0.9 inch)for 30 minutes. The average point duration of the rainfall during the 1556-1630 CST period (based on 10 network gages) was 17 minutes.

CROP LOSS FINDINGS

The adjusted crop losses produced by the hailfall were analyzed using the adjustor's actual loss percentage values listed on the work sheets for all locations in the storm area. Several member companies had sold coverage in the storm area, and the adjusted losses resulting from hail damage furnished considerable areal detail on the degree and variability of crop loss produced by this storm. A total of 91 point measurements of loss percentages to corn were available in the area, and a total of 75 measurements of losses to soybeans were available. These points of measured loss are shown in figures 12 and 13, The assistance of the insurance companies in furnishing these data is gratefully acknowledged.

Since the degree of loss suffered by corn crops differed from that of the soybean crops, the losses of these two crops were analyzed separately, evaluated, and compared. In general, when corn and soybean crops were in adjacent fields, the soybeans suffered greater losses than did the nearby corn plants. This factor of greater loss to soybeans at a point was most apparent in the area where both crops suffered their heavier losses. In this general area of maximum damage, the difference in loss at nearby locations was a ratio of about 1. 5 to 1. That is, the soybeans suffered about 50 percent greater loss than did a nearby corn crop. The maximum percentage loss measured for soybeans was 16. 8 percent as compared with a nearby maximum loss of 11.2 percent for corn. In the area where losses to both crops fell below the 4 percent level, there was no discernible difference in their loss percentages. However, comparison of figures 12 and 13 reveals that there were two low percentage areas of dissimilarity in the crop losses. In the area about one mile north of Weldon, low soybean losses occurred where no corn losses were reported. Conversely, in an area about two miles west of Weldon, 2-to 6-percent losses to corn were reported where there were no soybean losses. These regional discrepancies may result from inadequate point sampling (lack of insurance or crop types) in these two areas.

The areas enclosed by the 2-percent lines on figures 12 and 13 correspond well, in both size and shape, with the area of damage (fig. 4) which was determined by the relatively rapid visual inspection performed by the field survey team. The location of the maximum hailstone sizes ascertained by the field survey was at point B on figure 4, and this point is located at the center of the 10-percent corn loss area (fig. 12) and at the eastern edge of the 14-percent loss area to soybeans (fig. 13). The area of maximum stone sizes was identical with the one of maximum losses.

Several other interesting facts can be derived by comparing figures 4 with figures 12 and 13. The somewhat narrow southward extension of losses, ranging from 2 to 4 percent to corn crops and from 2 to 6 percent to soybeans, is in the area (one to two miles southwest of Weldon) where minor wind damages to trees and buildings had been noted (fig. 4). Although hailstone sizes were much smaller in this area south of Weldon, the greater wind speeds acted to produce crop damages from the smaller hailstones.

Inspection of the isopercentile patterns displayed on figures 12 and 13 reveals that, in general, the patterns had similar shapes and sizes. Considerable areal variability in losses is also a notable aspect of both patterns. In Table 1 the amount of area in each 2-percent loss increment is shown. The area of soybean losses was almost one square mile greater than the area of corn loss as shown by the cumulative values for 2 percent or greater. The primary differences in areal extent of losses is based upon the fact that corn did not experience any areal losses in the 12 percent and greater categories. No significant differences exist between areas of corn and soybean loss in the increments between 2 and 12 percent. The total area of hailfall shown on figure 4 was 17. 4 square miles. Thus almost one-half of the area of hailfall had soybean losses of 2 percent or more and about 43 percent of the area had measureable corn losses.

SUMMARY

The detailed investigation of this relatively small size summer hailstorm in Illinois revealed several new and interesting facts plus the existence of several conditions measured in previous studies of hailstorms.

There were two features of this storm which were quite interesting and unusual. Of great interest was the fact that damaging hail, although not excessive, was produced by an apparently typical air mass summer thunderstorm.

TABLE 1

Amount of Area Experiencing Different Degrees of Crop Loss

Loss Percentage Intervals	Area, Square Soybeans	Miles Corn	Loss Percentage Group	Area, Square Soybeans	Miles Corn
2-4%	2.7	3.1	2%	8.3	7.5
4-6%	2.0	.1.6	4%	5.6	4.4
6-8%	1.2	1.4	6%	3. 6	2.8
8-10%	0.8	0.5	8%	2.4	1.4
10-12%	0.8	0.9	10%	1.6	0.9
12-14%	0.5	0	12%	0.8	0
14-16%	0.2	0	14%	0.3	0
16%	0.1	0	16%	0.1	0

Such thunderstorms frequently do not even produce hail (7), and only infrequently do they produce damaging hail. The development of hail in this air mass thunderstorm and others on August 8 was related to three factors. Most important of these was the localized presence of a high amount of atmospheric moisture which had been largely produced by evaporation of antecedent rains on August 6, 7, and 8. The afternoon development of low-level high speed winds which produced shear in the storms greatly aided the convective processes, and the presence of a decaying warm front produced further instability in the area of moisture and shear.

The second unusual feature connected with this particular hailstorm was the extremely high level of first echo detection (above 28, 000 feet). First echoes of air mass summer thunderstorms normally occur at much lower levels (10,00-20, 000 feet). The high level of formation reflects the presence of very strong updrafts in the cloud and the fact that the initial echo was largely composed of ice particles.

Since this storm occurred during the mature stages of growth of the local corn and soybean crops, crop damages were produced, and excellent widespread measurements of losses were available. The area of crop damages was about 50 percent of the size of the total area where hail fell. The maximum adjusted losses to crops were 16.8 percent for soybeans and 11.2 percent for corn. In adjacent fields, percentage losses to soybeans were 50 percent greater than those to corn, and the area of soybean losses was 12 percent larger than that for corn. The greatest percentage losses to crops occurred in the area where hailstones were largest although damage did occur in one area where smaller stones but higher surface winds occurred.

The hail swath was generally an oblate shape, a shape which has been noted in other hailstorm studies. Certain other characteristics relating to the hail cell, such as the total and average point durations, speed of movement, and angle of stone fall in relation to storm direction, where similar to those found with another air mass hailstorm studied in detail in 1962.

Several other interesting findings concerning this storm were obtained from detailed regional rainfall data afforded by the dense raingage network. This hailstorm produced very excessive rainfall amounts for short durations with one once-in-30-year value for a 10-minute period (1.05 inches). Previous hailstorm studies had also revealed that heavy rains usually fell in the hail area, but the data available for this storm allowed a detailed and informative tracing of the storm's rainfall pattern and rain cell at the surface. The hail fell from the "right side" of the rainfall core, and this study further revealed a close association between the beginning and ending times of the heavy rain and hailfall.

The detailed PPI and RHI radar data collected for this storm revealed certain interesting facts. In addition to the high level of echo formation, the storm was found to be extremely complex and cellular with growth partially due to the propagation of new cells downwind from the main storm cell. In the developmental stage the radar-depicted cell moved with the upper level winds, but as the storm began to produce hail and heavy rain at the surface, the mature cell moved 30 degrees to the right of any possible steering wind. This hailstorm and others on August 8 moved from the north and northwest, and such directions of movement are quite infrequent in Illinois. An increase in crop damage from the hail was found to be related to a reduction in echo speed. As noted previously, the RHI data also revealed the presence of wind shear in the storm echo.

This study has furnished new and supplementary knowledge to complement that knowledge gain in previous detailed field studies of Illinois hailstorms. This latest study has shown that future detailed hailstorm studies will be more sucessful and meaningful if RHI radar data and rainfall data from dense networks of raingages and available.

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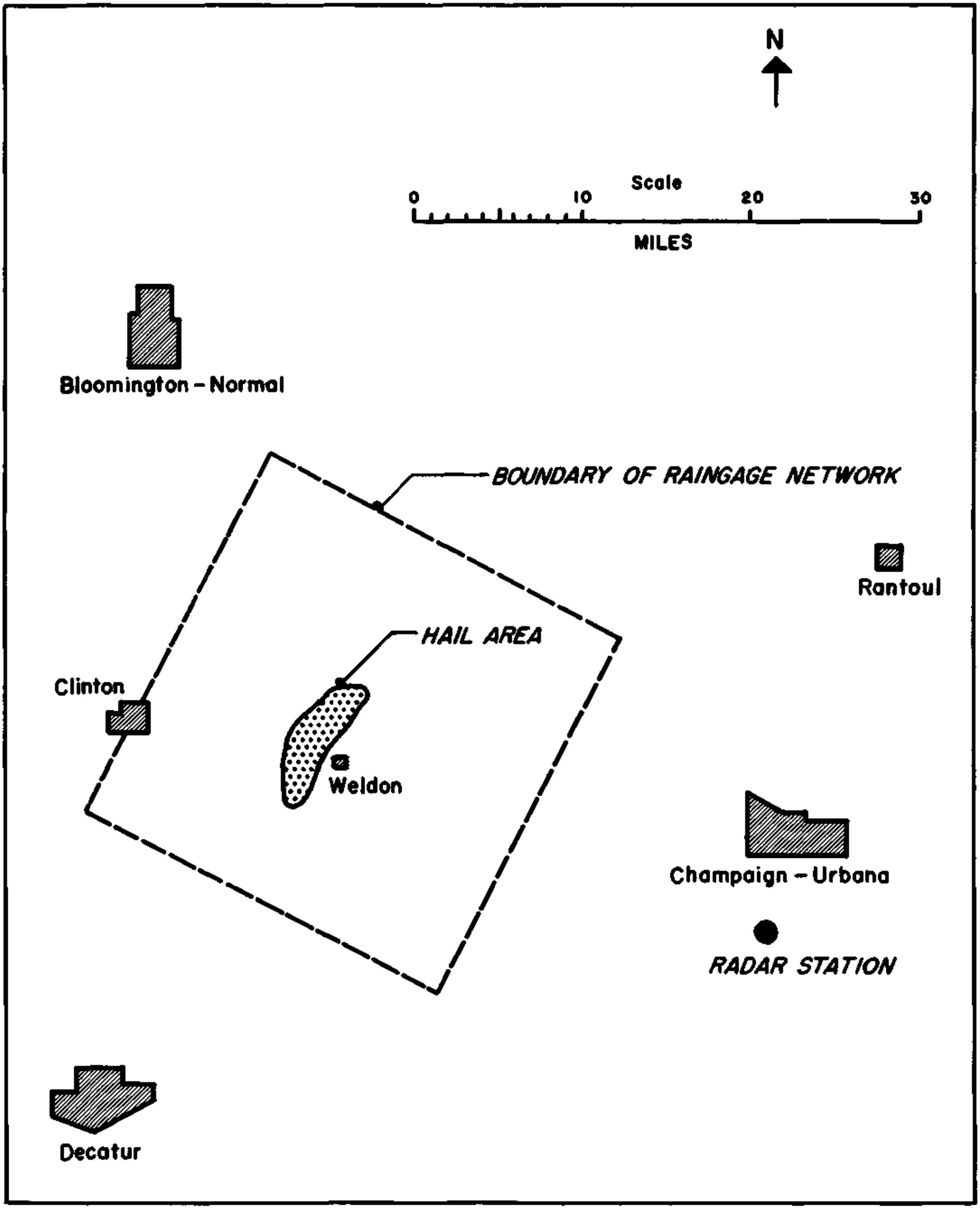


FIG.1 LOCATION MAP

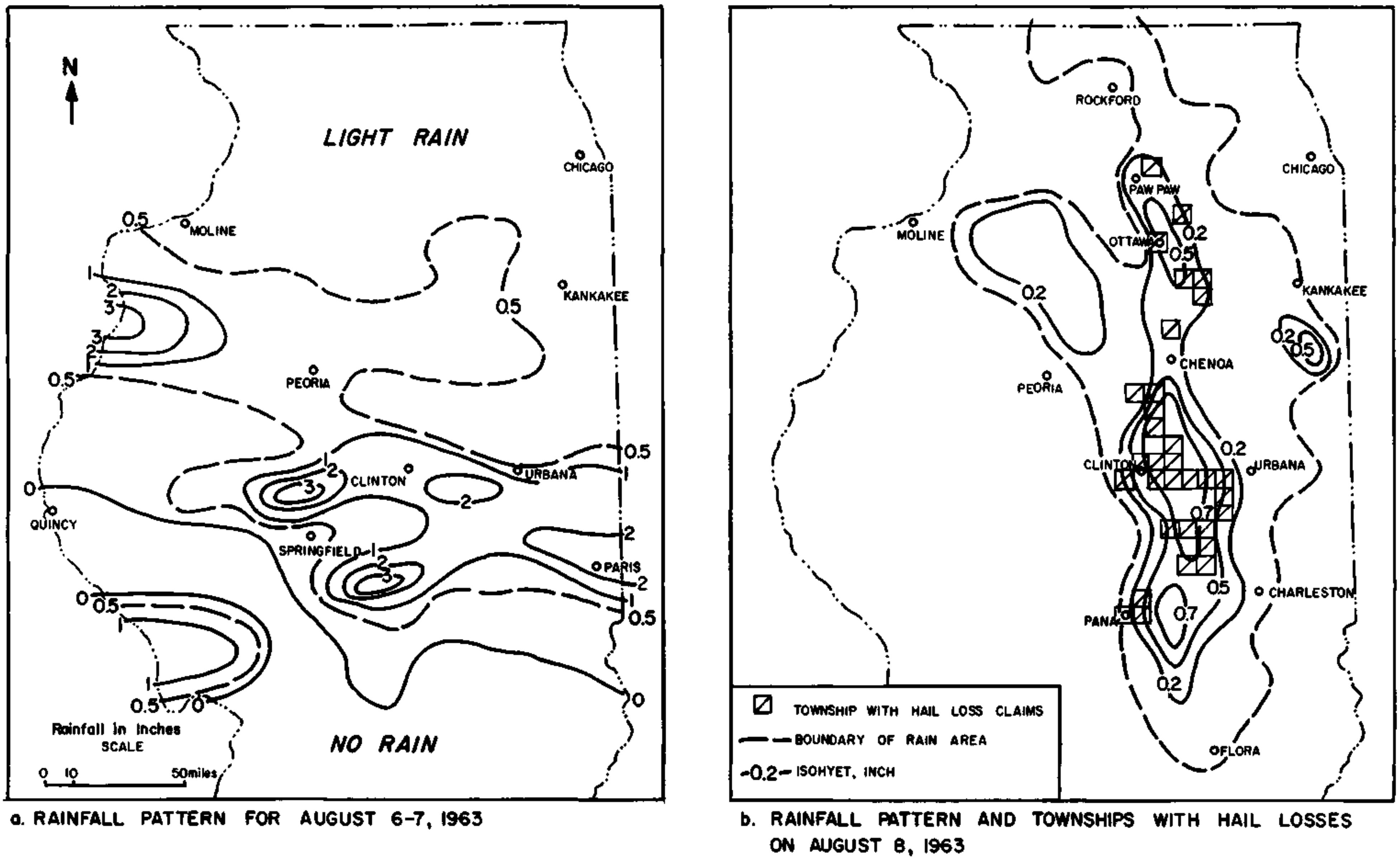


FIG. 2 RAINFALL ON AUGUST 6-7 AND 8, 1963 AND HAIL LOSSES ON AUGUST 8, 1963

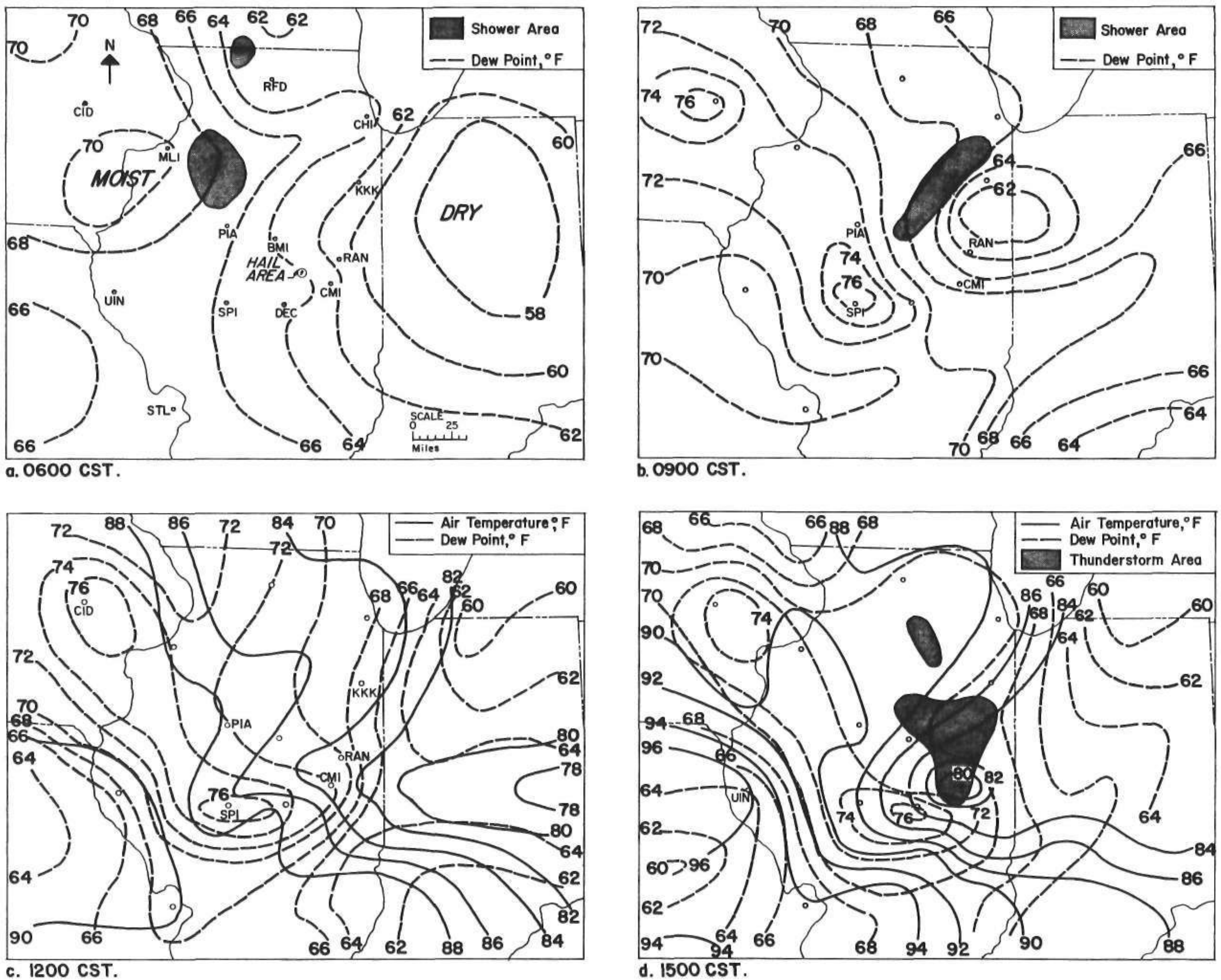


FIG. 3 SELECTED HOURLY SURFACE WEATHER CONDITIONS ON AUGUST 8,1963.

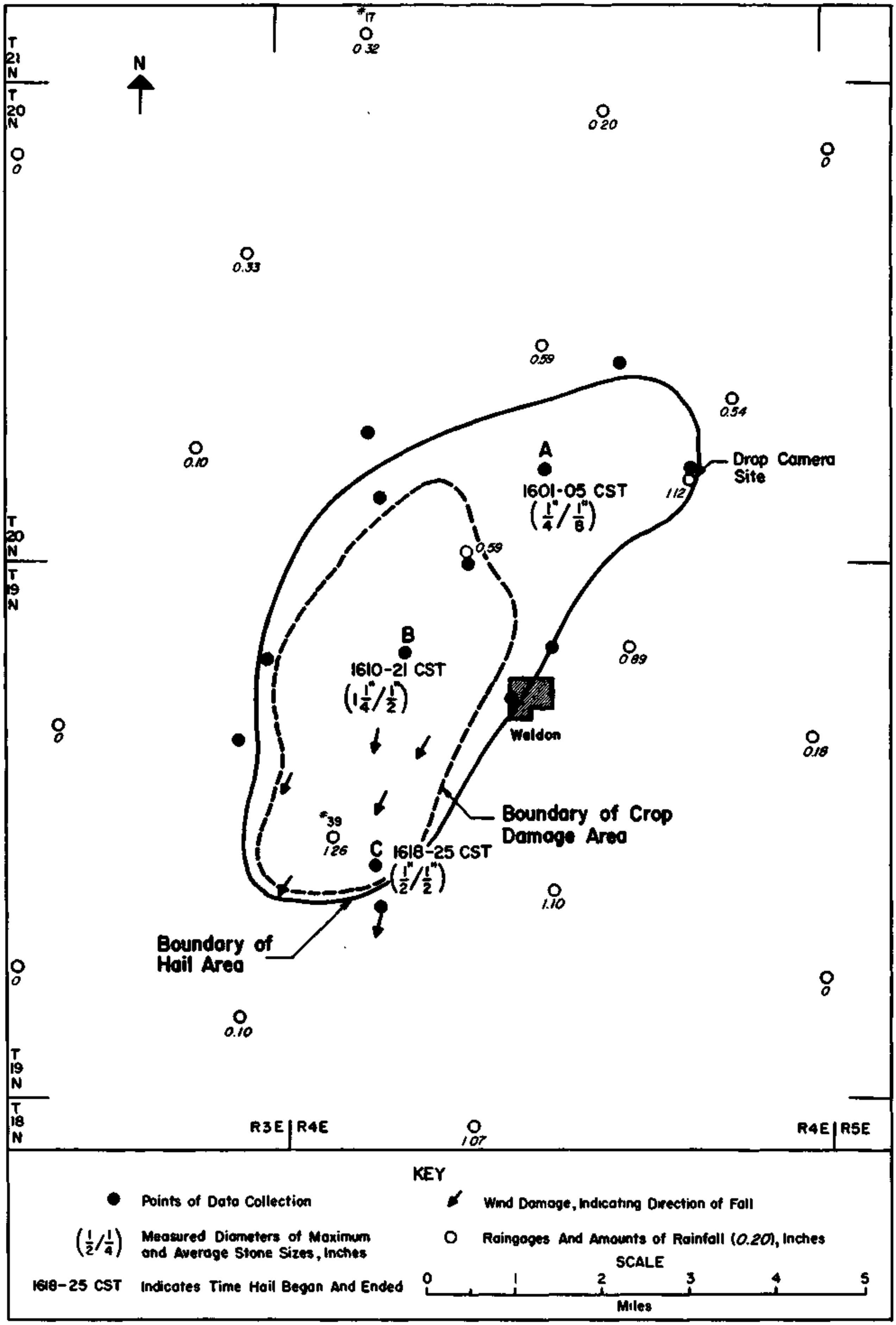


FIG.4 MAP OF HAIL AREA WITH ASSOCIATED RAINFALL,WIND DAMAGES, AND CROP DAMAGE AREA INDICATED

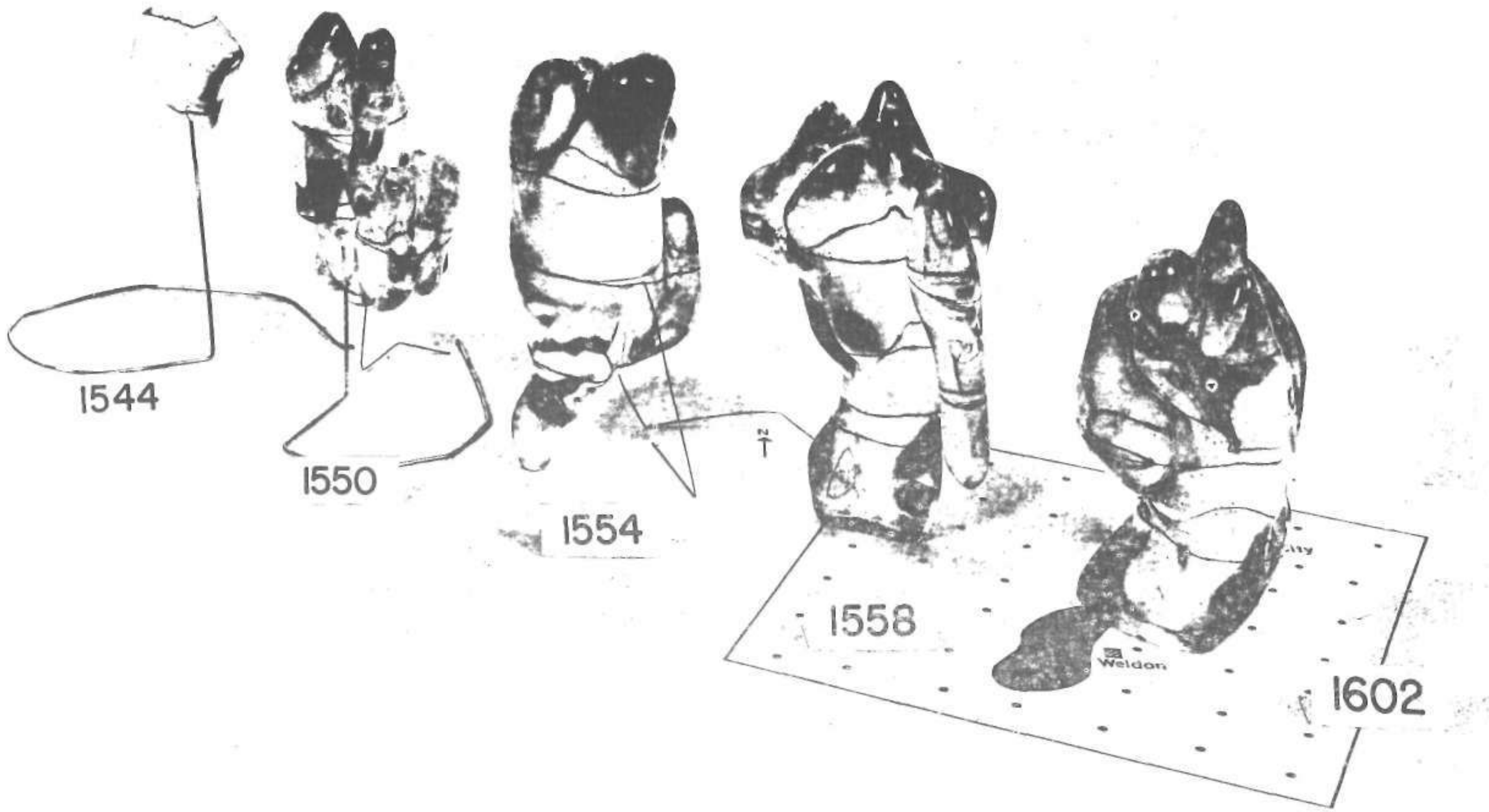


FIG. 5 THREE-DIMENSIONAL MODELS OF THE RHI-RADAR ECHOES SHOWING THE DEVELOPMENT OF HAILSTORM ON AUGUST 8, 1963. The Echo Numerical Labels Represent Time, And The Echo At 1602 CST Is Located On The Raingage Network Map in Its Correct Position. Because Of Positional Overlap Between Echoes, The Other Four Echo Portrayals At Earlier Times Were Not Placed In Their Correct Geographical Locations. The Black Lines Circumscribing The Models Are For 10,20,30, And 40 Thousand - Foot Elevations Above The Ground.

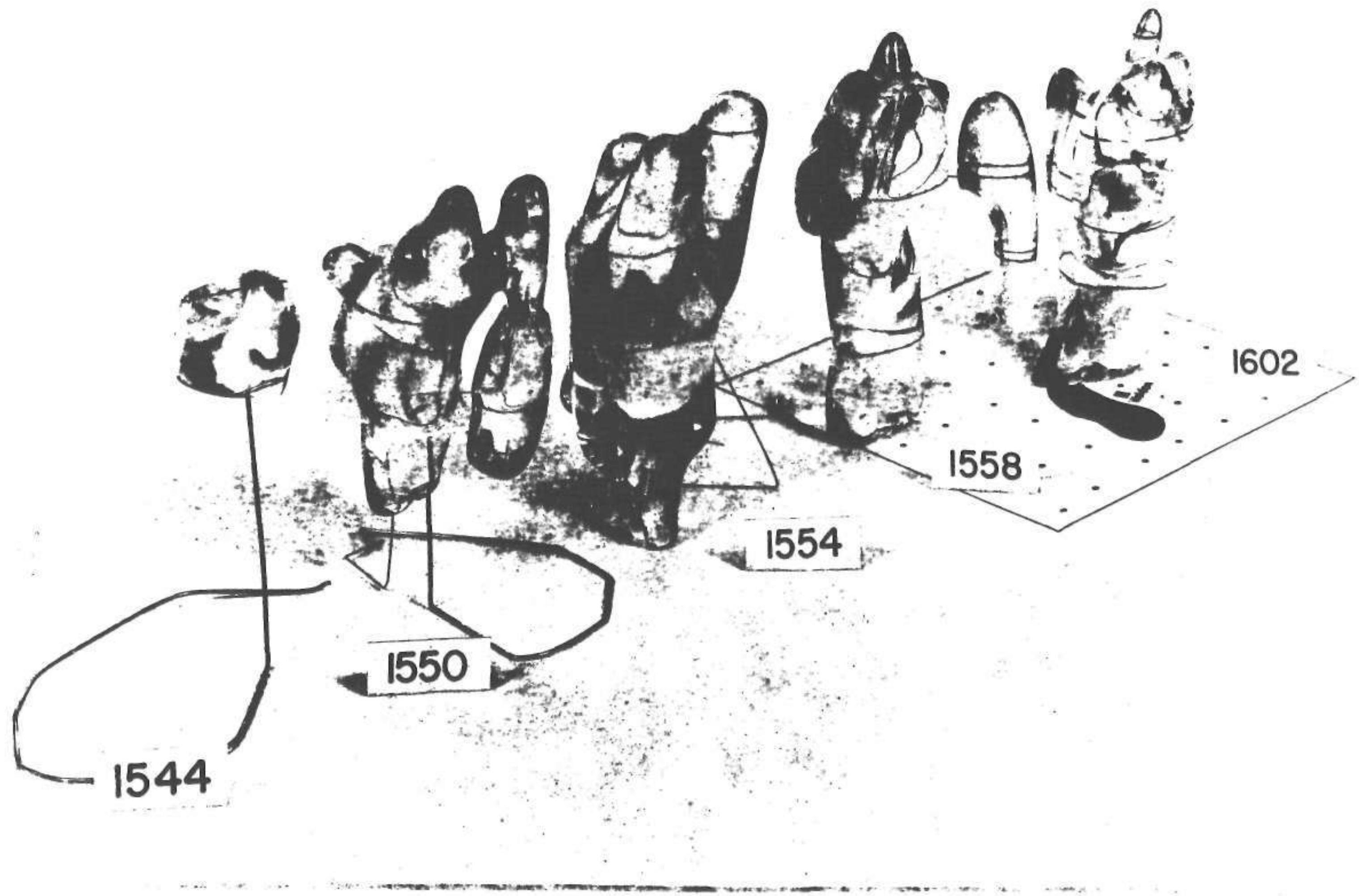


FIG.6 A VIEW OF THE STORM MODELS FROM A SOUTHWESTERLY POSITION REVEALS THE SEPARATION BETWEEN THE NEWLY-FORMING CELLS AND THE MAIN CELL AT 1550 C AND AT 1558 C.

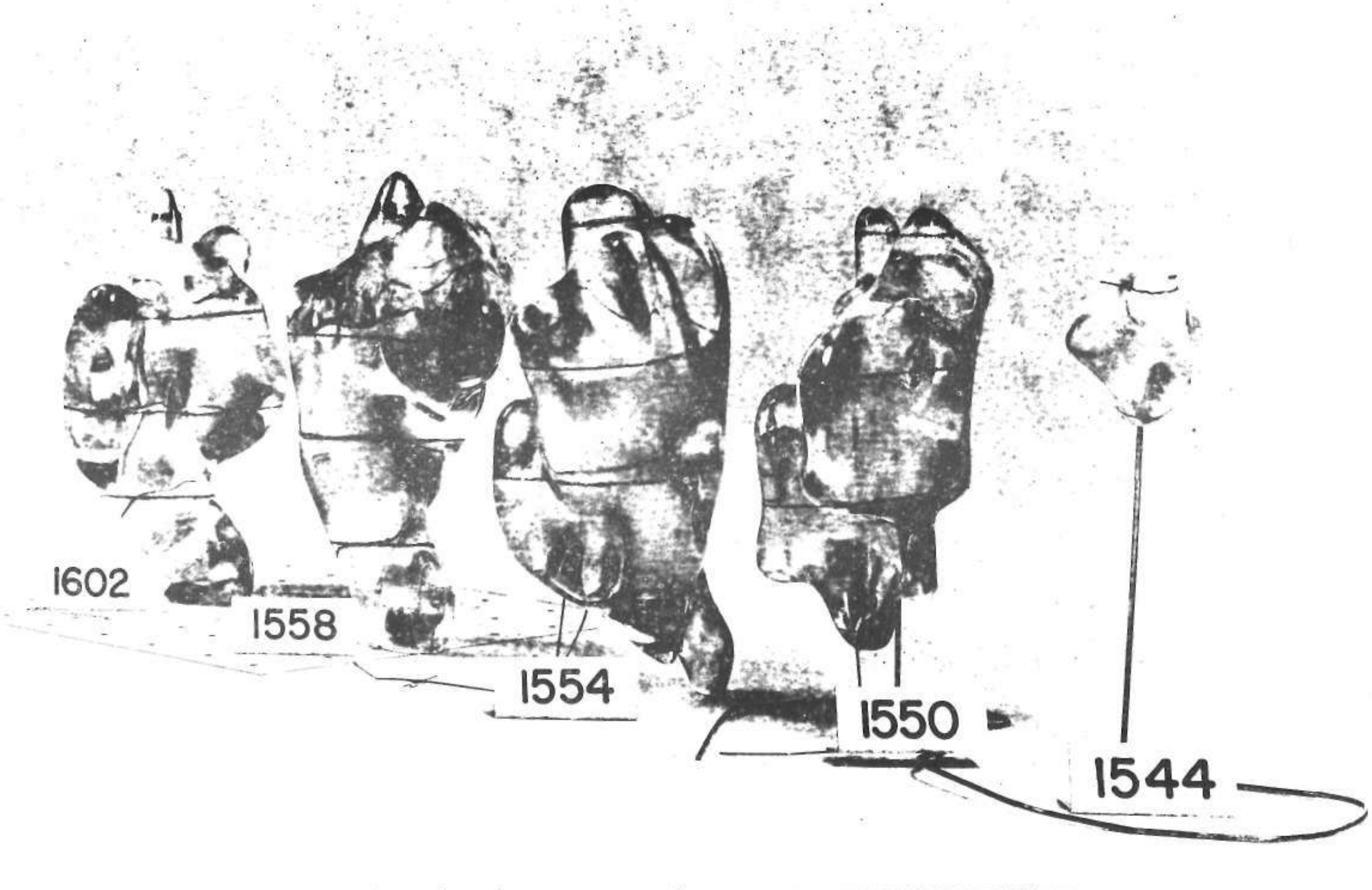
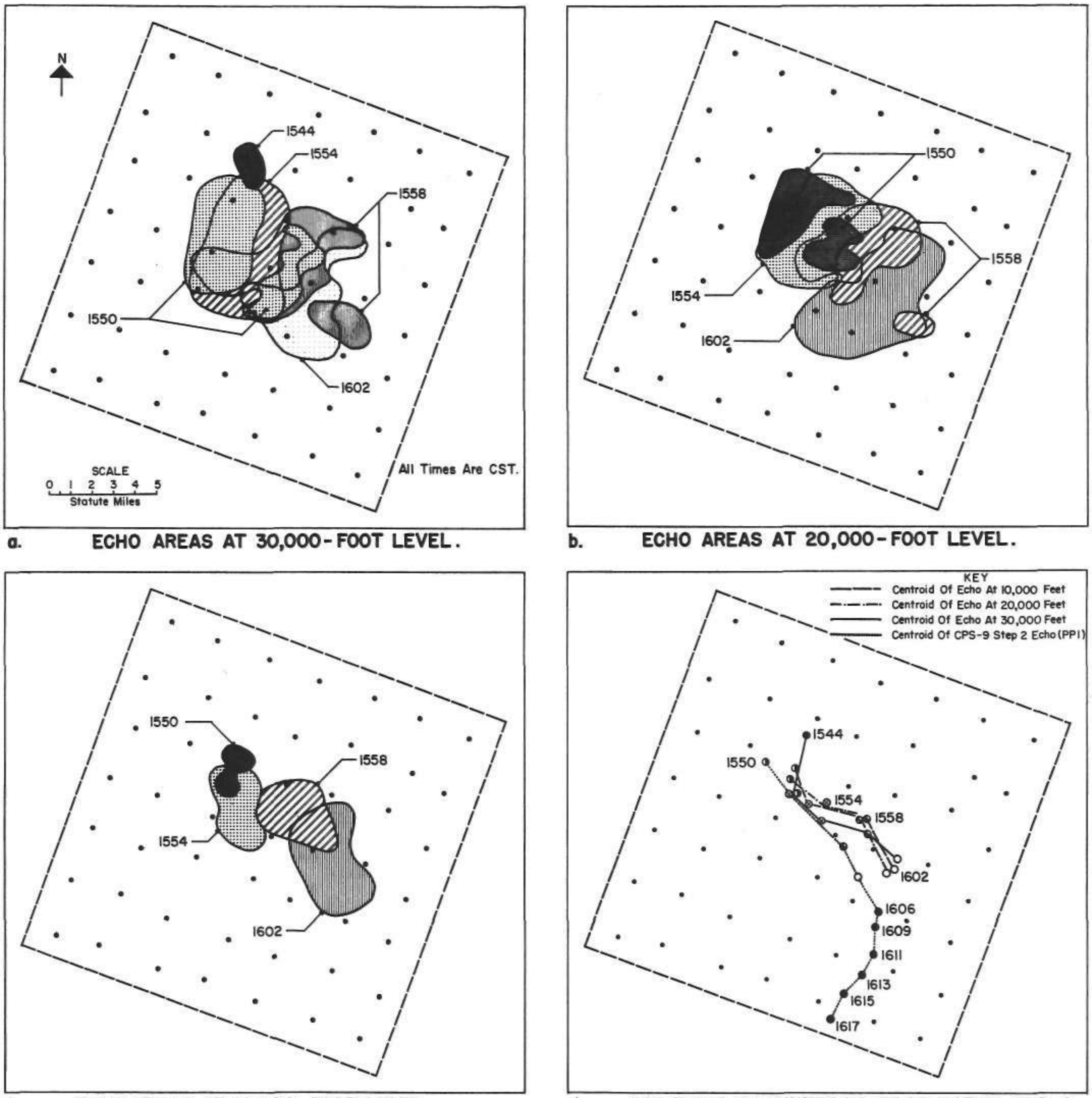


FIG.7 A LOWER ANGLE VIEW OF THE STORM MODELS FROM A NORTHERLY POSITION REVEALS THE DEVELOPMENT OF SHEAR AT 12,000 FEET ON THE 1554 C ECHO. Note The Increasing Amount Of Shear In The Two Subsequent Echoes Models. The Descending Rain Shaft At 1550C Is Easily Viewed With The Rain Shaft At The Surface By 1554 C.



a. ECHO AREAS AT 30,000-FOOT LEVEL.

b. ECHO AREAS AT 20,000-FOOT LEVEL.

c. ECHO AREAS AT 10,000-FOOT LEVEL.

d. POSITIONS OF CENTROIDS OF SELECTED CPS-9 AND TPS-10 ECHO AREAS.

FIG. 8 SEQUENCES OF SELECTED ECHO AREAS AND ECHO CENTROIDS, AUGUST 8,1963.

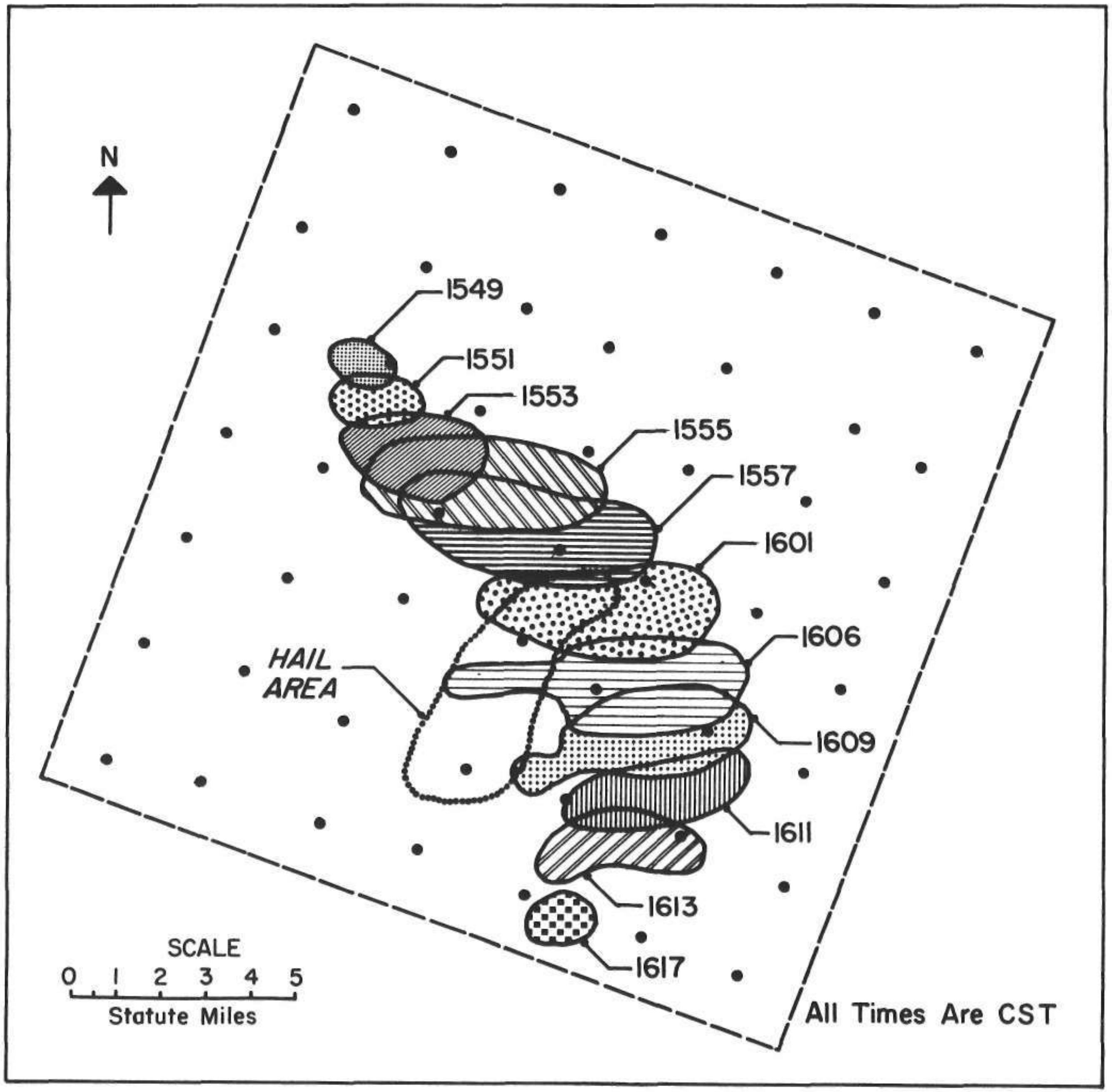


FIG. 9 SEQUENCE OF CPS-9 STEP 2 ECHOES ON AUGUST 8,1963.

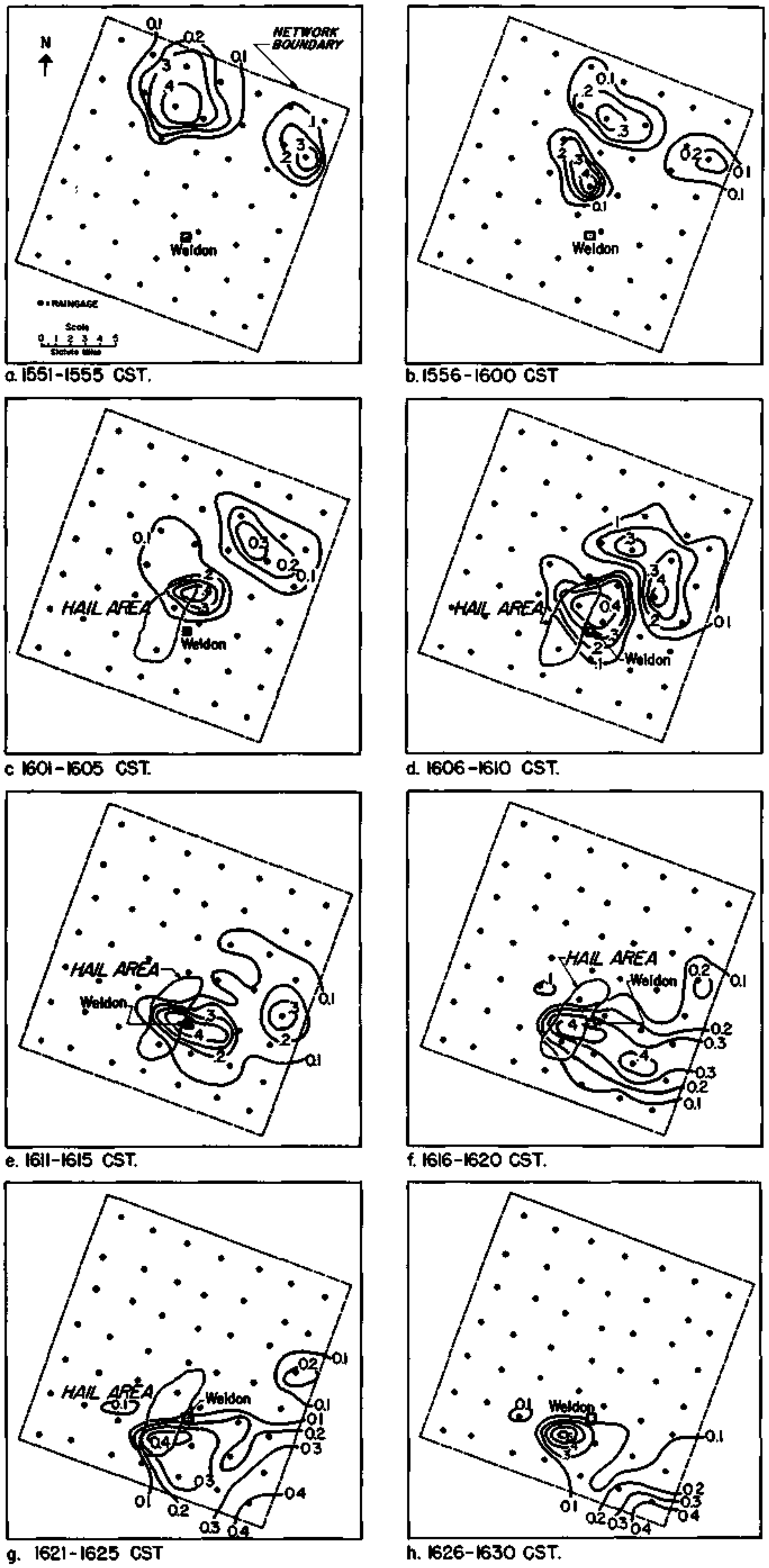


FIG. 10 ISOHYETAL MAPS OF 5-MINUTE AMOUNTS ON EAST CENTRAL ILLINOIS RAINGAGE NETWORK DURING 1551-1630 CST PERIOD ON AUGUST 8,1963.

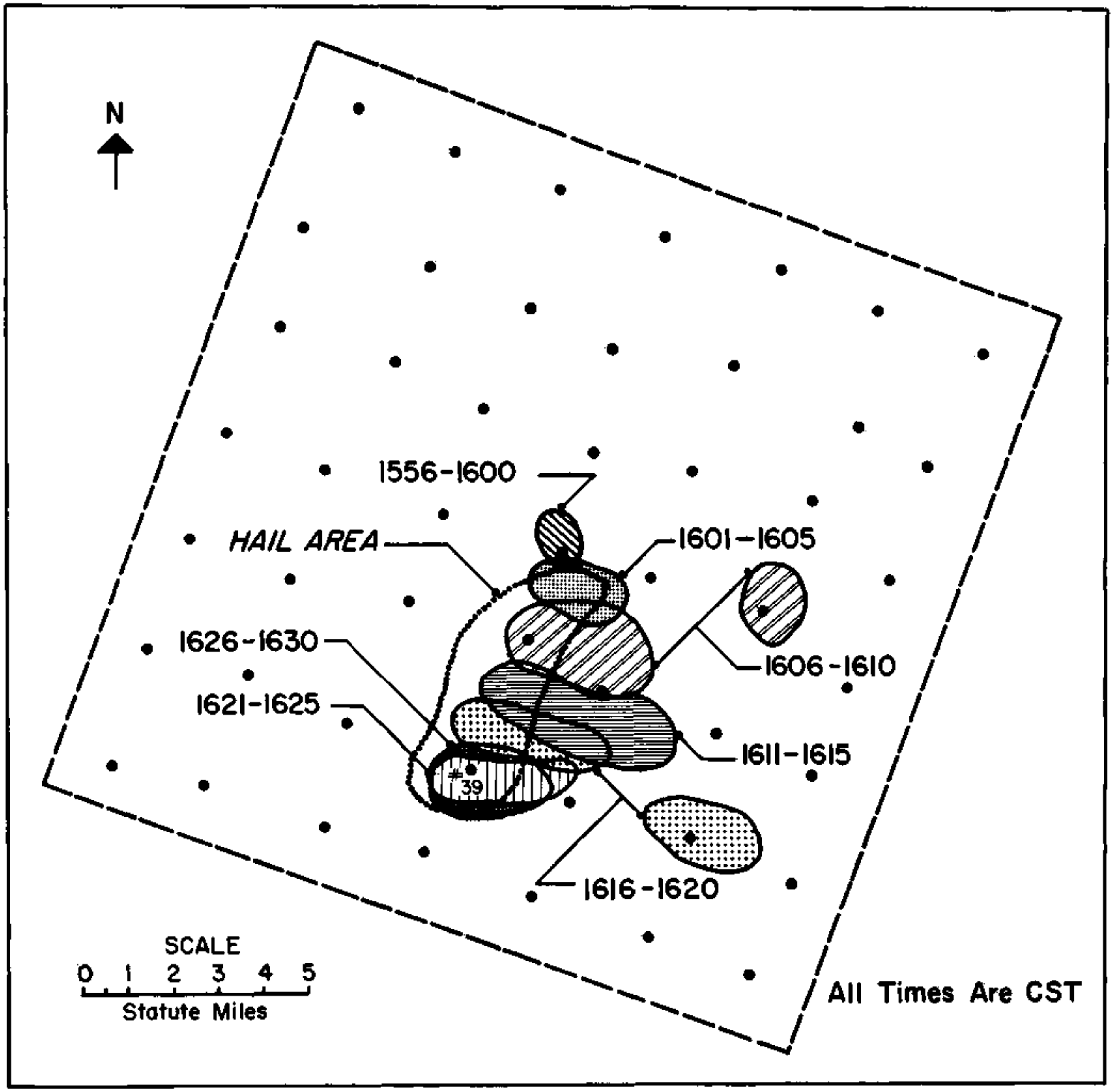


FIG. 11 SEQUENCE OF RAINFALL CORES (0.4-INCH AREAS) ON AUGUST 8,1963.

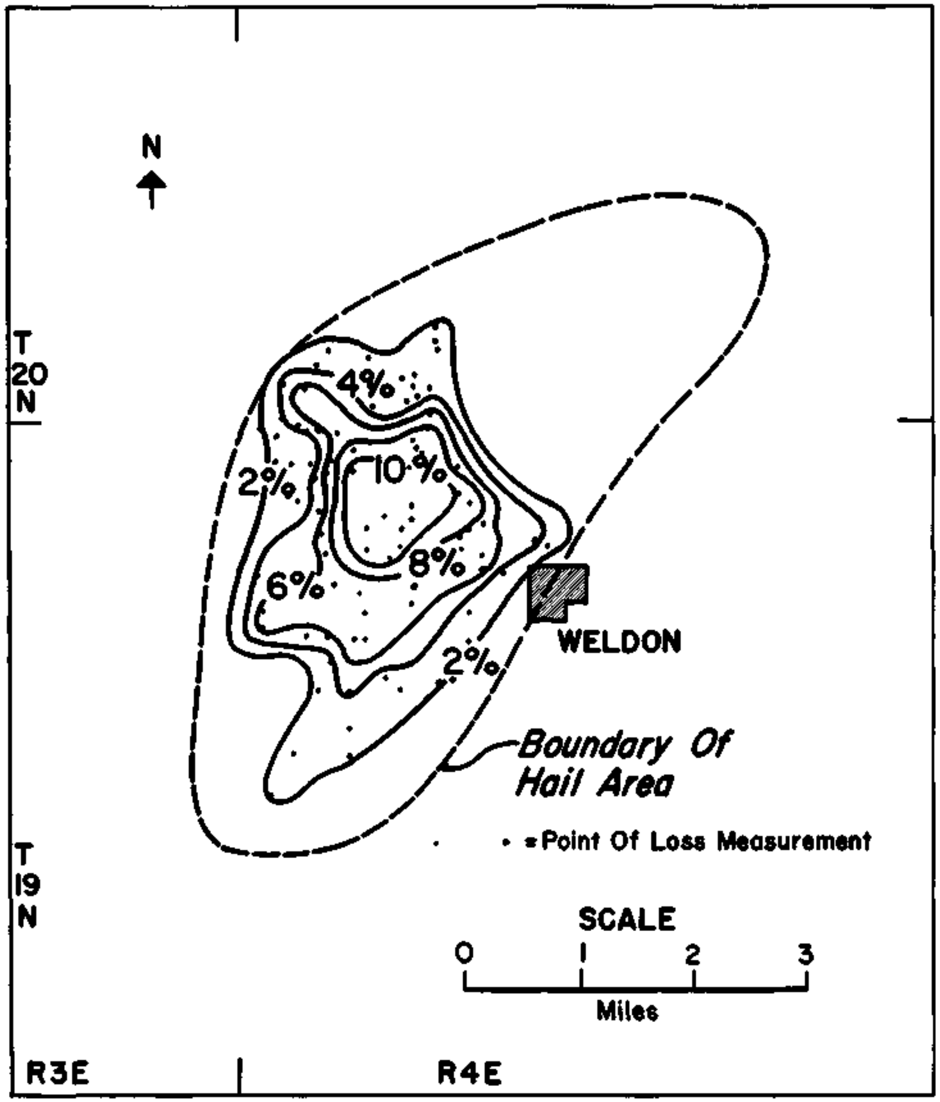


FIG. 12 ADJUSTED LOSSES TO INSURED CORN ACREAGE EXPRESSED AS PERCENT OF CROP VALUE,

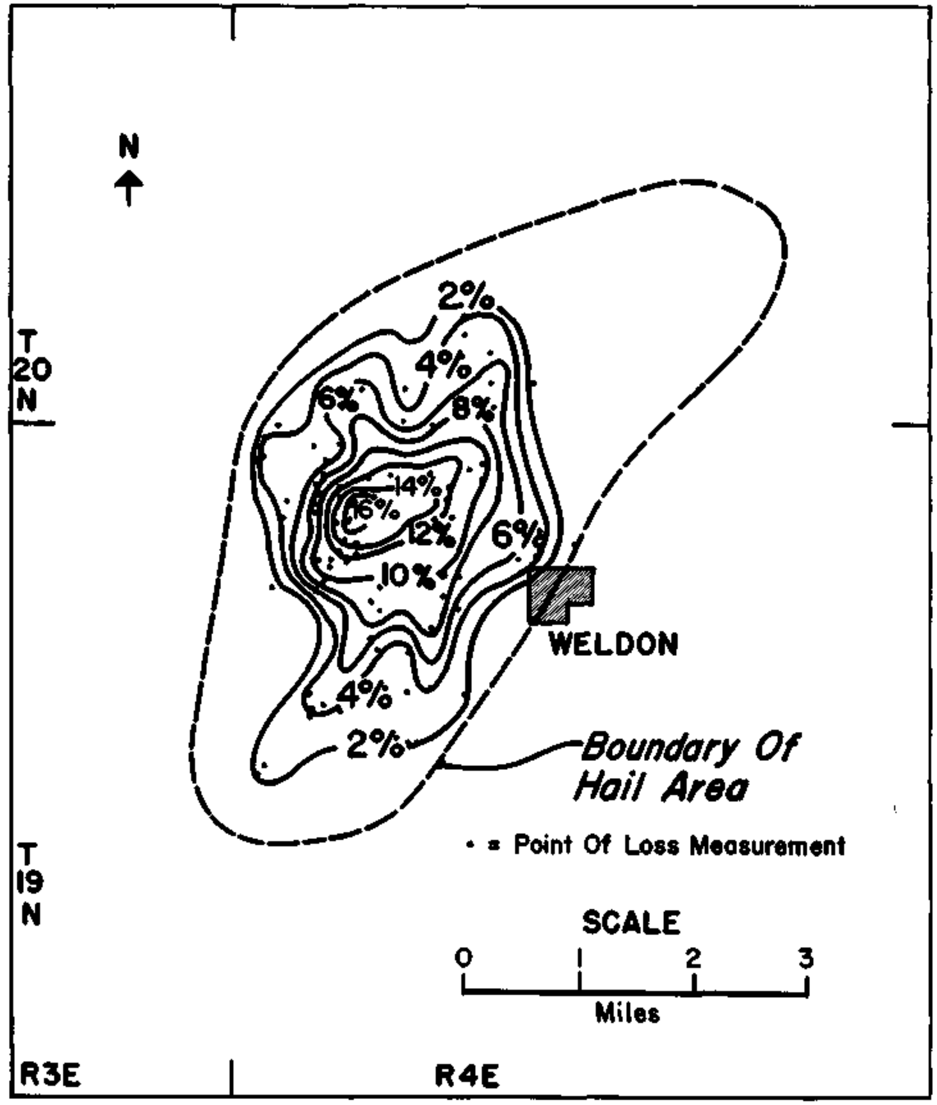


FIG. 13 ADJUSTED LOSSES TO INSURED SOY BEAN ACREAGE EXPRESSED AS PERCENT OF CROP VALUE.