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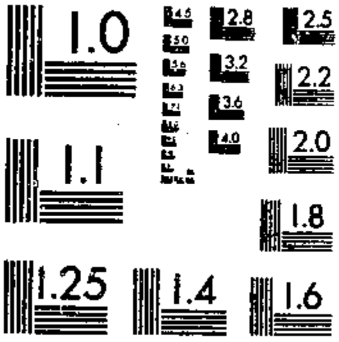

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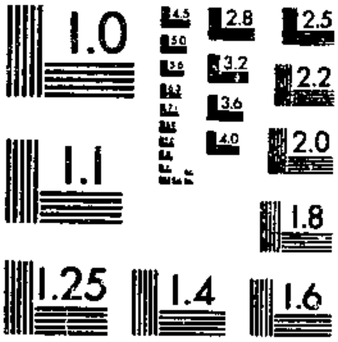

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By

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and

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United States Department of Agriculture, Washington, D. C.

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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

PRINCIPLES OF GULLY EROSION IN THE PIEDMONT OF SOUTH CAROLINA[1]

By H. A. Ireland, C. F. S. Sharpe, and D. H. Eargle, *associate soil conservationists, Section of Climatic and Physiographic Research, Division of Research, Soil Conservation Service*[2]

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[1] Submitted for publication May 13, 1938.

[2] The authors are indebted to C. O. Sauer for aid in initiating the program of research; to the South Carolina Agricultural Experiment Station at Clemson College, which cooperated in the work; to T. S. Buie, regional conservator of Region 2 of the Soil Conservation Service; to Ernest Carnes, State coordinator; and to S. L. Jeffords, project manager of the South Tyger River demonstration; and their staffs. Most of the gully maps used in this report were prepared by the drafting room of Region 2 under the direction of F. M. Orsini. Brice Latham of the South Tyger River project aided greatly by furnishing crop statistics and information about the local project area.

INTRODUCTION

Natural or geologic erosion of the land is one of the fundamental processes of nature and has long been studied by geologists. The accelerated erosion of our soils by sheet wash and gullying is an unnatural form of erosion and is most active on agricultural lands. Within the last few years much has been done to check this form of erosion and to heal the denuded spots and gullied areas on our farms. Engineers, agronomists, and foresters have studied individual gullies and have devised ways of checking their growth. Soil conservationists engaged in operations work, however, have had little time or opportunity for prolonged study of gullied areas. Their conclusions regarding the vital processes at work have usually been drawn from casual observation or brief study. Their examination of the gullies has in most places been followed quickly by initiation of protective measures which materially change the form and activity of the gully.

Recognition of the close relationship between accelerated soil erosion and the natural erosion of the lands led the Soil Conservation Service to institute a program in which geologic methods were used in the investigation of the soil-erosion processes. This bulletin presents the results of detailed study of the principles of gully erosion in the Piedmont of South Carolina, approached from the geological point of view, or more specifically from the viewpoint of physiography, that phase of geology which deals with the form and sculpturing of the land's surface. Detailed geologic studies covering a considerable period in the life of a gully are a new field in soil conservation research and should provide valuable information for use in controlling gully erosion.

The southern Piedmont was selected for this detailed study because it is an area in which gullying has been particularly destructive, and as conditions of climate, soil, and land use there are relatively uniform over a large area in several States, the findings of the work would have wide application. Reconnaissance studies of gullying, sheet erosion, and mass movement were started early in June 1936 under the direction of C. O. Sauer.[3] Conditions in Alabama, Georgia, and the Carolinas were examined and compared, and several areas in Spartanburg County, S. C., were selected for detailed study.

Spartanburg County is one of the northern tier of South Carolina counties and lies in the Piedmont upland province close against the foot of the Blue Ridge Mountains (fig. 1). The city of Spartanburg has long been the agricultural and industrial supply center of the area, and good highways radiate from it in all directions. It is the county seat, the headquarters of Region 2 and the State coordinator of the Soil Conservation Service and also of the South Tyger River demonstration project of the Soil Conservation Service.

The population of the county is approximately 116,000 persons, of whom one-fourth are Negroes. Spartanburg is the only large center, and the city population of about 30,000 is swelled considerably by

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[3] C. O. Sauer, head of the Department of Geography at the University of California and member of the land-use committee of the Science Advisory Board of the National Research Council, is a collaborator of the Soil Conservation Service and was in active service during the summer of 1936, advising and planning the field program of climatic and physiographic research.

that of satellite mill towns grouped close outside the city limits. Forty percent of the county population is on farms.

Intensive field work was carried on in the Spartanburg area during the summer and fall of 1936, and periodic observations of erosion conditions are being continued. The physiographic relationships and general geologic conditions at selected gully areas were observed and interpreted by H. A. Ireland, C. F. S. Sharpe, D. H. Eargle, and Glen Petrick. The rate and mechanics of erosion at all seasons and under various climatic conditions were studied, and periodically verified. Repeated measurements of gully erosion were made at established points, and the conditions were recorded by detailed maps, sections, photographs, and sketches. Oscar D. Price made most of the topographic surveys. Arthur Hall investigated and summarized the agricultural history of the county. J. C. Owen and Gragg Richards, of the Washington office, were members of the party for a few weeks and worked on topographic mapping and analysis of climatic data respectively.

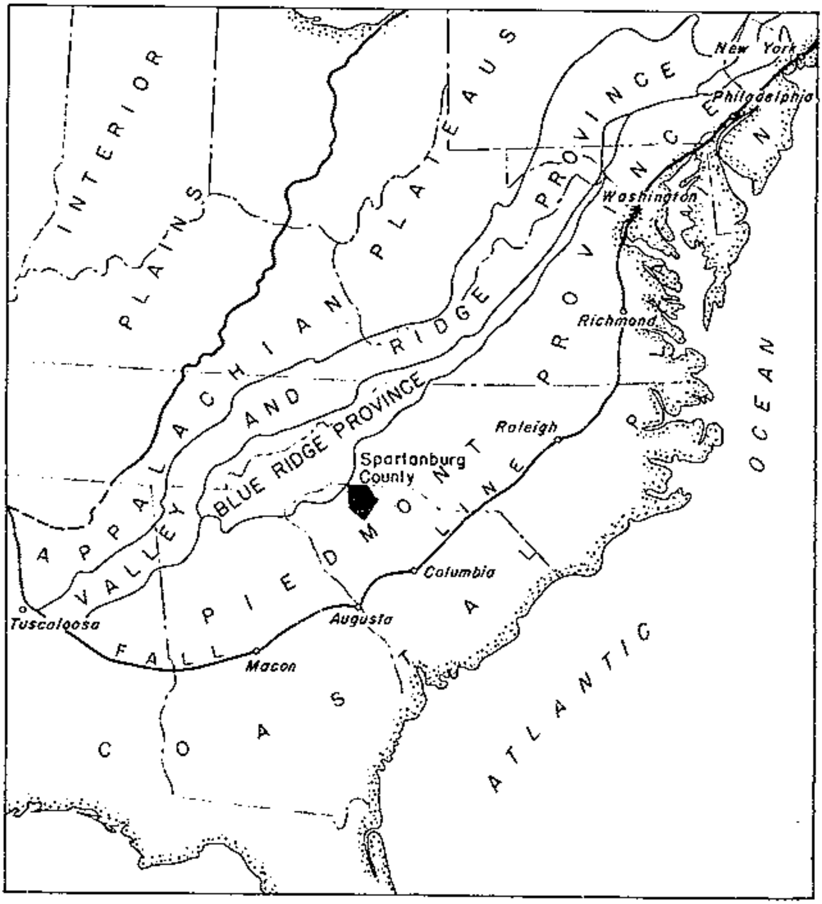

FIGURE 1.—Physiographic provinces of the southeastern United States, showing the Piedmont province, the Fall Line, and the position of Spartanburg County, S. C. (After N. M. Fenneman.)

CONDITIONS GOVERNING GULLY DEVELOPMENT

Even casual observation will show that the soil-erosion processes and their effects differ markedly in different parts of the country. Some agricultural areas have had to be abandoned because of dissection by gullying. Some have suffered soil depletion through sheet erosion. Other areas, however, have survived long periods of use with relatively little damage. These contrasts may be explained in part by certain obvious differences in conditions on the individual areas. Perhaps one is a region of rugged topography, and another is relatively flat. One may have been farmed in cotton and corn and another in small grains. Many of the factors affecting the erosion, however, are less obvious. The materials on which erosion works, the topography, the climatic influences, and the past land use all are important.

Erosion conditions in the southern Piedmont are particularly serious. Most of the area has lost some or all of its topsoil by sheet erosion, and many parts are cut by gullies 10 to 40 feet in depth. Much land that is submarginal for cultivation is being farmed, and badly washing fields, which should be returned to woodland, are still raising a meager crop. Why are conditions in the Piedmont so much worse than in the Coastal Plain to the southeast or in the mountainous country to the northwest? Why are the Piedmont gullies several times deeper than those of many other parts of the country?

This bulletin will consider various factors that control the vulnerability of the lands to soil erosion and determine the form which it

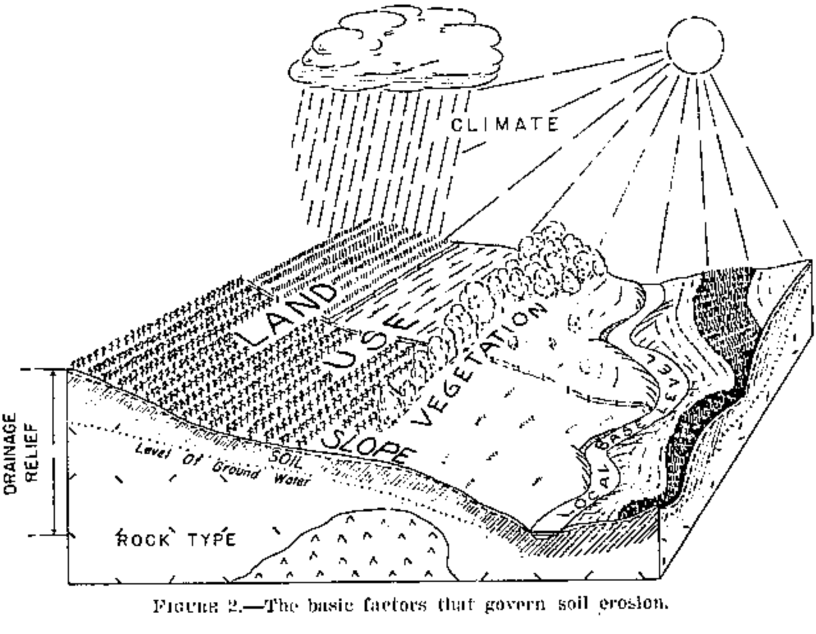

FIGURE 2.—The basic factors that govern soil erosion.

will take in any given area. The multiplicity of these factors (*1, p. 587*)[4] is suggested in the block diagram (fig. 2). Climate affects the processes of erosion in many ways. Climatic elements determine in large part the rate and kind of rock weathering, the rate of soil formation and type of soil, and the vegetation for which the region is suitable. In these ways, climate limits the land use. The geologic history of the area determines the type of bedrock or parent material, residual or transported, from which the soil is made. Geologic structure and physiographic history control the drainage pattern and degree of dissection of the land by streams. Slopes, drainage relief—the depth from principal ridge crests to major adjacent valley bottoms—height of local base levels, and the position of the water table are, in large part, results of these geologic conditions. Man, in his use of the lands, has stripped the soil of its protective cover of vegetation, and in certain areas serious erosion has taken place. Man-made changes in the natural drainage of the lands, producing unwise concentration of flowing water, have caused and are still causing the development of large gullies. In these and many other ways erosion has been given an opportunity to attack the soil with exceptional rapidity.

Although this bulletin pertains directly to Spartanburg County, S. C., the erosion conditions and processes described are much the same throughout the southern Piedmont. Most of the major principles are applicable to the whole country.

CLIMATE

The Southeastern States from the Mississippi Valley to the Atlantic coast are characterized by a humid, warm (mesothermal) climate with rainfall normally adequate at all seasons. There is considerable variation in actual temperature and precipitation within the area, but, owing to its moderate elevation and its location in the northwestern part of South Carolina, Spartanburg County has conditions which are a good average for the southeastern region. Stations in the Blue Ridge Mountains only 55 miles to the west, however, record an annual rainfall much higher than that in the Piedmont area and exceeded in the United States only on the Pacific coast.

A graphic summary of the climate of Spartanburg based on records of 36 to 62 years of observation at the Spartanburg station of the United States Weather Bureau is presented in figure 3. The three curves in the upper part of the chart indicate the monthly mean and the averages of the daily maxima and minima of temperature for each month. At the line of freezing temperature the minimum and average lengths of the growing season are shown. Average snowfall for each month is tabulated immediately below the growing-season data. The bar graphs at the bottom indicate the highest, lowest, and mean precipitation for each month, based on data from 1874 to 1936. Records for many of the years before 1895 are incomplete.

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[4] Italic numbers in parentheses refer to Literature Cited, p. 140.

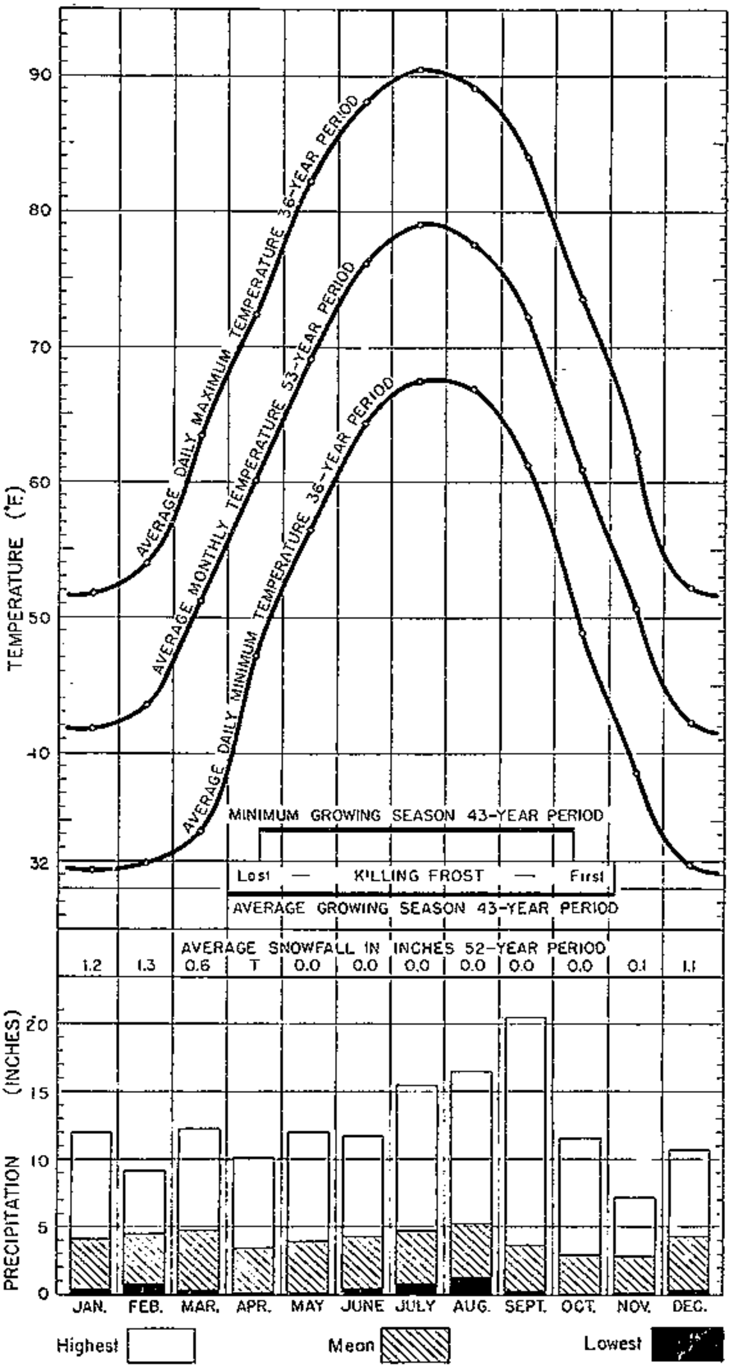

FIGURE 3.—Climatic summary, Spartanburg, S. C. Records for temperature, growing season, and snowfall are for years up to 1930 inclusive. Precipitation graphs include all years from 1874 to 1936 although there are many gaps in the records for years earlier than 1895. Based on records of the Spartanburg station of the United States Weather Bureau.

CLIMATE AND AGRICULTURE

The climate of the region is favorable to the growth regimen of the cultivated plants and is convenient for the farmers' work calendar. The average growing season is more than 7 months, and the annual precipitation averages 49 inches. Rainfall is light during the spring and early summer, when cotton requires heat but little moisture. The rainfall is lowest during the fall of the year, when dry weather is essential for cotton picking and the harvesting of other crops. The heaviest precipitation comes in the late summer, when crops are growing and when moisture is needed to offset the desiccating effect of the hot sun. Persistently high temperatures that might be destructive to plants during their critical growing season are infrequent. Tropical Maritime air usually occupies the Southeastern States for the greater part of the summer, and this warm moist air, because of its power to absorb solar radiation, tends to prevent excessive insolational heating of the ground. This condition is in marked contrast to that in the Great Plains region, where very dry and hot air masses may prevail for periods of a week or more at a time.

Precipitation in the Spartanburg area usually is adequate at all seasons. Annual rainfall sometimes drops to about two-thirds of the normal, but the actual moisture available is still ample for agriculture characteristic of a humid climatic province. Precipitation during the years 1906–35 ranged from a minimum of 32.29 inches in 1925 to a maximum of 73.93 inches in 1929. Years having lowest rainfall, however, are not always years of greatest crop failure. During the 30 years 1906–35 the climate varied as shown in table 1. Twenty-eight of the thirty years fell within one climatic type and the year classed as "moist subhumid" was only slightly below the limit of humid conditions. In the wet year, 1929, rainfall was well distributed, and flooding and agricultural damage were not as great as in some years of less abundant precipitation. There is apparently little likelihood that the climate of Spartanburg will become sufficiently abnormal to necessitate any change in agricultural economy.

TABLE 1.—*Climatic variability at Spartanburg, S. C., Oklahoma City, Okla., and Grant, Nebr.*

Climatic type [1]	Spartanburg, S. C. (30-year record, 1906–35)	Oklahoma City, Okla. (30-year record, 1906–35)	Grant, Nebr.[2] (17-year record)	Climatic type [1]	Spartanburg, S. C. (30-year record, 1906–35)	Oklahoma City, Okla. (30-year record, 1906–35)	Grant, Nebr.[2] (17-year record)
	Years	*Years*	*Years*		*Years*	*Years*	*Years*
Wet	[3] 1			Dry subhumid		9	6
Humid	28	6	1	Semiarid		2	5
Moist subhumid	[4] 1	13	4	Arid			1

[1] Based on precipitation effectiveness, the P/E index of the Thornthwaite classification of climates (*29, p. 641*).

[2] See Thornthwaite (*31, p. 479*).

[3] 1929.

[4] 1933.

The uniformity of the climate at Spartanburg can be seen clearly by comparison of this climate with that at stations situated in more changeable zones. Oklahoma City, Okla., for example, in the same years, 1906–35, had precipitation ranging from 17.27 to 52.53 inches. Its climate during this period varied as shown in table 1. An even more marked variability occurs at Grant, Nebr., where the annual precipitation ranged from a minimum of 9.47 inches in 1910 to a maximum of 35.84 inches in 1915 (*31, p. 479*). This difference was sufficient to bring an arid or desert climate in 1910 and a humid or forest climate in 1915. Climates of the 17 years for which complete records are available at Grant spread over the broad range shown. The significant fact from the agricultural standpoint is not the variability within one climatic type but the number of climatic types which may be represented at the station in successive years. Under such variable conditions as those at Grant, and to a lesser extent at Oklahoma City, crop yields are uncertain and land use proper for one year may be entirely unsuited for another. Although the rainfall at Spartanburg has a greater range than that at Oklahoma City or Grant, this variability is not significant because it rarely brings changes to other climatic types.

CLIMATE AND EROSION

Climate is doubly important to the farmer because it determines not only the type of agriculture in a region but also, to a great degree, the manner and rate of erosion of the lands. The climatic elements influencing weathering and erosion include the range of temperature, intensity and seasonal distribution of precipitation, variations in humidity, and wind. These climatic factors control in large part the operation and effectiveness of rock disintegration, the rate of run-off of surface waters and the regimen of the streams, frost and ice action, and the rate and extent of mass movement of the soils. Both natural and culturally induced erosion land forms reflect the main characteristics of the climate under which they were developed.

In the Spartanburg area there is a moderate daily temperature variation ranging from 29° F. in March to 20° in December and January. The extreme range is 110°, from −4° recorded in February to 106° in both July and August. The temperature falls to freezing or below on about 40 days each winter but seldom stays there for an entire day. Frost heaving is active during these periods, but owing to the lack of prolonged cold it affects only the surface soil. The ground does not freeze to any considerable depth.

Although the annual precipitation is well timed for crop growth, its distribution is less favorable from the standpoint of erosion control. The summer peak comes in July and August, when much of the land is clean-cultivated. There is a secondary period of high rainfall from December to March, when winter crops are the only protection for the soil. In colder climates, soils are covered by snow or are solidified by ground frost for much of this period. In the Spartanburg area, however, the annual snowfall averages only 4.3 inches, and snow seldom remains for more than 1 or 2 days. Winter temperatures are too high to offer much protection to the soil. In the past, the effect of winter rains has been particularly harmful because of the lack of cover crops. Within the last few years, however, a much larger acreage of winter cover crops has been grown, owing to the work of State and Federal agricultural services in promoting this practice.

The winter precipitation differs from the summer precipitation both in character and origin. Most of the rains in the late autumn, winter, and early spring are gentle, widespread, and of long duration. They are drizzling rains or "'tater soakers", which saturate the soil and give a maximum benefit to winter cover crops with a minimum of surface run-off. Meteorologically[5] they are of the warm-front type, caused by the steady advance aloft of warm moist Tropical Gulf or Atlantic air over a wedge of colder and denser air of polar origin. The Piedmont and the Appalachian Mountain region lie in an area where the movement of Polar Continental air masses frequently is greatly retarded, and where the boundary between the polar air and the warmer tropical air may occasionally become more or less stationary for as long as 2 days. Extratropical cyclones frequently originate or increase in intensity along this boundary, and the rainfall from the resulting warm-front storms may attain moderate or even high intensities that continue for 24 hours or more. Rainfall in these storms, however, rarely has exceeded 6 or 7 inches in 24 hours. Warm-front winter rains are not of the type that causes the greatest concentration of run-off and hence the greatest erosion by running water. Owing to their wide areal extent and their thorough saturation of the soil during a long drizzle, warm-front rains are important in inducing mass movements of the soil by slumping and caving and by slow downhill creep. Prolonged rains of this type create a definite flood hazard.

In late spring, summer, and early autumn most of the precipitation originates in convectional storms. These produce rains which may be of high intensity but are generally of short duration and of small areal extent. These storms are almost always associated with extratropical cyclones and occur along cold fronts caused by intrusions of bodies of Polar air, which generate huge convective currents in warm moist Tropical Maritime air masses.

Tropical cyclones occasionally pass through the area but their occurrence is confined largely to late summer and early fall. By the time the tropical hurricanes reach the Spartanburg area they are generally assuming extratropical characteristics, and the rainfall may be of the warm-front type, convectional, or a combination of the two. It is usually of high intensity. The characteristics of the rains in 1936–37 and their effect on erosion are discussed more fully and examples are presented on pages 76–91. (See also figs. 43 to 57.)

Erosion by surface run-off from a storm depends on the character of the soil, angle of slope, vegetal cover, and especially on the amount and intensity of the rain. Heavy summer rains, either convectional or tropical-cyclonic, are the major "gully washers." The heaviest rain period recorded for Spartanburg was in 1888, when 15.26 inches of rain was received in August and 20.44 in September, a total of 35.70 inches, a large part of which fell within 2 weeks. This was more than the rainfall for the entire year in either 1925 or 1930. The unusually

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[5] Meteorological interpretation was prepared in cooperation with Benjamin Holzman and K. Clarke-Hafstad of the Section of Climatic and Physiographic Research.

heavy precipitation in 1888 appears to have been caused largely by two tropical cyclones which passed through the upper Piedmont of South Carolina in rapid succession. The years 1928 and 1929 also had exceptionally heavy rainfall from tropical storms. On August 10–12, 1928, the Southeastern States were deluged by heavy rains from a tropical cyclone which passed northeastward from the Gulf of Mexico and left the continent again near Chesapeake Bay. Spartanburg was one of the centers of highest precipitation (fig. 4) and received a total of 7 inches of rain, all of which fell between 8 a. m. August 10 and 8 a. m. August 11. This was followed on August 15–17 by a second tropical disturbance, which may be considered as an extension of the earlier one (fig. 5). Spartanburg received 8.10 inches of rain, 7 inches of which fell in the 24 hours between 8 a. m. August 15 and 8 a. m. August 16. In these two storms of August 1928, 15.10 inches of rain fell within the 6 days from August 10 to 16.

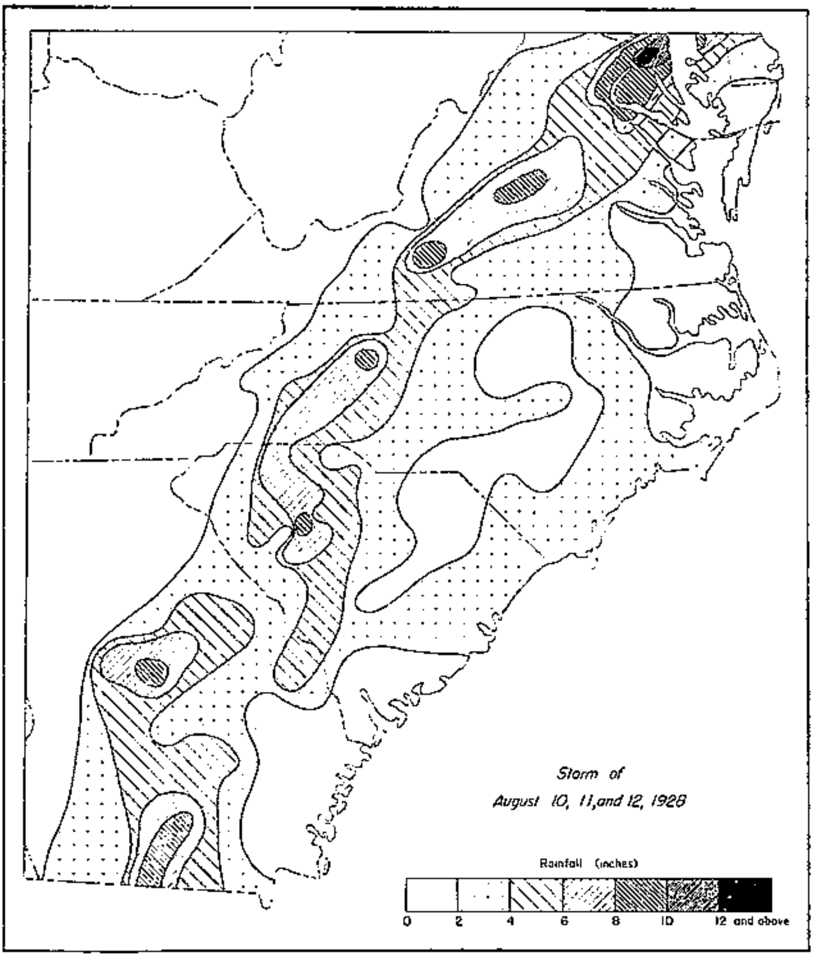

FIGURE 4.—Distribution of total precipitation in tropical cyclone of August 10–12, 1928. The 7 inches of rain received at Spartanburg, S. C., fell within 24 hours.

The storms of 1929 were even heavier. A hurricane on September 23–27, 1929, brought unprecedented rains to many stations in the Southeastern States. A total of 15 inches was recorded in a single day in Glennville, Ga. Crescent, in Spartanburg County, S. C., reported 12.08 inches from sunset September 25 to sunset September 27. Spartanburg itself received 6.15 inches between 8 a. m. September 25 and 8 a. m. September 27. This was followed within 3 days by a tropical cyclone of unusual duration, which caused high winds and heavy rains. Between 8 a. m. September 30 and 8 a. m. October 2, 9.86 inches of rain fell at Spartanburg, and 6.93 inches of this came in the 24 hours from 8 a. m. October 1 to 8 a. m. October 2. These two outstanding storms in September and October 1929 thus brought to the Spartanburg area 16.01 inches of rain within 7 days.

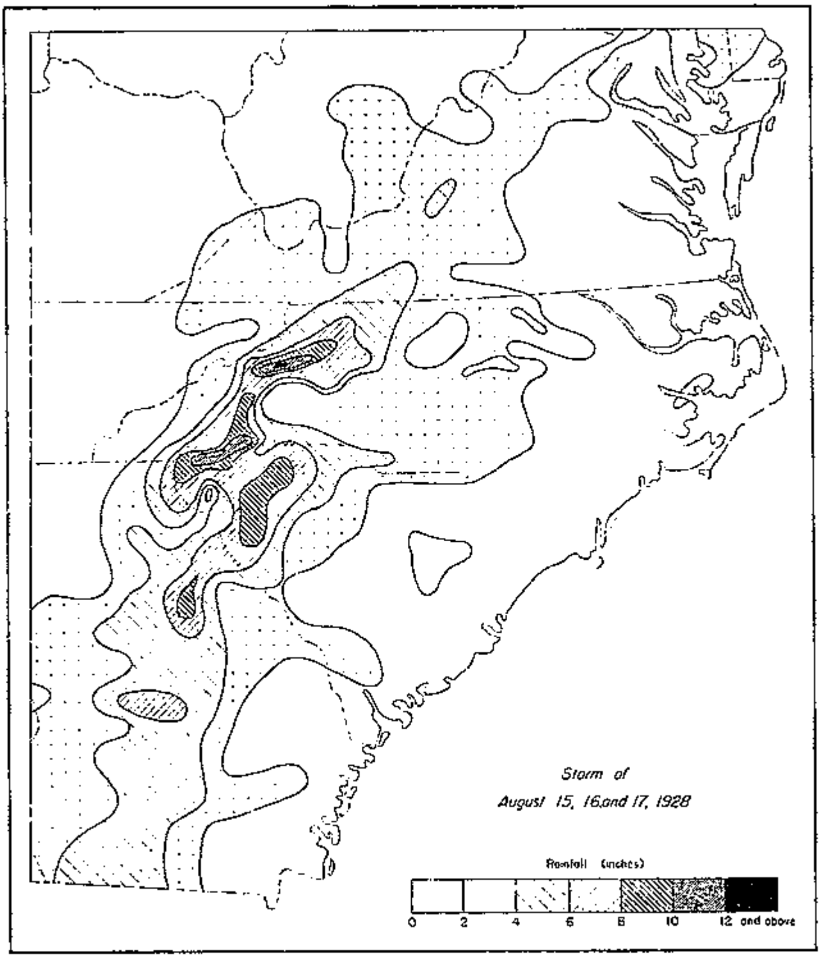

FIGURE 5.—Distribution of total precipitation in tropical cyclone of August 15–17, 1928. Spartanburg, S. C., received 8.10 inches of rain, 7 inches of which fell within 24 hours.

The probability of occurrence of high and low monthly precipitation for periods of 1 to 52 years is shown in table 2, based on records of the United States Weather Bureau (*34, pp. 15–16; 35*). It is to be expected that in an average 5-year period, for example, the precipitation for 1 and only 1 month would exceed 12 inches and for 1 and only 1 month would be less than 0.19 inch.

TABLE 2.—*Probable frequency of occurrence of high and low monthly precipitation, Spartanburg, S. C.*

Frequency (years)	Monthly precipitation more than—	Monthly precipitation less than—	Frequency (years)	Monthly precipitation more than—	Monthly precipitation less than—
	Inches	*Inches*		*Inches*	*Inches*
52	20.43	(1)	5	12	0.19
26	16.49	(1)	2	10	.60
10	15.25	0.05	1	8	1.02

[1] Trace.

In the 46 years for which Weather Bureau records of precipitation at Spartanburg are complete, the monthly distribution of heavy and light precipitation is as follows: March, July, August, and December have the greatest frequency of heavy monthly precipitation; May, September, October, and November are the months which most frequently have had precipitation of less than 1 inch (table 3).

TABLE 3.—*Number of monthly occurrences of heavy and light precipitation, Spartanburg, S. C., 46-year record*

Precipitation for the month (inches)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
10 or more	1	0	3	1	1	2	3	5	2	2	0	3	23
1 or less	2	1	0	1	5	2	0	0	4	8	9	0	32

Records of storm intensity at Spartanburg are available only since 1934, when automatic rain gages were installed in the Tyger River basin by the United States Geological Survey. Since June 1935 these have been operated in cooperation with the Soil Conservation Service. From 1918 to 1930 the Weather Bureau station at Greenville, S. C., 30 miles to the west and 200 feet higher, recorded the short-period precipitation intensities shown in the following tabulation:

Length of period:	*Maximum precipitation in inches*
5 minutes	0.52
10 minutes	.90
15 minutes	1.25
30 minutes	2.30
1 hour	3.43
2 hours	3.59
24 hours	8.20

The maximum precipitation, by months, for a 72-hour period at Greenville, in the 47 years ended 1930 was:

	Inches		*Inches*
January	3.72	July	5.94
February	5.16	August	14.14
March	5.61	September	7.43
April	5.21	October	7.79
May	9.36	November	2.96
June	5.70	December	5.75

Late in October 1936 the Section of Climatic and Physiographic Research of the Soil Conservation Service installed four recording rain and snow gages of the weighing type adjacent to selected gullies and other study areas within 14 miles of Spartanburg (fig. 6). The daily precipitation from each of these gages has been graphed, and the precipitation for ½-hour periods during storms has been tabulated. Precipitation before October 1936 and that of exceptional

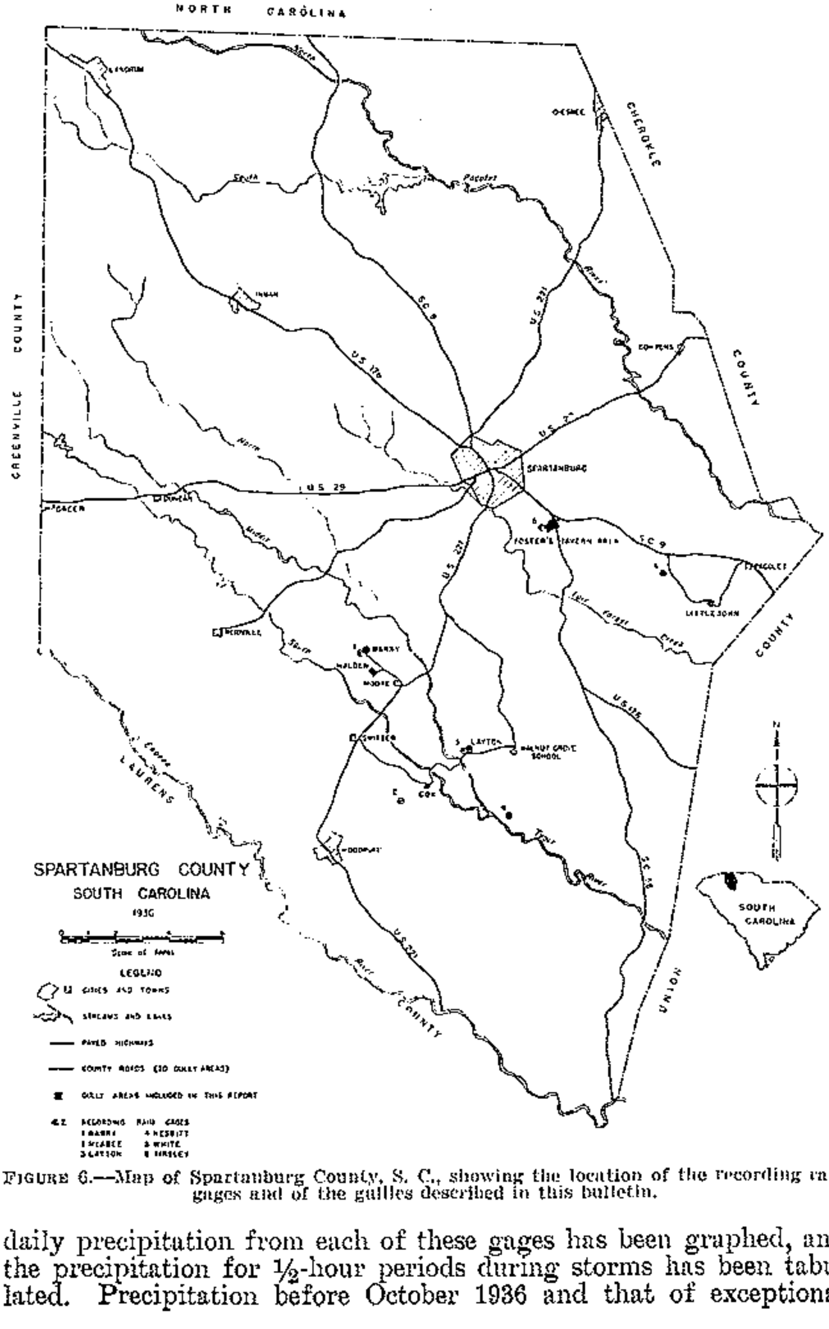

FIGURE 6.—Map of Spartanburg County, S. C., showing the location of the recording rain gages and of the gullies described in this bulletin.

storms since that date has been charted from records of two recording gages maintained in the same area by the United States Geological Survey and the Soil Conservation Service. Owing to the distances of 3 to 14 miles between these six recording gages, their results show considerable variation but give a moderately good representation of rainfall throughout the area. Microclimatic studies made in western Oklahoma during the past 2 years by the Section of Climatic and Physiographic Research have shown marked spottiness of rainfall (*30*). Preliminary results obtained in Oklahoma show considerable variation in the records of gages only 3 to 5 miles apart.

Rain intensities in the Spartanburg area from July 10, 1936, to July 9, 1937, ran as high as 1.65 inches for a ½-hour period recorded on October 16. Intensities in excess of 1 inch per hour are given in table 4.

TABLE 4.—*Precipitation intensities of more than 1 inch per hour,*[1] *Spartanburg, S. C., July 10, 1936, to July 9, 1937*

Date	Maximum precipitation for—				Date	Maximum precipitation for—			
	½ hour	1 hour	2 hours	24 hours		½ hour	1 hour	2 hours	24 hours
1936	*Inches*	*Inches*	*Inches*	*Inches*	*1937*	*Inches*	*Inches*	*Inches*	*Inches*
Aug. 7-8	0.84	1.30	2.05	2.50	June 2	1.38	1.40	1.45	1.45
Aug. 28	.93	1.18	1.57	1.60	July 6	1.23	1.74	1.76	1.92
Sept. 3	.92	1.12	1.72	4.16					
Sept. 30	1.05	2.05	2.33	3.26	Maximum	1.65	2.55	3.62	5.93
Oct. 15-16	1.65	2.55	3.62	5.93					

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[1] 2 gages were in use from July 10 to Oct. 21, 1936, and 6 from then on. The records from only 4 gages were used in compiling the data for the period after Dec. 28, 1936.

The storm of October 15–16 had the greatest intensity for all periods from ½ hour to 24 hours. The intensity of that storm for a 2-hour period exceeded slightly the highest 2-hour intensity recorded in the 13-year record for Greenville (p. 12). The heavy rains listed in table 4 were the most destructive of the entire year, from the erosion standpoint. The close relation between precipitation intensity and rate of gully erosion was clearly shown by field observations and is set forth on pages 75–91.

GEOLOGY

PHYSIOGRAPHIC SETTING

South Carolina may be divided physiographically into three major provinces or belts which roughly parallel the coast (fig. 1). Within each of these areas, similarity of bedrock and of physiographic history have brought about more or less uniformity in topography, soils, and erosion forms.

Approximately half of South Carolina is in the Coastal Plain, a broad lowland developed on sedimentary beds which dip gently seaward. Topographic relief in this province is low except in the western part, where sand hills rise a hundred feet or more above their surroundings. On its landward side the Coastal Plain abuts against the Piedmont, an area of much older and more resistant rocks of igneous and metamorphic origin, which extends almost to the northwestern corner of the State. Owing to its resistance to erosion and its greater distance from the sea, this area has not been worn down so low, and many of the streams and rivers crossing the Piedmont cascade over rapids or falls where they pass from this province to the Coastal Plain. From this Fall Line or Fall Zone the Piedmont extends westward to the base of the Blue Ridge Mountains, which are formed of the same general types of rock but in this area stand about 2,300 feet higher. These are characteristically mature complex mountains with subdued topography. Their rounded crests and smooth, flowing slopes are well clothed by forest. Cliffs and other bare rock surfaces are not common.

Spartanburg County lies entirely within the Piedmont province. The northwestern corner of the county includes several hills which are outliers of the Blue Ridge, but the area in general is characterized by the gently rolling topography typical of a land surface naturally dissected by running water. The divides, with few exceptions, rise to a remarkably even sky line, the trace of an old erosion surface (the Piedmont peneplain), which has been uplifted and now slopes gently toward the sea. Elevations in the county range from an average of about 1,000 feet in the northwest to 500 feet in the southeastern part, an air-line distance of some 45 miles.

The major streams of the county, the Pacolet, Tyger, and Enoree Rivers, head in the mountains to the west and flow southeastward, following the regional slope of the land (fig. 6). The available relief, or difference in elevation between the main stream channels and the divides, is from 100 to 200 feet. Slopes are steepest close to the streams and, through much of the area, pass into the more gentle upland by a marked shoulder or break in slope.

Few of the streams have become well graded, except for short reaches. Owing to the thick zone of weathered rock, many of the smaller creeks have not cut deeply enough to encounter solid material except where a hard mass or vein is exposed unusually close to the surface. The levels of the graded portions of the streams are controlled by the temporary barriers or shoals thus formed, or by the level of the master streams to which the smaller ones are tributary. Most of the major streams have reached the submature stage in their development. They flow in valleys with discontinuous flood plains, which at some places reach widths of one-half to three-quarters of a mile. A few shoals are found along even these larger rivers, and there the bottom lands are scarcely wider than the river channel.

Most of the bottom lands are subject to frequent floods, and many such areas are now unfit for cultivation. Flooding has resulted in the deposition of infertile sand over the silts of the normal flood plain. Many bottom lands, once farmed, have been abandoned and allowed to grow up in willow, alder, and other lowland vegetation.

BEDROCK IN THE PIEDMONT

The rocks of the Piedmont province are highly complex and have had a long and varied history. Some of them, for example marble and quartzite, were originally sedimentary rocks but have since been changed by regional metamorphism. Others such as granite and diorite, and more mafic types including peridotite and diabase, are igneous rocks and still retain their original character. The greater part of the province, however, is composed of gneisses, gneissic granites, schists, slates, and altered volcanic rocks. In some of these the mineralogical composition gives an indication of their original character, but in many of the rocks of the area metamorphism has almost completely obscured their earlier condition.

Little geologic mapping has been done in the southern Piedmont in recent years, and the geology of Spartanburg County has never been studied in detail. The most closely related region for which there is a published geologic report is the Gaffney-Kings Mountain area, which lies close to the northeast corner of Spartanburg County. The work was done by Keith and Sterrett, of the United States Geological Survey and published in 1931 as Folio 222 of the Geologic Atlas (*14*). Owing to the trend of outcrop of the rocks of the Piedmont northeast-southwest paralleling the mountain front, the belts of rock mapped in the Gaffney-Kings Mountain quadrangles pass southwestward, and many of them enter or cross Spartanburg County. There is a close relation between the type of bedrock, and the soil and erosion conditions in the Piedmont. A knowledge of the geology of the area is helpful, therefore, in interpreting the erosion conditions. Preliminary tracing of the boundaries of the various rock formations in Spartanburg County has been done in connection with the physiographic research. More detailed investigation of the geologic relations is being carried on but has not been completed.

According to Keith and Sterrett the oldest rock recognized in this area is the Carolina gneiss (*14, p. 3*), a complex series of interbedded gneisses and schists heavily injected with granite. It is believed to be of Archean age.[a] Intrusive into this is the Roan gneiss, a dark hornblendic rock of schistose and gneissic structure and variable composition, which occurs in large masses or as dikes and narrow belts cutting the Carolina gneiss. Dikes of pyroxenite, amphibolite, gabbro, and other basic materials, many of which have now altered into soapstone, are associated with the Roan gneiss. The Battleground schist (*14, p. 4*), a manganese-bearing sericite schist named for the historic battleground at King's Mountain, is of Algonkian age, next younger in the sequence. The King's Mountain quartzite, Blacksburg schist, and Gaffney marble, believed to be of Cambrian age, follow in that order.

Several different granites have invaded the rocks of this area. The oldest of these which has been distinguished is the Bessemer granite (*14, p. 4*), named for Bessemer City, in the Lincolnton quadrangle, N. C. This is a much-metamorphosed, fine-grained, muscovite-biotite granite, locally with porphyritic texture. It is younger than the Roan gneiss but is believed, like it, to be Archean. Two granites (*14, p. 6*) which cover wide areas appear to have been intruded much later, as they show less deformation and shearing than the older rocks. The Whiteside is essentially a light-gray muscovite

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[a] Geologists have divided into a series of eras the time between the formation of the oldest rocks exposed on the earth's surface and the present. Some of the Piedmont rocks are believed to belong to the oldest era, the Archean, and some to the following era, the Algonkian. Other rocks are considered to have been formed much later in the Cambrian, the earliest period known to have had abundant animal life of complex type. Most of the Piedmont rocks are believed to have been formed before the Carboniferous period, the time when the major coal deposits of the Eastern States were made. From the Carboniferous to the Recent is a stretch of hundreds of millions of years, during which erosion has worn down and carried away vast thicknesses of the uppermost series of rocks.

biotite granite thought to have been intruded during the period of mountain building at the end of the Carboniferous. The Yorkville is probably younger than the Whiteside and is a gray to dark-gray coarse-grained biotite granite possessing, in places, a porphyritic texture and a roughly parallel arrangement of feldspar phenocrysts. Portions of it grade into diorite as a result of absorption of preexisting dioritic rocks.

Owing to the lack of good exposures and the extreme variability in composition of the Piedmont rocks, identification of the parent material of the soils is difficult. Each successive igneous intrusion or regional deformation has greatly altered the preexisting rocks. The dark-colored Roan gneiss, for example, has absorbed the Carolina gneiss so thoroughly at some localities that little trace of the original rock is left. Masses of the Carolina gneiss and to a greater extent of the Roan gneiss are recognizable in the Whiteside granite. Blocks of Roan gneiss have been included in the Yorkville granite, and where blocks of the dioritic facies of the Roan were digested or incorporated into the molten mass of the Yorkville, the composition of the invading magma has been completely altered and passes from a granite into a granodiorite, quartz-diorite, and diorite (*14, p. 6*). With such complexity in the history and composition of the rocks of this area, pure rock types are almost unknown. Geologic boundaries are seldom sharp and distinct, and correlations of rock type with soil series and erosion hazard must be based on general rock groupings rather than on minute subdivisions of rock types.

WEATHERING

In a warm, humid climate like that of the southern Piedmont, coarse-grained igneous and metamorphic rocks weather deeply. Chemical decomposition of feldspars is active, and rocks of granitic type quickly give way as the feldspar is converted into kaolin or clay. Although granite and granite-gneiss of the types mentioned in the preceding section comprise a major part of the area of the Piedmont, outcrops of such rocks are rare and are found chiefly in shoals along the major streams. Throughout much of the province these rocks are weathered to depths of 25 to 50 feet, and on the gently rolling interstream divides weathering may have penetrated 100 feet or more below the surface. Many of the schists also weather rapidly owing to breaking down of the feldspars and micas. Rocks rich in dark ferromagnesian minerals (mafic) are generally less deeply weathered than those which are richer in feldspar and quartz, or silica (felsic); and in areas where mafic formations predominate, the solid bedrock can usually be found a few inches to several feet below the base of the subsoil.

In Spartanburg County mafic rocks are of small extent, and soils developed from them occupy only about 2 percent of the land surface. This fact is of great significance in the erosion of the county, because the rate of gully cutting in areas of such rock is much less than the rate in areas of granite or other deep-weathering felsic types. The character of the rock and the depth of weathering also determine, in large part, the depth to which the gully channel can be cut (fig. 7). In areas where the bedrock contains many resistant rock masses, dikes, or veins, these will retard or prevent down-

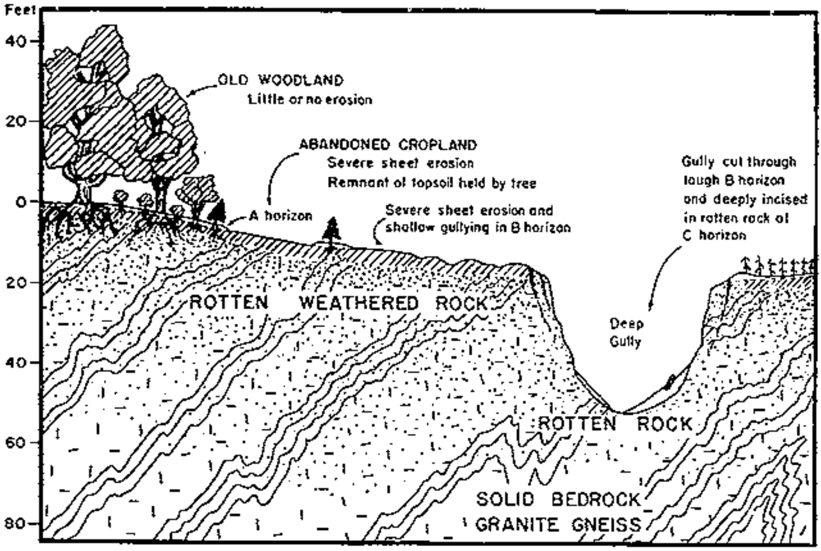

FIGURE 7.—Relation of sheet erosion and gullying to soil horizons, zone of weathering, and solid bedrock. The deep gully can cut downward 5 to 8 feet more before reaching solid bedrock, where its progress will be checked.

cutting of gullies through the surrounding friable rock. A gully cut in such an area usually has many steps or barriers in its channel and will not reach its maximum depth and a fully graded condition until the rock masses which form the temporary base levels are cut through. Resistant dikes or ledges of this sort provide at least temporary stabilization in the segment of the channel immediately upstream and in regions of weak rock are in many situations the only suitable foundations on which control dams or other protective works can be built.

RELATIONS BETWEEN GEOLOGY AND SOILS

The upland soils of the Piedmont are formed from residual soil materials derived from the underlying rock or from bedrock higher on the slope. Weathering of the solid bedrock produces a friable zone of rotted rock or saprolite, which although badly decomposed is still in place and retains its original arrangement and structure. This rotted rock is neither rock nor soil, but is a stage intermediate between the two. It is the parent material from which the soil-forming processes develop the characteristic topsoil and subsoil of the mature soil profile.

In the Piedmont, more than in many other parts of the country, the soils are intimately related to the bedrock. In this area there has been no glaciation to remove the soil cover or to bury it beneath a layer of transported debris; slopes are gentle and suitable for the formation of thick mature soils; and the climate promotes deep weathering, thus providing an abundant supply of decomposed parent material ready for the soil-forming processes. The major kinds of bedrock in the Piedmont and the soil series to which they have given rise are shown in table 5.

TABLE 5.—*Relations between parent rock, color of B horizon, drainage, and soil series in the southern Piedmont*

Drainage	Felsic rocks[1]				Intermediate and mafic rocks[2] (such as diorite, diabase, hornblendite, mafic gneiss)		Mixed rocks[3] (rocks highly injected or areas too small to map)	Slate and volcanic rocks (such as metamorphosed clay shales and fine-textured volcanic tuffs)		
	Granite and granite gneiss			Mica schist						
	Red to reddish-brown B horizon	Yellow to red B horizon	Gray B horizon	Red to reddish-brown B horizon	Red B horizon	Yellow or brownish-yellow B horizon	Yellow B horizon	Red B horizon	Yellow to reddish-yellow B horizon	Gray B horizon
Good	Cecil Lockhart	Durham		Louisa Madison	Davidson		Wilkes	Georgeville	Alamance Herndon	
Intermediate		Appling Colfax				Mecklenburg	Helena			
Poor			Worsham			Iredell				Orange.

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[1] High in feldspar and silica, or quartz, low in ferromagnesian minerals, light in color.
[2] Lower in quartz, higher in ferromagnesian minerals, medium to dark in color.
[3] Felsic, intermediate, and mafic.

From table 5 it may be seen that in the Piedmont related soil series fall into groups the members of which although derived from the same parent materials have somewhat different solums. Distinction between such groups, which have recently been named "catenas" (*24, pp. 16–17*), can be no sharper than the distinction between rock types. Where a gneiss becomes excessively micaceous and grades into a schist, a soil of the Cecil group will give way to a Louisa or a Madison. Similar transition in soil series occurs where rocks are heavily injected with igneous material of a different composition, thus locally changing the rock character. Such changes are usually gradual, but where dark-colored dikes cut across lighter felsic rocks, such as granite, the resulting differences in soil may show as a distinct color band on the ground surface.

The local distribution of individual soil series such as the Cecil, Appling, or Worsham, depends on relief, drainage, and vegetation. Appling soil, for example, indicates felsic rocks and a fairly flat or gently rolling upland with moderately good drainage. Cecil soil comes from the same type of parent material, but is found on well-drained sloping land in areas of more broken topography. Worsham soil is formed from the same parent rock, but is found only in poorly drained belts in low areas along streams.

Each soil series may be divided into several subdivisions known as types. These are based on differences in soil texture and are controlled in part by original geologic conditions and in part by erosion. The Cecil sandy loam, for example, can develop only where quartz or other sand-forming material in the parent rock is sufficiently plentiful and is in large enough grains to be preserved in abundance in the soil. Cecil clay loam may result from a rock of finer texture or from the removal by erosion of the sandy surface layer of soil, thus exposing the underlying clayey subsoil. Stony or gravelly phases of a soil type may result from the presence of dikes or hard rock layers, fragments of which accumulate in the soil. In some soils, such rock fragments cover almost the entire surface.

Agriculturally the different soil series find different uses. From the erosion standpoint, too, there are certain differences between Cecil, Appling, and Worsham, but these result largely from the topographic position and drainage of the series. The fundamental differences are found between the groups of soil series and are based on the parent material of the soils. For this reason, a geologic map of an area furnishes valuable information as to the future erosion hazard there. It is not always necessary, however, that complete geologic conditions be mapped. A map of the rock type regardless of the age or stratigraphic position of the individual formations (geognostic map) is an aid in delimiting the areas of high and low erosion hazard. Mapping of the rock types in the area of the South Tyger River demonstration project has recently been completed.

SOIL MIGRATION

Although the upland soils of the Piedmont are residual and are closely related to the bedrock of the area, this relationship is somewhat modified or disturbed by the downhill mass movement of the soil. Owing to the action of this process, the soil at any point on a hill slope may be more closely related to bedrock farther up the slope than to the rock immediately beneath. Soil creep, the slow down-slope movement of soil or rock debris, acts so slowly that it is usually imperceptible except when periodic observations are made over a long space of time. Soils on sloping surfaces everywhere are gradually creeping down the slope. Although the pull of gravity is constant, movement of the soil mass usually takes place intermittently. Movement is especially active (1) in periods when the ground is saturated and friction is reduced to a minimum; (2) in periods of maximum variation of temperature, when expansion and contraction cause minute movements of the surface soil; and (3) in cold weather, when frost heave causes more extreme displacement. Movement of the first type takes place by plastic flow. In movement of types 2 and 3, the soil particles are lifted perpendicular to the slope by thermal expansion or by frost heave and they return to a position slightly lower on the slope as they settle downward, more or less vertically, under the influence of gravity (pp. 62–65).

Soil creep is most effective in the surface layers of the soil and tends to keep the A horizon, or topsoil, migrating downhill. There is evidence, however, that the entire solum, to the base of the B horizon is in motion. In many road and railroad cuts, on stream banks, on gully walls, and in other deep exposures in the Piedmont, the boundary between the clayey B horizon and the underlying rotten rock or parent material is quite distinct (fig. 8). Above the line is a normal soil profile, which shows in some places, toward the base of the B horizon, a faint stratification parallel to the topographic surface. Beneath the line the rock structures are preserved; dikes and rock laminae rise to that elevation and are truncated sharply there. The division is sometimes marked by a distinct change in color, and usually also by a more or less definite line of stones or subangular

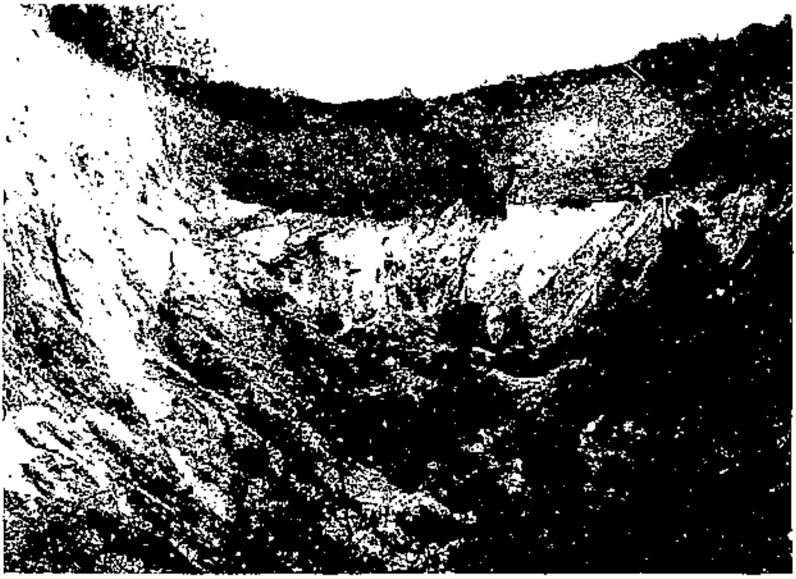

FIGURE 8.—The distinct change in color, level with the head of the hammer, marks the boundary between the reddish-brown Appling subsoil above and the gray rotten rock below. The lower 2 feet of the soil profile shows an indistinct stratification parallel to the dividing line. Below the line the original rock structures are preserved.

rock fragments, most frequently of quartz, which may be called a stone line (fig. 9). This distinct boundary at the approximate base of the subsoil suggests that the entire soil profile above the parent material has moved downhill. The layer of rock fragments along the boundary gives further evidence of soil creep.

The stone lines of the southern Piedmont are directly related to the climatic conditions and geologic history of the area. Owing to the warm humid climate, the rocks are deeply weathered and abundant parent material is available for soil formation. The mature soils of the Southeast are very old and deep, and were not disturbed by the Pleistocene glaciation, as were the soils in the Northern States. Soil creep in the Piedmont, therefore, can have operated without interruption since before the Ice Age.

FIGURE 9.—The stone line across the middle of the picture lies at the base of the B horizon of the soil. Beneath the line, traces of the original rock structure are visible. The scale at the left is 6 feet high.

On a slope underlain by weak, weathered rock, containing more resistant rock layers and dikes, the weaker material is the first to be acted on by the soil-forming processes and gradually becomes part of the subsoil. The resistant rock layers are left projecting upward into this subsoil, and it is believed that as the soil creeps slowly downhill the hard rock layers are sheared off at the soil base and fragments are carried along at the bottom of the creeping mass (fig. 10). If the hard layers are strong and massive they may temporarily prevent soil creep or at least impede its action.

The abundance of rock fragments which form the stone line at the base of the B horizon and the scarcity of such fragments higher in the soil appear to result largely from the fact that the rock fragments enter the creeping mass at the base and tend to stay there. This may be due partly to gravity, as the rocks are somewhat heavier than an equal volume of soil. It appears also that the faster movement of the upper soil layers would cause them to tend to override the rocks rather than to carry them along. Even if the source of the rock fragments were such that the rocks were released uniformly into all layers of the soil, the spacing between fragments in the various layers would not be equal but would be proportionate to their rate of movement. That is, a layer moving twice as fast as another would have the rock fragments twice as far apart. If the soil at the surface moves 5 or 10 times as fast as the base of the subsoil, which seems not improbable, the rock fragments would be 5 or 10 times more widely spaced in the upper layers. Scarcity of stones in the upper part of the soil is also to be expected, in that the forces of weathering are more active close to the surface and rock fragments would be broken up and rounded off more rapidly there.

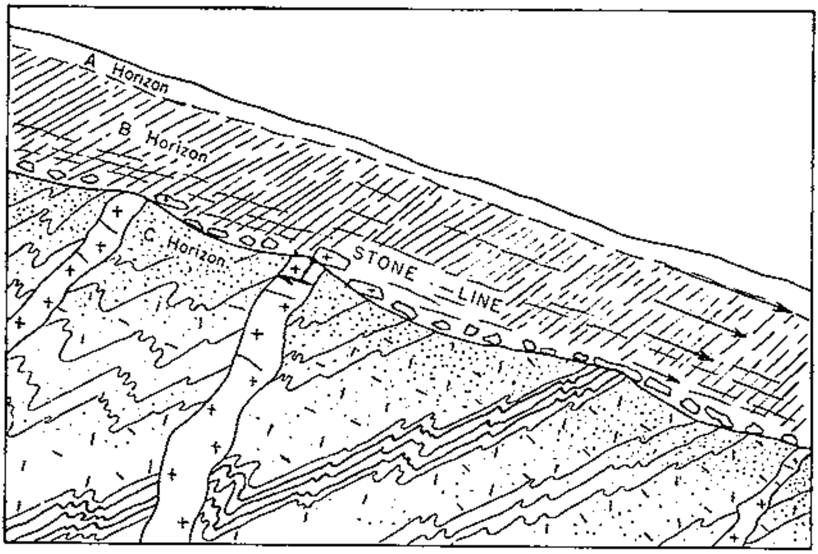

FIGURE 10.—Soil creep, and the method by which stone lines are believed to be formed. Rock fragments sheared off from the resistant layers and dikes in the C horizon are carried down slope at the base of the creeping soil. The arrows at the right indicate that creep is greatest at the surface but is active even at the base of the B horizon.

Stone lines and the distinct boundary between the subsoil and parent material are only two of the many signs of creep. Tilted fence posts and poles, broken rock strata bent down-slope, trees with curved trunks concave on the up-slope side, and broken or tilted retaining walls are some of the common indications of soil creep (*27, pp. 22–23*). Measurements of the rate of movement of different soil layers or of relative rates of movement in the different soil types are not available. Movement is undoubtedly very slow but varies greatly with different conditions of climate, slope, and vegetal cover. The evidence of movement is clear, however, and displacements of many feet are indicated. On cultivated lands the process is greatly accelerated. A single plowing of a hillside field may transfer the surface soil 6 inches or more down the slope.

Down-slope movement of the upper soil layers also takes place by washing. Sheet wash during heavy showers rapidly carries away the surface soil of bare slopes, and unless the material is swept into a gully, stream, or river, it accumulates in minor depressions in the slope. Removal of the topsoil by sheet wash thins the soil profile in the areas where the erosion takes place. Where the washed material, or overwash, is deposited, it tends to thicken the soil, usually making the surface layer coarser and of more sandy texture. The sedimentary structure of the overwash, in most places, shows imperfect but distinct stratification, and in many places it is cross-bedded.

In the Piedmont, overwash resulting from man's use of the land is especially noticeable in the valleys and behind the older terraces on the hillsides. In many valleys where the water table is high, overwash of coarse and usually infertile sand overlies a well-developed profile of bluish or grayish fine-textured soil. In poorly drained depressions on cultivated land, overwash may be found to have buried the soil profile completely. On terraced slopes, much of the coarser material of the overwash is deposited in the water furrows behind the terraces, gradually filling them and producing level benches on the slope. Overflow of water from the choked water furrows increases sheet erosion in the area immediately down slope, so that on many fields little or no topsoil is left except on the tops of the benchlike terraces.

The valley soils of the Piedmont bottom lands differ from the mature soils of the uplands in that they usually are immature and in that they bear little or no relation to the underlying bedrock. The materials of these soils have come from higher ground by overwash down the slopes, by stream transport, and by slow soil creep. Under natural conditions they consist largely of fine-textured clays, silts, and organic matter. Where flooding has occurred as a result of man-induced erosion the material deposited has as a rule been more sandy, and bottom lands which were once fertile have become unproductive wastes (*2, p. 8*).

PETROGRAPHY

In order to verify the correlations between the major soil series and bedrock types of the Piedmont, a brief petrographic study was made. Specimens were collected from outcrops of firm bedrock of representative types. Thin sections were prepared and were studied under the microscope. A summary of the approximate mineralogical composition of the rocks examined is shown in table 6.

The results showed that many of the rocks differed markedly from what they appeared to be when examined with the naked eye. Neither did the information obtained with the microscope agree always with the traditional correlations of the Piedmont soil series and rock types. This may result in part from inaccuracy of rock identification in previous correlations, from lack of uniformity in the rock masses, from the limited number of thin sections examined, and in part from the difficulty of obtaining specimens suitable for grinding into thin sections. Only firm and reasonably fresh outcrops of the bedrock could be used, and the very fact that these outcrops were sufficiently resistant to withstand erosion better than the rocks of the surrounding area indicates that they may not have been entirely typical. In the Piedmont, however, solid rock at the surface is so rare that even if all outcrops were studied, large intervening unknown areas would still remain.

TABLE 6.—*Approximate mineralogical composition of representative specimens of bedrock from the Piedmont of western South Carolina*

Minerals	Composition of rock specimen—[1]						
	No. 1, Biotite granite (Cecil soil)	No. 2, Porphyritic quartz diorite (Lockhart soil)	No. 3, Peridotite (Iredell soil)	No. 4, Olivene diabase (Iredell soil)	No. 5, Quartz chlorite slate (Wilkes soil)	No. 6, Quartz-epidote gneiss (Wilkes soil)	No. 7, Quartz-garnet gneiss (Davidson soil)
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Quartz	14	20			40	50	19
Feldspars:							
Orthoclase	60						
Microperthite and micropegmatite	10	20					
Albite	10						
Andesine		50					
Bytownite				65			
Ferromagnesians:							
Biotite	5	9					
Olivine			95	30			
Garnet							80
Antigorite					50		
Epidote						35	
Alteration products			5	5			
All others	1	1			10	15	1

[1] No. 1 from quarry 1 mile south of Cedar Hill School, 5 miles southwest of Buffalo, Union County.
No. 2 from rapids in stream below Layton's Gully, 1.8 miles west of Walnut Grove School, 11 miles south of Spartanburg.
No. 3 from South Carolina Highway 56, about 1.5 miles north of Tyger River, 18 miles southeast of Spartanburg.
No. 4 from South Carolina Highway 7, 11 miles west of Abbeville.
Nos. 5 and 6 from United States Highway No. 29, 0.5 mile west of Broad River, Cherokee County.
No. 7, characteristic float block from Rich Hill, 1.4 miles south of Whitestone, Spartanburg County.

Specimen No. 1 (table 6) came from an area of Cecil soil and is identified as biotite granite. Much of the Cecil soil is believed to be derived from this rock type. Specimen No. 2, from an area of Lockhart soil, has a normal amount of quartz but is approximately half andesine feldspar and is a porphyritic quartz diorite. The diorites are border-line rocks, some belonging to the felsic and some to the intermediate groups. Their identification depends largely on the character and proportions of the feldspars. In soils work, diorites have usually been classed with diabase as "basic" or mafic rocks, and diorite has been stated to be the parent rock of the Davidson and other similar soils. Specimen No. 2 belongs to the diorite group but is closely related to the granites and gives a Lockhart soil.

Specimen No. 3 shows Iredell soil formed from peridotite, a very dark, highly mafic rock which consists almost entirely of one mineral, olivine. Specimen No. 4, also from an area of Iredell soil, shows the formation of that soil from a diabase containing about one-third olivine and two-thirds bytownite feldspar.

The Wilkes soils, many areas of which were formerly mapped as Iredell, are of mixed types; hence a wide variety of rock specimens might be collected from areas belonging to that soil group. Specimens Nos. 5 and 6 are from an area of Wilkes soil. Both are high in quartz, and the structure of the rocks and the character of their minerals give them the names, "quartz-chlorite slate" and "quartz-epidote gneiss," respectively. Both are products of metamorphism.

Specimen No. 7 was obtained from the abundant "float" of blocky rock fragments which covers parts of the crest of Rich Hill, about

8 miles southeast of Spartanburg. This is an area of Davidson soil, and it has previously been assumed (*17, p. 431*) that the parent rock there was diabase, which was intrusive into the country rock in the form of a dike. The analysis given in table 6 shows that the heavy hard dark rock owed its character not to the abundance of basic feldspars and dark ferromagnesian minerals but to an unusually high proportion of garnet. Keith and Sterrett, writing of the Gaffney-Kings Mountain quadrangles (*14, p. 13*), commented on the presence of compact masses as much as 3 feet thick, consisting of small grains of garnet generally mixed with quartz and stained with manganese oxides. They noted that in places the weathering of the garnetiferous rocks (schists) set free the partly decomposed garnet crystals, which in some places covered the surface like pebbles of rusty gravel. It seems likely that much of the blocky float rock of Rich Hill also may be derived not from diabase but from garnetiferous gneissic layers in the schist which outcrops near the middle of the hill.

These few petrographic studies give only a suggestion of what might be done in correlating soil series with rock types. Valuable information as to erosion hazard can also be obtained in this way. Even the few specimens listed in table 6 give information as to the erodibility of the areas from which they come. The high percentage of silicic feldspar in specimen No. 1 indicates that kaolinization would be rapid, hence the C horizon or parent material of the soil would be weak and nonresistant to erosion. The mica in specimens Nos. 1 and 2 would also tend to weaken the rock. The high percentage of quartz in specimens Nos. 5 and 6 and of garnet in specimen No. 7 would be expected to form a somewhat tougher parent material more resistant to erosion than that of the Cecil and Lockhart soils.

SOILS OF THE PIEDMONT

EROSION AND THE SOIL PROFILE

Mechanical and chemical sorting in the upland soils of the Piedmont have differentiated those soils into several distinct horizons which together make up the mature soil profile. The nature of this profile determines to a great extent the erodibility and the particular manner of erosion of the various soils.

The principal divisions of the mature soil profile, from the surface downward, are designated the A and B horizons, which together constitute the solum and are the layers commonly referred to in any mention of soil (*15, p. 3*), and the C horizon or parent material of rotten rock. The A horizon usually contains a surface layer of organic matter, but in some soils this may be thin or absent. In this region of Red and Yellow soils, as is general in humid climates, the A horizon has lost most of its bases and its colloids and other fine soil particles by leaching and eluviation. These have been carried downward and the colloids and some of the bases deposited in the B horizon, which is usually of deeper color and finer texture, and may be extremely tough. The thickness of these horizons as well as their chemical properties varies from place to place and may change markedly within a few feet. Parent material, slope, vegetation, relation to drainage lines, and extent of erosion or soil creep may cause such local variations. The C horizon or parent material, being directly a product of the bedrock, varies in general as the rock does, and is much less affected by surface conditions than is the overlying solum.

The properties of the soil which control its erodibility are many and varied. Texture, structure, colloidal condition, state of oxidation, and thickness of the several horizons all play a part. Soil texture, or the size of the individual particles, is dependent on the nature of the parent material and on the action of the processes by which that material was formed. Textures are described according to the proportions of sand, silt, and clay; and most soils such as loam, silt loam, and loamy sand are mixtures of two or more of these grades. The coarser soils are the more absorptive and allow better percolation, and hence do not erode so easily. In the finer grades the condition of the colloidal material is a major factor in determining their erodibility.

Soil structure, or the manner of arrangement of the soil particles, is dependent on the texture, the chemical characteristics of the finer constituents, the plant life in the soil, and other factors. The structure may be massive or may be an aggregate of smaller particles and be described as, nut, shot, crumb, or single grain (*15, pl. 2*). It may be prismatic, columnar, fragmentary, or platy, according to the way the B horizon fractures. Structure is of great importance in controlling vulnerability to erosion. Within the same soil profile, structural differences between the A and B horizons may result in the erodibility of the two being widely different. The success of certain kinds of soil conservation treatment also depends on the soil structure. The construction of check dams, for example, is practicable where the subsoil is firm and massive but in platy soils, or soils with a loose nut or shot structure, crumbling around the abutments would soon render a check dam useless.

The effect of the colloidal condition of the soil on erodibility has been studied by Lutz (*19, 20*), Middleton (*21*), and others. This seems to be a particularly fruitful field, and much valuable information on erodibility may result from continuation of studies of soil colloids. Briefly, the condition of the colloids, whether they are dispersed or flocculated, has an important bearing on the ease with which they can be removed by erosion. In the flocculated condition the fine colloidal particles are gathered together into larger units and are not easily transported. Dispersed material is highly subject to eluviation and washing.

Although color in itself may be of minor importance, it is frequently a significant criterion of other soil conditions. Other factors being constant, soil colors may range from light gray through brown to black with increased content of organic matter. Subsoils usually contain less organic matter than topsoils, and their colors depend more on the mineral content, especially on the amount and form of the iron that is present. If the iron is oxidized and nonhydrated (hematite) the subsoil is red, but if oxidized and hydrated (limonite) it is yellow. If iron is present in the reduced state, as in the imperfectly drained soils of valley bottoms, the subsoil is usually gray or grayish blue. The mottled gray, yellow, and rusty brown soils of the valleys, stream terraces, and lower "benches" of the Piedmont are also evidence of poor drainage (*15, p. 5*).

The thickness of the various soil horizons has a vital effect on erodibility. The A horizon is commonly loose and sandy, and if it is thick, perhaps 10 to 18 inches, it will act as a sponge and absorb much of the rainfall, thereby preventing immediate run-off. If this horizon is very thin, however, it can have little beneficial effect regardless of its porous character. A tough clayey B horizon many feet thick may retard violent gullying for a long period, but a thin B horizon may be cut through in a very short time and, if the underlying material is weak, the destructive, caving type of gully will result.

The character and thickness of the C horizon is of prime significance in determining the progress of gully cutting. In some areas this zone of rotten rock or parent material is only a fraction of an inch in thickness and is underlain by solid rock that will effectively resist erosion for thousands of years. Elsewhere, as in much of the southern Piedmont, the C horizon is 10 to 50 or more feet deep, and the transition into firm bedrock is very gradual. Under these conditions, deep gullies can develop with phenomenal rapidity, and the thicker the C horizon the greater the erosion hazard to the area (pp. 17–18).

SOIL SERIES OF SPARTANBURG COUNTY

The Cecil soils are by far the most extensive series in the upper or western part of the South Carolina Piedmont. In Spartanburg County, according to the soil survey published in 1924, they occupy 89 percent of the total area of 524,160 acres (*17, p. 423*). The Appling and Durham soils, members of the same family, increase to 91 percent the total area of soils formed mainly from granites and granite gneisses. Louisa soils, formed from mica schists and quartz-mica schists, form about 2 percent of the area and in many places grade into the Cecil. Iredell and Davidson soils, derived from mafic rocks, cover scattered areas totaling 1.8 percent of the county. The remainder, slightly over 5 percent, is in bottom lands having Meadow and Congaree soils.

Since Spartanburg County was surveyed in 1921, two new series, Lockhart and Colfax, have been established and other older series, among which are Madison, Worsham, and Wilkes, have been recognized in the county for the first time. The Lockhart and Madison soils were formerly mapped as either Cecil or Louisa. The Colfax soil, a down-slope phase of Cecil, Appling, or Durham, was formerly mapped largely as Durham. The Worsham is a poorly drained valley soil derived from granitic rocks. Areas of the Wilkes, a soil derived from mixed rocks, were formerly mapped as Iredell.

Many types of Cecil soil have been recognized in this area. Most widespread of these is the Cecil sandy clay loam, now classified as Cecil sandy loam, eroded phase, which occupies almost 40 percent of the county. The Cecil sandy loam comes second, with 32 percent, and the Cecil clay loam next, with 12.7 percent. The Cecil gravelly sandy clay loam, gravelly sandy loam, coarse sandy loam, and fine sandy loam together make up a little more than 4 percent (*17, p. 423*).

The Cecil soils were among the first to be tilled in the Piedmont. They erode easily, and owing to the combination of long use and high erodibility they have suffered severely. In their original condition, most of the soils derived from granites were probably sandy loams. Remnants of sandy topsoils in areas having apparently virgin profiles suggest a much deeper and more widespread sandy A horizon. Much of the sandy topsoil has been carried away by sheet erosion, so that the soils now mapped as Cecil sandy loam, eroded phase, and Cecil clay loam, eroded phase, represent progressive degrees of removal of sandy topsoils that were once 8 to 16 inches thick. Gullying in the Cecil soils and related series has been particularly serious because of the deeply weathered bedrock and the lack of hard barriers to retard or prevent down-cutting. Many of the Cecil gullies are 20 to 30 feet deep, and a few have reached twice that depth.

The Cecil soils[7] are characterized by a topsoil which, in the different types, ranges from brownish-red friable clay loam 3 to 7 inches deep to a yellowish or reddish-brown gravelly sandy loam 6 to 8 inches in depth. The sandy clay loam and sandy loam, both yellowish brown to reddish brown, are the most widespread types, and the topsoil on the sandy loam is in some places 12 to 18 inches deep. The subsoils or B horizons are red stiff clays, brittle when dry but plastic when wet. They often contain coarse quartz grains and mica flakes. The B horizon extends to a depth of about 3 feet in some of the coarser types but may be 5 or even 10 or more feet in depth in the finer textured soils. Where undisturbed or little affected by creep, the base of the B horizon grades almost imperceptibly into the parent material or C horizon. The depth to firm bedrock may be 5 feet or less in some of the areas of gravelly loam but is often 40 or 50 feet in the finer types and may be much more. The coarse gravelly types of Cecil soil are derived from granites, gneisses, and quartz schists containing abundant veins, dikes, or layers of quartz. Owing to the gravelly surface, the coarse members of the Cecil group are less subject to sheet erosion than the fine-textured soils. The sandy loams and clay loams are derived largely from granites, granite gneisses, and schists. Owing to the heavy, tight, clayey nature of the B horizon, gullies in the Cecil soils are characteristically shallow and V-shaped while cutting in that horizon, but become deep and U-shaped in cross section when they have entered the weak parent material.

The Appling sandy loam has a topsoil 10 to 12 inches thick consisting of light-gray to yellow loamy sand or friable sandy loam. The subsoil begins as a yellow to orange sandy clay and quickly passes into a reddish-yellow or yellowish-brown stiff clay, the lower parts of which are mottled with red where well drained and with gray in wetter areas. The Appling is derived largely from light-colored granites. It is subject to sheet erosion and is gullied readily, but, owing to its position on undulating land and on divides instead of in rougher locations, the Appling usually has fewer gullies than the Cecil soil.

The Durham soil is closely related to the Appling. It occupies the same topographic positions, on flat or almost flat land, and is

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[7] The following descriptions of the profiles of the soils of Spartanburg County are based in part on SOIL SURVEY OF SPARTANBURG COUNTY, SOUTH CAROLINA (77); in part on EROSION CONTROL METHODS FOR THE SOUTH CAROLINA PIEDMONT, prepared by the Soil Erosion Service, U. S. Department of Interior, in 1935; in part on an unpublished manuscript by Charles B. Gay on the soils of the South Tyger River watershed; and in part on the personal observations of the writers.

usually derived from light-colored granites. The surface of the Durham topsoil often has a whitish appearance, but the A horizon in general is a yellow or yellowish-gray sandy loam 10 or 12 inches deep, passing downward into a thin layer of light sandy clay or heavy loam. The subsoil is a bright-yellow to orange friable clay or heavy sandy clay, which extends to a depth of 2 to 2½ feet. Below this is a friable sandy clay, dull yellow to orange yellow and faintly mottled with red. The subsoil grades into the C horizon, and the mottling may extend to a depth of 10 feet or more.

The Colfax, one of the newly described soils of this area, is the down-slope, less well-drained counterpart of the Cecil, Appling, or Durham, and is considered as a transition to the Worsham soil. It occurs most commonly in drainageways and depressions on broad, almost flat ridges in areas underlain by granites and acid gneisses. Smaller areas are found on lower slopes and around streamheads. The Colfax soil is characterized by a mouse-gray loamy sand topsoil and a subsoil of yellow sandy clay which becomes mottled and heavier within 36 inches. The parent material is normally gray to white sandy clay containing one or more layers of tough plastic clay and scattered crystals of incompletely kaolinized feldspar. At some localities, as shown in gully walls in the Foster's Tavern area, the upper part of the parent material is about 10 feet thick and has a higher sand content than the underlying decayed rock. This upper layer gives evidence of having been accumulated either by mass movement or alluviation. Although the Colfax soil is resistant to channel cutting, it erodes readily where kept continuously moist by the water from a spring or seep.

The Worsham soil is even less well drained than the Colfax, and is found low on the slopes around streamheads and along valley sides. It is the wettest of the soils derived from the felsic igneous rocks. Many of the areas formerly considered as Worsham would now be mapped, at least in part, as Colfax. The topsoils of the two series are similar, but the Worsham subsoil is characteristically gray or bluish-gray heavy clay, sometimes mottled with yellow or brown, whereas that of the Colfax is normally yellowish.

The topsoils of the Louisa sandy clay loam and clay loam are dark brownish to reddish brown and contain noticeable amounts of mica. The A horizon is seldom more than a foot thick and passes downward into a friable, micaceous, red or reddish-brown clay which has a slick, greasy feel. Mica becomes increasingly prominent as the subsoil grades downward into the parent material, which is a badly weathered mica schist or gneiss. Gullies cut rapidly in the parent material. (See Cox's gully, p. 115.)

The name "Lockhart" has recently been applied to a soil series derived from a slightly gneissic porphyritic granite or diorite which underlies large areas, especially in the southeastern part of the county. This soil is intermediate in character between the Cecil and Louisa. It resembles the Louisa more closely, but differs from it in that the profile of the Lockhart is shallower and the subsoil is more friable and of lighter color. The Lockhart has 6 to 8 inches of yellowish-gray gravelly sandy loam topsoil and a firm but brittle light-red highly micaceous subsoil 20 to 30 inches thick which contains large white crystals of partially decomposed feldspar which have weathered from the bedrock. The parent material is highly micaceous and friable. This soil is very erodible where cultivated. New rills appear after every rain, and washed material quickly clogs terrace channels. Because of the vulnerability of this soil to sheet wash and gullying and because of the difficulty of protecting it with erosion-control structures, many areas of Lockhart soil now support only marginal or submarginal agriculture.

The Davidson clay loam has a dark-reddish or chocolate-colored topsoil 4 to 10 inches deep. The subsoil is a heavy clay, dark to maroon red, somewhat deeper in color than the Cecil subsoils. The Davidson is derived from dark mafic rocks, which in most places are not deeply weathered. For this reason, although sheet erosion is severe and small gullies are numerous, the gullies usually remain V-shaped even after they have cut through the base of the B horizon.

The Iredell soils have a grayish-yellow to brown sandy to clayey loam topsoil 5 to 10 inches thick. The subsoil can be easily recognized, as it is yellow to brownish-yellow impervious plastic clay, extending to a depth of 2 to 2½ feet. On exposed surfaces of this clay, desiccation develops a distinctive cracked pattern unlike that of any of the other soils mentioned above. The parent material is greenish and micaceous and is derived from dark-colored mafic rocks. Sheet erosion is moderately active on these soils. Shallow gullies are found, but deep gullying is rare.

The Wilkes is not a distinct soil series but is a mixture of many kinds of soil. The term is used where the soil, owing to complexity of the parent material or to other factors, does not fit into any of the defined series, or where several soil series are present but the areas of each are too small to map. The bedrock of the Wilkes soil ranges from granite and felsic gneiss to dark-colored mafic rock such as underlies the Iredell soil. Injected rocks and areas containing numerous dikes are common sources of Wilkes soil. The largest area of Wilkes in Spartanburg County is underlain by banded hornblende gneiss, and by talc schist. The soils described as Wilkes vary in character from Cecil and Appling to Iredell and Mecklenburg (table 5). The topsoil is usually light, sandy, and 2 to 10 inches in depth. The subsoil varies from plastic clay to sandy clay and the color may be any shade from gray to red, depending on local conditions. In most places the Wilkes soils are easily eroded by sheet wash and gullying.

LAND USE: PAST AND PRESENT[8]

Many factors, including climate, bedrock, soil, vegetal cover, and steepness of slope, determine the erodibility of the lands in any region. The rate and manner of soil erosion, however, and the localization of its action depend largely on the treatment that the land receives. Improper methods of farming, construction of roads and railroads, digging of ditches, and throwing up of poorly planned terraces share the blame for destructive erosion of the soil. All have had their effect in Spartanburg County. The agricultural background of this area is typical of the upper Piedmont as a whole just as the erosion conditions in this county are similar to those in adjacent areas of the Piedmont in both North Carolina and South Carolina.

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[8] Prepared in cooperation with A. R. Hall of the Section of Climatic and Physiographic Research.

SETTLEMENT AND EARLY AGRICULTURE

The first white settlements in Spartanburg County were made during the period 1750–60 (*23, p. 724*). One group of pioneer farmers settled between the North Tyger River and Jordan's Creek, in the western part of the county. Others took up land along the Middle Tyger and Pacolet Rivers (*7; 16, p. 25*). Settlement of the remainder of the county, however, was retarded until after 1770 because of the hostility of the Indians. Many of the early settlers came from Pennsylvania, Virginia, or North Carolina, and some directly from Ireland.

The farm economy of the pioneers was relatively simple. Cattle raising was an important industry. The stock was allowed to roam through the woods but was rounded up at various "cow pens" for branding and preparation for driving to Charleston or some northern market. Corn, wheat, and oats were raised on the bottom lands along the streams, but until after the Civil War the interstream ridges were considered of little value. Charleston was the nearest market; hence little production of staple crops for sale was attempted. The one exception to this was the growing of tobacco. This crop was raised by some farmers during the colonial period and early national times and was transported to the coast in large hogsheads on wheels. Cotton production began in the southern part of the county about 1802. At first the cotton, like tobacco, had to be transported to the coast for sale. Columbia later became a market. Even as late as the Civil War, however, Spartanburg County had not become an extensive cotton producer. Cotton gins were few in number and usually the lint was separated from the seed by hand. The larger planters, owners of slaves, were the principal cotton producers. Very little cotton was grown in the northern part of the county.

Agricultural practices of this early period were characteristically of pioneer type. Land was cleared of its timber, cultivated until it was worn out, and abandoned; then a new area was cleared. Under this wasteful system of farming much more land was cultivated in proportion to the production than now, especially in the southern half of the county. The destruction of the forest was very rapid, and apparently most of the virgin timber had been cut by the middle of the last century.

In 1826 there were estimated to be 50,000 acres of land under cultivation in the county (*23, table p. 311*). The area of improved land expanded greatly until 1850. In the next decade, population growth, especially among the whites, came almost to a standstill, and there was extensive emigration of small farmers to newer sections of the country. A decline in the total acreage under cultivation and in the output of the three principal crops, cotton, corn, and oats, resulted. This condition continued through the Civil War and reconstruction period. It was not without its benefits, however, for much of the land retired from cultivation soon was protected by a covering of second-growth pine. Improved methods of cultivation and better varieties of seed brought greater returns from the fewer acres that were tended.

The coming of the railroads furnished a better outlet for the cotton crop and made commercial fertilizers available at a comparatively low cost. The first railroad to enter Spartanburg connected it with Union and Columbia in 1859. Others were not finished until after the Civil War. The railway known as the Richmond & Atlanta Airline, now the main line of the Southern, was completed through the county from east to west in 1873, and the line from Spartanburg to Asheville, N. C., several years later.

Return of more normal economic conditions in the 1870's brought about rapid expansion. Many of the old fields that had reverted to forest were cleared again and returned to cultivation. The area exposed to erosion was increased, and most of the farmers in this post bellum period paid little attention to the preservation of the soil. The destructive practice of clearing, farming, and abandoning was all too common. The farmer who enriched his land with manure or by turning under grass crops, legumes, or rye was the exception. Continued predominance of the two clean-tilled crops, cotton and corn, in the agricultural economy of the county hindered the adoption of any systematic rotation and allowed erosion to progress rapidly. Land considered good for one particular crop was used for that crop continuously. There are instances of land having been planted exclusively to cotton for a period of 50 years. When it was found desirable to rest a piece of land after continuous cropping in cotton, the piece was usually planted to one crop of corn followed in the fall by a crop of small grain. Another method was to omit the crop of corn from the sequence and sow the land to small grain directly after the cotton.

When one-horse plows were used, it was customary to plow to a depth of about 3 inches. Since the two-horse turning plow has come into use, plowing is deeper, usually 4 to 6 inches. Before the introduction of terracing, plowing was done in straight rows, and in corn tillage it was often the practice to "check" or cross plow. The field was plowed and cultivated first in one direction and then at right angles to the first rows. If the rows last plowed happened to run up and down the hillside the erosion hazard was greatly increased. The building of terraces made it necessary to abandon the straight-row method, and contour cultivation is now used almost exclusively.

Terracing has been used widely since the 1890's, and some farmers adopted the practice as early as 1866. Types of farmer-built terraces are almost as numerous as the farms on which they are used. One set of specifications widely used when terracing was first introduced called for a vertical interval of 3 to 3½ feet between terraces and a fall of about 1 foot per 100 yards along the terrace water channel. The terraces were generally made 4 plow furrows wide, although some farmers made broad-base terraces 12 furrows wide, similar to the type now advocated. Many terraces were run exactly on the contour except near the end, where some fall was given. Because terraces frequently were laid off by eye, without the aid of an instrument, they were inaccurate and their rate of fall varied greatly. Most farmer-built terraces have a fall much greater than that now used by the Soil Conservation Service and terracing associations. Water from most of the terraces was led into some convenient depression such as an old gully, road drain, or ditch along the property line. If no convenient outlet was at hand the terrace water was sometimes conducted down the slope through a hillside ditch with a grade considerably greater than that of the terraces. Some of the worst gullies were started from hillside ditches and unprotected terrace outlets, which eroded rapidly because of their steep gradient.

Many of the old terraces have not been well maintained, and filling of the water channels has converted them into bench terraces. Water flowing over the rim of these flat-topped terraces has caused severe erosion and gullying on the areas immediately down slope (fig. 11). Some of the larger bench terraces are now being regraded mechanically in order to redistribute the accumulated topsoil more evenly over the slope.

FIGURE 11.—Water flowing over the edge of these old bench terraces has caused severe sheet erosion and shallow gullying on the areas immediately down slope. Six miles south of Spartanburg, S. C.

POST BELLUM EXPANSION

The dependence on cotton as the major cash crop increased steadily from 1870 until almost the present time and was paralleled by the growth in the acreage of improved land. By 1890 the total improved land had surpassed the ante bellum high of 1850, and expansion has continued fairly steadily ever since. This growth was largely in the northern part of the county, which before the Civil War was more remote from outlets for its produce than was the southern part. The shorter growing season in the northern area *(11, v. 6 p. 513; 34, p. 19)* had also discouraged extensive cotton production. The introduction of railroad transportation and cheaper commercial fertilizer in the 1870's encouraged cotton raising in the northerly part of the county and enabled the farmers there to mature their crop earlier, thus overcoming the climatic handicap. Cotton production reached its high point during the World War but declined shortly afterward owing to the boll weevil invasion and the low prices of the post-war depression. Production had recovered by 1930, but low prices and crop-reduction programs have since led to further restrictions of cotton acreages.

PRESENT LAND USE AND EROSION CONDITIONS

Since 1929 there has been a marked shift in the utilization of farm land. Although the acreage of land in farms increased 8.4 percent from 1929 to 1934, there was a slight reduction in the acreage of cropland planted (table 7). Farm land of all other classifications was increased, largely as a consequence of the reduction of cotton acreage. As cotton prices dropped, some of the marginal land became submarginal and was diverted to other uses or was abandoned. This is reflected by the large increases in "idle or fallow" land, in "woodland not pastured," and in "all other farm land." Part of the increase of these three classifications resulted from the abandonment of rough gullied land no longer suitable for planting.

TABLE 7.—*Acreage and percentage of farm land in Spartanburg County, S. C., according to land use, 1929 and 1934*

[Approximate total land area 489,600 acres]

Land use	1929		1934	
	Acres [1]	*Percent* [2]	*Acres* [3]	*Percent* [2]
Cropland:				
Planted (harvested and failure)	224,878	45.9	208,124	42.5
Idle or fallow	17,280	3.5	38,502	7.9
Pasture:				
Plowable and other nonwoodland	32,306	6.6	37,982	7.8
Woodland	41,240	8.4	42,639	8.7
Woodland, not pastured	66,951	13.7	92,905	19.0
All other	22,302	4.6	25,891	5.3
Total	404,957	82.7	446,043	91.1

[1] From UNITED STATES BUREAU OF THE CENSUS (*32, v. 2, pt. 2, County table 1, pp. 460-461*).
[2] Percentage of total area of the county.
[3] From UNITED STATES BUREAU OF THE CENSUS (*33, v. 1, County table 1, pp. 480-481*).

The effect of these changes from the standpoint of erosion hazard is suggested even more strongly in table 8, in which the major crops are classified as clean-tilled, or erosion-inducing, and close-growing, or erosion-resistant.

None of the clean-tilled crops offers the soil much protection against the climatic forces. Owing to the character of the cotton plant and the method of cultivation, cotton land erodes particularly badly. It is significant, therefore, that although cotton occupied 27.7 percent of the total land area of the county in 1929, by 1934 the acreage had fallen to 16.0 percent of the total. Corn is also a clean-tilled crop, but gives the soil somewhat more protection, and has a shorter growing season than cotton. After the corn is "laid by" in the summer, the natural growth of grass between the rows may offer some protection against erosion, or legumes may be planted there for the same purpose.

More land has recently been planted to orchards, especially in the northern section of the county. The first orchards on a large commercial scale were set out in 1920.[9] In 1929 the county as a whole had 2,760 acres in orchards, vineyards, and planted nut trees; in 1934 the acreage had almost doubled, the greater part of the increase being in the townships of Beech Springs, Campobello, and Cherokee.

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[9] Personal communication from Ernest Carnes, State coordinator for South Carolina, Soil Conservation Service, formerly county agent of Spartanburg County.

The major plantings are of peaches and apples; vineyards are increasing in importance. Orchards and vineyards are classed as erosion-inducing, because they offer little protection to the soil, especially when the plants are young and during summer seasons when the space between the rows is clean-tilled.

The close-growing crops such as those listed in table 8 help to protect the land against erosion. Although they form a less efficient protection than dense unpastured woodland or natural sod, they are among the best of the erosion-resistant cultivated crops and often are used in horizontal strip cropping to check erosion on sloping fields. The increase in these crops from 4.4 percent of the total land area of the county in 1929 to 10.7 percent in 1934, an increase of 139.4 percent, helps materially to reduce the erosion hazard. The clean-tilled crops listed in table 8 showed a decrease of 21.9 percent from 1929 to 1934.

TABLE 8.—*Acreage and percentage of principal erosion-inducing and erosion-resisting crops harvested and percentage of total area of the county in each crop, Spartanburg County, S. C., 1929 and 1934*

[Approximate total land area 480,600 acres]

Land use [1]	1929		1934	
	Acres	*Percent* [3]	*Acres*	*Percent* [3]
Principal clean-tilled (erosion-inducing) crops: [2]				
Cotton	135,456	27.7	78,500	16.0
Corn	59,031	12.1	69,628	14.2
Land in orchards, vineyards, and planted nut trees (not necessarily harvested)	2,700	.6	4,559	1.0
Sweetpotatoes and yams	860	.2	1,527	.4
Total	198,107	40.5	154,814	31.6
Principal close-growing (erosion-resistant) crops: [4]				
Wheat threshed	5,455	1.1	18,204	3.7
Oats threshed or fed	15,035	3.1	18,127	3.7
All hay crops [5]	1,296	.3	15,821	3.2
Total	21,786	4.4	52,152	10.7

[1] A part of the acreage is listed twice, because on some land 2 crops were raised in the year, as of winter grain followed by summer legume hay.

[2] Acreages of cotton, corn, and sweetpotatoes and yams harvested are from UNITED STATES BUREAU OF THE CENSUS (33, v. 1, pt. 2, County table 3, pp. 488–489). Acreages of land in orchards, vineyards, and planted nut trees are from UNITED STATES BUREAU OF THE CENSUS (33, v. 2, 2d series, County table 6, pp. 510–511)

[3] Percentage of total area of the county.

[4] Acreages for 1929 are from UNITED STATES BUREAU OF THE CENSUS (32, v. 2, pt. 2, County table 5, pp. 482–483). Acreages for 1934 are from UNITED STATES BUREAU OF THE CENSUS (33, v. 1, pt. 2, County table 3, pp. 488–489).

[5] Includes census classifications: "alfalfa," "timothy and clover," "sweet clover and lespedeza cut for hay," "all other tame and wild grasses," and "annual legumes saved for hay."

Many gullies in the Spartanburg area have originated on pasture land, much of which is abandoned cropland now fenced. Owing to soil impoverishment and the lack of a hardy pasture grass the vegetation is sparse. Most of the volunteer grasses of this region provide only a poor cover during the drier months, and overgrazing and trampling by livestock quickly denude the soil, forming bare areas or galled spots where sheet erosion and gullying can gain a foothold. Although tilled land and pasture are highly susceptible to erosion, recently abandoned areas are even more vulnerable. On tilled land the inequalities and minor channels produced by a rain are evened out or filled by cultivation, and future rains cannot enlarge them. On abandoned land, however, rills and channels remain and are enlarged by each succeeding rain so that they quickly grow to large gullies.

Soil erosion has seriously affected most of the agricultural land. Sheet wash has removed 25 to 75 percent of the A horizon from at least three-fourths of the county. Only about one-tenth of the county has lost less than 25 percent of the A horizon, and most of this area is in valleys too small to cultivate or on rough broken land. About 15 percent of the area has been practically destroyed by soil erosion. Even the woodlands, which are chiefly worn-out agricultural land abandoned and grown up to pines, have little topsoil remaining. Land which has never been cleared for cultivation is not necessarily in an undisturbed virgin condition. Almost all such areas have been thinned periodically and have also been affected by fire and by grazing.

Gullies are "occasional to frequent" on about 90 percent of the land. On fields now under cultivation the gullies generally are shallow and are confined to the B horizon. Abandoned fields, however, whether grown up to woodland or covered with younger pioneer plants, are generally riddled with gullies cut deep in the friable C horizon.

Much of the history of land use in Spartanburg County is reflected in the present erosion conditions. The southern half of the county, embraced in the townships of Cross Anchor, Glenn Springs, Pacolet, Reidville, Walnut Grove, and Woodruff, was the first to be devoted to cotton culture. Now it has a slightly higher proportion of woodland and a considerably smaller proportion of cropland than does the northern half of the county. The recent decrease in number of acres cultivated seems to have been greatest in this section, and many old fields, abandoned because of soil depletion, are now growing up in pine woods. Within any area of uniform soil and slope the fields cultivated first and longest are, in general, the ones most severely eroded. The pioneers cultivated first the flat bottom land along the streams and the sloping lands of the valley sides. Now much of the bottom land is buried by silt and sand washed from higher ground. The valley sides are deeply cut by gullying. Present-day agriculture is predominantly on the uplands.

CAUSES AND MECHANICS OF GULLY EROSION

METHODS OF INVESTIGATION

Reconnaissance studies of the character and distribution of gullies in the southern Piedmont show a close relation between gullying and the past and present land use. Many types of irritation of the soil have been produced by man's use of the land, and most of the areas of severe erosion are directly related to roads, ditches, terraces, and other water channels, or to the type of cultivation practiced.

Detailed field observations on typical active gullies have brought to light the major principles of gully formation—the dynamics of gullying in the Piedmont. These principles were derived from study of some 12 representative gullies in Spartanburg County, of which 9 are described in this bulletin (pp. 94–136). In order to establish a permanent record of the present condition of these gullies, to measure the erosion, and to estimate the run-off, each gully and its drainage area was surveyed. Topographic maps on a scale of 20, 25, or 50 feet to the inch were prepared, with a contour interval of 2 feet.

On these maps the positions of individual cutting heads in the gullies were noted, and the major heads have been designated by a key letter and number. Longitudinal profiles down the gullies and their tributaries and cross sections at selected positions aid in giving a full record of the condition of the gully when mapped. Periodic remapping furnishes a record of the gully's growth.

Base maps of the gully areas, on a 10-foot contour interval, have been used for plotting additional information. One set of maps was prepared showing vegetation and land use, and for two of the gullies, maps were made of the erosion features and physical relationships in the gully area (figs. 60 and 71).

Observation of some of the gullies studied has been continued for more than a year, but records on others cover a shorter time. Periodic observations are being continued. Various methods have been used for the measurement of gully erosion. Retreat of gully rims has been computed from stakes driven in the ground surface 5, 10, 15, and in places 20 and 25 feet back from critical parts of the gully rim. Similar stakes have been used in the water channels leading to active cutting heads. From these many stakes, accurate data have been obtained showing the amount of erosion and caving or slumping from gully rims. By comparison with records of rainfall intensity at adjacent recording rain gages, rates of gully enlargement for given precipitation, soil type, slope and land use were determined. Where recession is rapid, frequent measurements are made and the area remapped periodically on a large scale, such as 10 feet to the inch. This has already been done on critical areas at several of the gullies.

FIGURE 12.—Thirty-inch iron rods driven into the gully heads serve as markers from which the headward erosion can be measured.

To measure the rate of cutting of plunge pools, iron rods three-eighths of an inch in diameter and 30 inches long were driven horizontally into the walls (fig. 12) to serve as markers. In a few of the more active heads, selected for especially detailed measurement, a larger group of rods has been used. Periodic measurements from these make possible the construction of a series of accurate profiles showing the manner and localization of the erosion and caving.

Photographs of significant parts of the gullies at various stages and under all weather conditions give pictorial evidence of the changes taking place and of the actual operation of the processes which cause them. Periodic rephotographing of some of the same features gives an accurate record of the erosion. Considerable work has been done during rain periods in order to observe directly the processes which operate. Winter studies have been made of the action of frost in the soil. One entire night in February was spent observing and photographing the growth of frost crystals on gully sides. Pictures taken at frequent intervals throughout the night and during the forenoon of the following day show the ice crystals first growing and carrying soil material upward, then melting and allowing it to fall down slope.

Other specialized methods were used in particular parts of the work. The techniques of the soil scientist, geologist, ecologist, climatologist, and historian all contributed.

GULLY INITIATION

CONCENTRATION OF FLOW OF WATER

Few if any of the gullies in the Piedmont upland have been developed by normal geologic erosion. The natural stream channels of this region are bordered or overgrown with vegetation. Under natural conditions bare sides are the exception. Accelerated run-off of surface waters, however, has so increased the rate of cutting in excess of the geologic norm (*18*) that in many places deep, steep-sided gullies have been formed by incision in the bottoms of old and fairly well adjusted normal valleys (p. 101). Not all gullies follow old drainage lines. Many of the gullies of the Piedmont have been developed where formerly there was no channel drainage.

Almost all gullies result from the acceleration of run-off or from an unnatural concentration of flowing water. Acceleration and concentration of water have been brought about in various ways, and gullies may be classified into several groups on the basis of their origin. Increased amount of run-off results from overgrazing, burning, deforestation, or denuding of the land by cultivation. Concentration of the run-off is caused by construction of roads and railroads, with their accompanying ditches, by construction of terraces and terrace outlets, by contour plowing followed by the breaking-over of furrows during heavy rains, and by stock paths, which in many cases become rills and gullies. Acceleration of the movement of water in stream channels is sometimes brought about by clearing of brush from the banks, a practice which often results in accelerated bank erosion (*26*).

Almost everything man has done to the land has tended to increase the rate of run-off rather than retard the flow. Clearing of land for cultivation removed the protective canopy of tree branches, and the organic litter and humus soon were destroyed or washed away. Cultivation of the ground speeded the removal of the A horizon and left in many places only the less absorptive clayey B materials, which shed a large percentage of the rainfall and cause high immediate run-off. Raising of cattle, sheep, and other livestock, so frequently accompanied by overgrazing, has made the land more vulnerable to erosion, by reducing both the quantity and quality of the vegetation, leaving only a sparse plant cover poorly adapted to absorbing rainfall and slowing the run-off. Paved highways, cities, and other man-made structures allow almost no rainfall to reach the ground directly, but divert it through channels prepared for the purpose. The damage is done where the concentrated flow of water is released onto the unprotected land. Within any area having moderate uniformity of climate, bedrock, and soil type, the slope and the past and present land use are usually the dominant factors in determining the localization of severe soil erosion.

In the southern Piedmont there is a very close correlation between land slope and suitable land use within any one soil type. The steeper the slope the more rapid will be the surface run-off and the greater the tendency to soil erosion. Land use safe for a gentle slope may be entirely unsuitable for a slightly steeper slope. The limiting slopes for different uses vary in different regions. It appears that the steepest slope suitable for any form of cultivation in most of the soils in the Piedmont is about 12 per cent.[10] Much of the worst gullying in the Spartanburg area is on the steep or moderately steep slopes, but gullies, once started, may eat headward into lands which slope only gently or are practically flat.

FIGURE 13.—Many gullies have developed from road ditches and wheel ruts. This hillside road has been abandoned and a roundabout route by way of the concrete highway must now be used.

ROADS AND RAILROADS

Many of the largest and most striking gullies in the Spartanburg area were caused by old roads. Some of the gullies were developed from drainage ditches paralleling the road (fig. 13). Others have

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[10] UNITED STATES DEPARTMENT OF THE INTERIOR, SOIL EROSION SERVICE. EROSION CONTROL METHODS FOR THE SOUTH CAROLINA PIEDMONT. 64 pp., illus. [1935]. [Mimeographed.] See pp. 33, 36.

formed from deep ruts. There are also a large number of gullies, tributary to the road ditches, and lying approximately at right angles to the course of the road. These have developed where water enters the road ditches from terrace outlets or, having passed under the road through a culvert, is released to continue down slope (fig. 14). Many of the older roads in this area have been relocated several times because of severe gullying, and some of the prominent gullies follow roads which are known to have been in use as early as 1819 (*22*, *Spartanburg County Map*.) Little has been done to check erosion along these old routes. Roads have been moved a short distance to one side or, more recently, have been entirely realined.

With the passing of the old unimproved road, conditions have become even worse. Graveled highways and the main routes paved with asphalt or concrete usually have more efficient drainage ditches. Run-off from the prepared or paved surface is immediate and almost complete; ditches are large and carry the accumulated water to a point where it can be discharged conveniently with a minimum of harm to the highway. This flow of water, which during heavy rains may become torrential, soon cuts new channels. Slopes below the road are gullied by water from the road ditches. The area up slope from the road suffers too, but in a different way. Road cuts break the continuity of preexisting drainage lines, and water pouring over the edge of the cut is able to eat back quickly into the fields above. Sears has pointed to the "highway menace" (*25*) in Oklahoma and other younger States, where roads have been laid out on section lines, regardless of the topography, and have therefore disrupted the natural drainage to an unusual extent. Similar disruption is caused in other parts of the country by new straight highways, which make use of deeper cuts and higher fills than did the old carriage roads.

FIGURE 14.—Water from this culvert under a topsoil road has cut a gully 7 feet deep. When the gully penetrates a little deeper into the C horizon, cutting will be greatly accelerated.

In the old unimproved roads, the areas drained were usually small, and the ditches were shallow. The water of excessively heavy rains could cross the road in broad sheets and continue on its way. The introduction of the machine grader, which cuts a sharp V-shaped ditch section, has made the ditches more efficient drains but has also made them much more vulnerable to erosion (*12, p. 26; 25, p. 232*). The tendency to keep all drains free from weeds has made matters still worse. In the Piedmont, roadside ditches often become deeper than they are wide and may even undercut the road although the surface is left intact. In contrast to the erosion along highways is the lack of gullying along railroad rights-of-way. This may be due in part to the use of a flat-bottomed ditch, partly to the less frequent reworking of the ditch sides and profile, and partly to the low gradient of the railroad lines and the consequent low angle of most of their drainage ditches. At many railroad cuts, a diversion ditch several feet up slope intercepts the surface drainage and carries it downhill in a separate channel well away from the track. Although a diversion ditch of this sort may, for many years, keep the water out of the cut, it usually produces a deep gully parallel to the railroad and some feet farther up the slope. The same plan has been used to a smaller extent along some of the highways. It changes the site of erosive activity and thus protects the road, but it does not check the erosion. If the diversion ditch is too shallow or too close to the road, breakage of the dividing wall allows the water to pour down the slope into the road drain.

Culverts tend to cause gullying both at their inlets and outlets. The ordinary pipe type of culvert establishes the base level for its drainage area at an elevation several feet below the surface of the road. The lower end of such culverts may cause cutting unless provided with a suitable apron to lower the water harmlessly to a natural drainage line. This type of culvert allows removal of several feet of soil from the uphill side of the road and promotes rapid deepening of the road ditch. The drop-inlet culvert obviates many of these disadvantages.

TERRACES AND TERRACE OUTLETS

Terracing came into wide use in this area in the 1890's. Although the terraces constructed during that period gave some degree of protection to the fields, they were the direct cause of many of the gullies now present in the Piedmont. In laying out a system of terraces on a field, a farmer commonly arranged to make the water furrow empty at a road, where the disposal of the water became the problem of the highway engineers. Or the terraces might be run to a fence line, often a property boundary, where a ditch led the water straight down the slope. If the fields were too large for the terraces to carry the water all the way across, additional spillways had to be constructed. The dangers of the outlet ditches were not always immediately apparent. The water cut only slowly in the tough clay of the B horizon; but once down into the rotten rock, or parent material, the ditches deepened rapidly. Many of the deep gullies of the Spartanburg area started from terrace drains. The old low terraces were easily overtopped by the water from heavy rains, and where terrace breaks occurred new channels down the slope soon developed. Unless prompt action was taken these too became gullies.

The broad-base terraces in use today are much more efficient than the type constructed 40 or 50 years ago, and more attention is now paid to the safe disposal of the terrace-outlet water. Instead of being allowed to run down an unprotected slope, this flow is spread out over a meadow strip—a broad grass-floored waterway—or it is carried in an outlet channel protected with masonry or vegetation baffles.

Even contour plowing has a tendency to promote gullying, unless the rows are run exactly on a level and are well maintained. If there is a slight sag as the rows cross a draw or depression, water tends to accumulate there and breaks over from one row to another. In exceptional rains this may cause deep rilling, or even the development of a moderate-sized gully.

CLASSIFICATION OF GULLY FORMS

In working with gullies it is often convenient to have some simple means of describing their outline or form. Just as the natural drainage of the lands gives definite information as to the geologic structure and physiographic history of the region, so the gully outline and drainage are related to the physical features and land use of the gully area. Gully forms are controlled in large part by the distribution of terrace outlets, terrace break-overs, road drains, and other channels

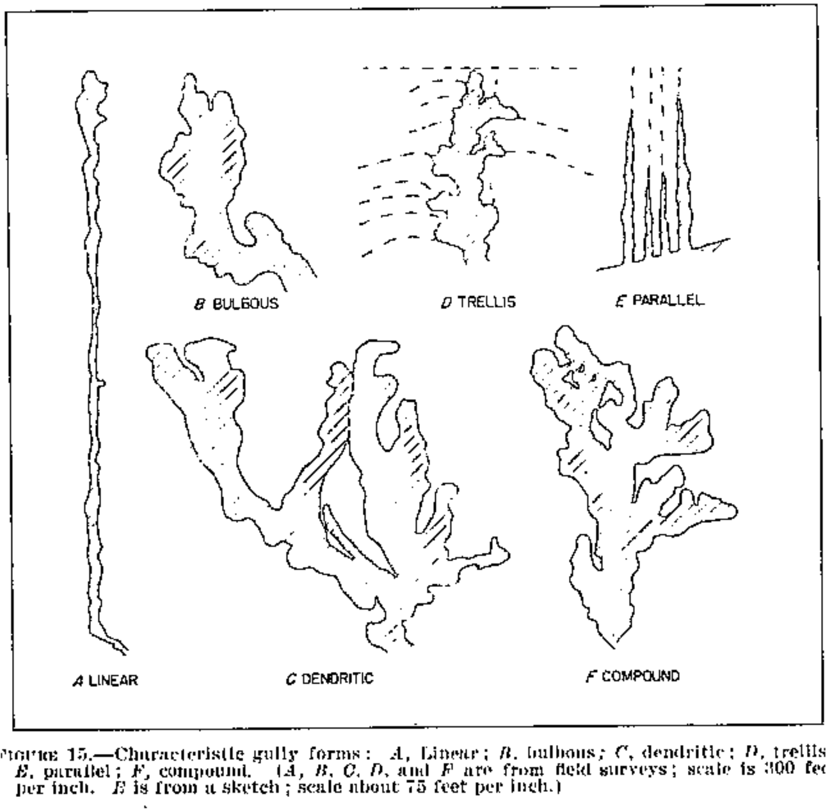

FIGURE 15.—Characteristic gully forms: *A*, Linear; *B*, bulbous; *C*, dendritic; *D*, trellis; *E*, parallel; *F*, compound. (*A*, *B*, *C*, *D*, and *F* are from field surveys; scale is 300 feet per inch. *E* is from a sketch; scale about 75 feet per inch.)

which carry water to the gully. Six of the most characteristic gully forms (fig. 15) are:

A. **Linear**: Long and narrow, with narrow head and few important tributaries along its sides; common along property lines; follows old or existing drainage ditches, many of which have been dug or plowed out to serve as terrace outlets. Linear gullies may grow broader at the head and with further growth may develop a bulbous, dendritic, or compound pattern.

B. **Bulbous**: Broad and spatulate at upper end, but may be linear in downstream portion; incised in upland, often following the course of an old natural drainage having a semicircular or amphitheatre-shaped head with small tributaries or rills entering from all sides. The pattern is likely to become dendritic as the gully grows older.

C. **Dendritic**: Formed of many branching tributaries; usually developed following the natural drainage lines but may be due in part to ditches, terraces, road drains, in a semicircular or amphitheatre-shaped head. Headward cutting along tributaries accentuates the dendritic character.

D. **Trellis**: Tributary gullies or branches enter the main channel at angles approaching 90°; developed on a flat or evenly sloping area where a system of terraces empties into a central terrace drain or outlet. Headward erosion along the terraces further accentuates the trellis effect.

E. **Parallel**: Composed of two or more parallel tributaries which empty into a main gully, as with drainage of old roads where ruts and road ditches run parallel for some distance before coming together into a main gully channel. Headward cutting accentuates the parallel development for a time but capture of one tributary by another is likely eventually to destroy the parallel pattern.

F. **Compound**: Combinations of any two or more of the gully forms. The main channel may have tributaries entering in trellis pattern and the tributaries themselves may be dendritic, parallel, or bulbous.

STAGES OF GULLY DEVELOPMENT

A typical gully in the southern Piedmont passes through four distinct stages in its life history.[11] In gullies that are large or old, there may be considerable difference in character between the head and the lower portions, and several or all of the stages are usually present at one time. The four stages of the cycle thus apply not only to the sequence of events at any one point but to the present condition of the various segments along the length of the gully. The conditions here discussed are characteristic of the Cecil soil and similar types, in which a resistant subsoil overlies weak parent material.

The first stage consists of the development of a channel cut through the topsoil and the upper part of the B horizon. This stage may be brought about by rilling, or may be initiated artificially through excavation of a ditch, furrow, or terrace. The second stage begins when the gully penetrates downward into the weak C horizon; a steep or overhanging head develops and begins to migrate headward by cutting and by undermining and caving of the B horizon. This is the most violent stage of gully growth. The rapid deepening of the channel keeps the walls bare and in an unstable condition, and the active caving of the head of this section of the gully constantly increases the gully area. Additional substages in the growth of the gully may be marked by the headward progression of successive waterfalls, each of which deepens the gully and produces renewed channel cutting. When the gully channel has eroded to a graded condition controlled by some local base level, there is a retardation of erosion. Stage 3 is a period of readjustment. Weathering, slope wash, and mass movement slowly remodel the slopes, and

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[11] The four stages were suggested in a brief report, PIEDMONT GULLIES, submitted by A. A. Normand, December 30, 1934.

the steep, barren gully walls give way to more gentle slopes with talus accumulations at the base. Plants can take root and grow on these more moderate slopes, and as healing continues and vegetation gains control of the situation, the fourth stage, stabilization of the gully area, is attained. New topsoil slowly but steadily is formed and accumulates over the old scarred surface.

Each of these stages is characterized by a more or less typical cross section. In the first or channel-eroding stage the cross profile is shallow, V-shaped, and narrow. This type of section is maintained as long as the gully is cutting in material of uniform consistency. The second stage, that of headward cutting, tends to have a boxlike profile with walls vertical at the top, steeply sloping at the base, and with a narrow but rather flat gully floor. When healing begins, the slope of the walls grows gentler, and the cross profile of the gully becomes more like that of a normal stream valley. When stability is reached the profile is fixed and has the shape of a broad V.

These stages of gully history are developmental and grade one into another. Each is fundamentally different, however, and recognition of the stage reached in the cycle of gully cutting is of great assistance in judging the future hazard and in planning the best means of control.

STAGE 1: CHANNEL EROSION BY DOWNWARD SCOUR

Where rain falls on smooth sloping lands, the water, theoretically at least, flows off as a more or less uniform sheet. Perfectly smooth surfaces, however, are almost nonexistent, and even small inequalities in the slope tend to concentrate the flow of water, forming minute channels or rills. If the material is easily eroded, these rills deepen during each successive rain and, unless filled or obliterated by cultivation, soon grow to gullies (fig. 16) that require special measures

FIGURE 16.—Unless rills are filled or obliterated by cultivation they soon grow to gullies. The young gullies on this denuded land are cutting downward in the tough B horizon.

to arrest their growth. Hillside gullies of this sort usually are cut in a normal, well-drained or moderately well drained soil.

Gullies may be formed also by accelerated erosion of the channel of a normal stream or drainageway. A single torrential rain or freshet has, in some cases, transformed the valley of a perennial or an intermittent stream into a deep, barren gully. In such instances, removal of the vegetal cover within the drainage basin has usually been a causative factor. The normal stream channel may have been adequate to carry the water and its load of debris for all average rains, but may finally have given way under one of torrential magnitude. The soils along streams and in minor drainageways down the hillsides differ somewhat from the average soils of the hill slopes. Those along major streams are usually thick, poorly drained, grayish, and fairly tough. Soils of minor drainageways down hillsides may be identical with those of other parts of the slope except that they are commonly of unusual thickness, owing probably to soil creep.

During the first stage of erosion of a hillside gully, abrasion and transportation are the main processes, as in any natural stream. Water flowing through the gully softens and loosens the soil and then carries it away. Owing to the absence of protective vegetation and of properly adjusted drainageways, cultivated lands are particularly vulnerable, and are subject to rapid erosion. In material of uniform resistance the entire gully tends to deepen and enlarge at a fairly uniform rate, as, for example, in the ruts and drainage ditches along old roads (fig. 13).

In the Cecil and related soil types under cultivation in the Piedmont, the sandy or loamy A horizon is removed by sheet erosion and rilling. Gullying proper makes its start in the resistant clay subsoil, or B horizon. This is in most places fairly uniform in texture but is not necessarily of uniform depth. Many of the gullies cut to a depth of 2 to 6 feet in the Cecil, Appling, Durham, and Louisa soils and have moderately smooth and narrow V-shaped channels. Where the resistant subsoil extends much deeper, V-shaped gullies 10 or 12 feet deep are sometimes seen. The more continuous the slope and the more uniform the material, the more consistent is the size and cross profile of the channel. Cutting is rapid on steep slopes and is slower where the hillsides flatten out.

When the gully channel has been cut almost to the bottom of the B horizon, the material becomes somewhat less uniform in resistance. Minor irregularities are revealed by the differential erosion of the flowing water. These tend to enlarge and deepen, and in many places pot holes develop. Some are only a few inches in diameter, but others are 2 to 3 feet across and of even greater depth (fig. 17). These pot holes are enlarged as the water churns with a circular motion and abrades the sides and bottoms with sand and stones carried along by the current. As they cut into the underlying C horizon, the pot holes enlarge more rapidly at their bottoms, and may be of much greater diameter there than at their necks in the tougher B horizon clay. Under rare conditions, enlarging pot holes may intersect the wall of a deeper and larger gully, thereby producing an underground passageway for the water. As the pot-holing process continues, the lower part of the B horizon is quickly cut away and the gully floor, now cutting entirely in the parent material or saprolite, deepens even more rapidly.

FIGURE 17.—Pot holes 3 feet deep cut in the bottom of a gully channel.

During the pot-holing process, irregular water currents are set up, which tend to undermine the gully walls. This lateral scour may cut many feet into the channel sides, thereby causing higher portions of the wall to collapse.

STAGE 2: HEADWARD CUTTING AND RAPID ENLARGEMENT

When a gully cuts downward through the base of the tough B horizon the rate of erosion usually is increased manyfold. The weak parent material is removed rapidly, and a waterfall develops where the flow plunges from the higher or upstream segment of stage 1, down over the lip of B horizon material into the deeper gorge characteristic of stage 2 (fig. 18). Enlargement of this plunge head and upstream migration of the fall may be caused by lip scour, plunge-pool cutting, caving, and seepage, any or all of which may operate simultaneously.

FIGURE 18.—Waterfall and plunge pool where the flow from the shallow V-shaped channel characteristic of stage 1 falls to the deep, steeper walled channel of stage 2. Upper fall, gully basin L, Foster's Tavern area.

OVERFALLS AND PLUNGE POOLS

Where a gully channel has been overdeepened by rapid erosion in the C horizon, the lateral tributaries and the upper end of the main drainage line may still be eroding in the tough B horizon at a much higher level. They therefore enter the deepened segment of the gully as hanging valleys. Water flowing into the deepened gully from these higher channels plunges to the floor as waterfalls, or in rare cases cascades down the walls. Waterfalls formed in this way tend to carve niches in the gully walls and depressions in the floor, which together are described as plunge pools (figs. 18 and 19).

Gully heads of the plunge-pool type enlarge partly by abrasion at the lip or brink of the fall. Where the material is tough, as in the B horizon of Cecil soils, wearing away of the lip by the action of running water and the sand and silt it carries is extremely slow. Some of the gully lips which were observed for a period of a year showed only insignificant recession.

Erosion and mass movement of the weak C horizon result in caving of the overlying subsoil and are of great significance in the enlargement process. The material of the C horizon is removed in several ways. Surge of water in the plunge pool at the base of the fall soaks the rotten parent material and so softens it that portions flow slowly outward or fall away, leaving the overlying part of the wall unsupported. Spray from the waterfall and splashing from the plunge pool also wet the base of the wall and prepare the way for caving or collapse. Another cause, and one which is often overlooked, is the saturation of the parent material by water which trickles downward from the lip of the waterfall.

FIGURE 19.—Two plunge pools formed beneath lips of resistant subsoil. They are cutting headward into an abandoned field.

When water is flowing into a gully over the lip of a plunge pool, part of the flow plunges clear of the wall and falls to the gully floor. Owing to surface tension, however, a portion of the flow clings to the wall and flows downward in a thin film (fig. 20). As the B horizon of the soil is almost impervious, little water is absorbed there. When the flow reaches the parent material, however, much of it soaks in, and the soft, wet, rotten rock flows or falls from the wall, thus developing a cave with an overhanging roof of B horizon. The surface tension is strong enough so that the trickling water will cling not only to a vertical wall but to the under side of a cave roof or overhang. Some of this back trickle drops from projections in the roof of the cave, but much of its flows down to the C horizon. When wet, this weak material becomes a soft pasty mass. Portions of it break away and slide down the slope, or, if on an overhang, the material falls to the cave floor where it accumulates as a shapeless mass of mud.

Although the back trickling of this thin film of water may at first sight seem trivial, repeated observations during rainstorms have shown that this part of the erosion process produces one of the most dangerous stages in the cutting of the deep gullies of the southern Piedmont. The process is effective not only during rains but as long as any water flows over the lip of the fall. It acts during voluminous flow when the main stream of water shoots far out from the lip and is equally effective when the flow is slight and all of the water clings to the wall. If the drainage area of the gully has a thick absorptive topsoil or layer of plant litter, the flow may be prolonged for hours, or even days, after a storm.

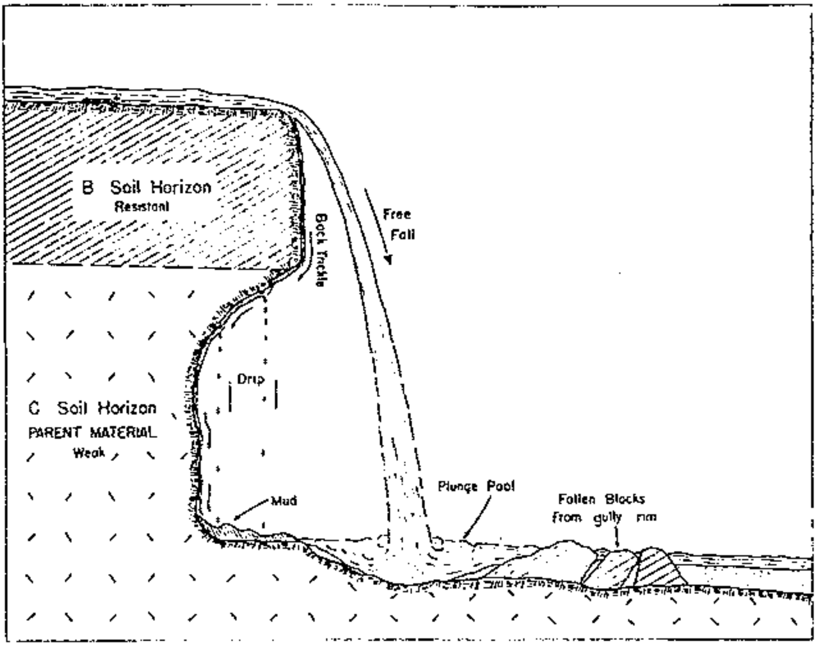

FIGURE 20. Section of a typical gully head plunge pool in a soil having a resistant B horizon and weak parent material. Back trickle along the overhang moistens the C horizon and promotes caving.

Back trickling of water below waterfalls and the part it plays in geologic erosion in the Southwest were described in 1917 by Gregory (*10, pp. 132-133*). He stated that this process and seepage of ground water from the rock wall were largely responsible for the development of rock niches or caves in the head walls of box canyons. Bryan (*3, 4*) later described a similar action which takes place on the under surface of pedestal rocks formed where boulders or other resistant rock masses have protected underlying weaker material from erosion. On several pedestals of this sort near Lees Ferry, Ariz., Bryan observed that the water ran inward along the under surface of the capping blocks to about 3 feet from the rim. There, much of the water dropped to the ground as a drip curtain (*3, p. 3*), or a discontinuous sheet of droplets and threads of water analogous to the sheet of water falling from the eaves of a house. Some of the thin film, however, flowed inward to the top of the supporting pedestal and wetted the top layers of the soft pedestal material. A drip furrow formed at the base of the drip curtain and deepened as little rivulets carried material away from it.

Similar back trickle of water adhering to the under side of sills, cornices, and other projections from buildings would be more common except for the use of a longitudinal groove or gorge on the under side of the protruding member to keep the water from running down the wall. This architectural solution of the problem of back-trickle is worthy of consideration. Even a small groove on the under side of an overhanging cave head of a gully would be sufficient to break the trickling film of water and prevent its reaching the weaker C horizon material lower on the back wall of the cave.

CYCLES OF GULLY-HEAD CUTTING

As erosion of the weak parent material of the soil undermines the tough B horizon, tension cracks develop, and eventually the overhanging block falls. The depth to which the cave in the weaker material can be enlarged before collapse of the lip depends on the strength and thickness of the subsoil and the width of the arch. Periods of cave cutting are invariably followed by periods of collapse of the cave roof, and a simple cycle of activity of these processes may be outlined. The three steps of this cycle are shown in figure 21. In the gully head illustrated, the resistant B horizon is from 2 to 6 feet thick, and overlies a weak C horizon. The depth of the gully in the C horizon depends on the depth of weathering, the grade of the gully floor, and other factors, but typically is 3 to 20 feet. The steps shown in figure 21 are as follows:

STEP 1.—The gully-head wall is vertical or nearly vertical and has little or no overhang. (See figs. 18 and 50.)

STEP 2.—The recess in the C horizon has been cut back by erosion and by the caving of weak material saturated by water from back trickle, seepage, and spray. The overhang of the B horizon is becoming prominent. Plunge-pool action removes the eroded material and increases the vertical drop of the water by lowering the floor. Tension is increasing in the upper part of the B horizon and a crack is beginning to develop. (See figs. 12 and 56.)

STEP 3.—This is the time of maximum recession of the cave and shows a further increase in vertical drop in the plunge pool. There is a marked overhang of the B horizon. Small portions of the B arch may have fallen, and the major tension crack is enlarged almost to the breaking point. (See figs. 19, 22, and 64.)

Return to a former condition.—Collapse of the overhanging B horizon material (figs. 23, 33, and 57) brings a return to stage 1, or 2, depending on the proportion of the overhang which breaks away. The head wall is left with less overhang. Caved material on the gully floor may produce temporary damming of the channel and promote the development of underground drainage.

During moderate flow of water, the base of the waterfall is far out from the rear of the cave. The energy of the fall is dissipated with little effect on the gully head wall except in stage 1, when undermining is promoted. The falling water, however, deepens the plunge basin and brings the gully floor to grade level. The action of the plunge water is also essential for the removal of material which has caved or slumped from the head wall and sides. In places where an unusually large volume of undermined material collapses, the plunge water may be able to break down only the debris immediately at the foot of the fall. The remainder acts as a barrier and, if it completely fills the channel and is impervious, it may pond water temporarily in the gully head (figs. 20 and 54). The standing water softens the material of the C horizon and promotes further caving from above. Water passing over the gully lip and falling on the inner slope of the barrier is deflected back against the head wall and brings about additional cutting and caving. If the barrier is high and much water is poured into the gully the hydraulic head increases and underground channels may be opened through the barrier, or the water may overtop the dam at a low point and rapidly cut it away. Removal of the barrier prepares the way for further caving in the gully head.

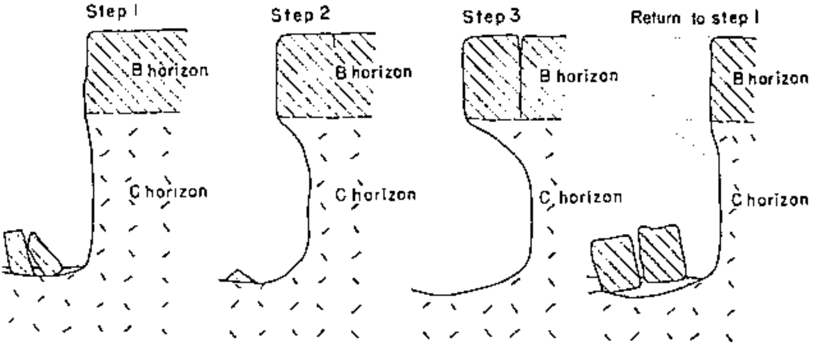

FIGURE 21.—Steps in the cycle of gully-head caving.

If the gully floor is at grade and cannot cut deeper because of control by a local base level farther down the channel, the plunge pool in the gully head may be very shallow. The total depth of the gully may be little more than the thickness of the B horizon, so that the cave in the C material is very low. Owing to the shallowness of the cave, the roof usually is well supported at the sides and may remain in place until the low cave has been extended far back into the bank.

MODIFICATIONS OF GULLY HEADS

Irregularities in the material of the gully walls may modify the shape and rate of cutting of the gully heads. Resistant dikes and veins or harder strata of the bedrock itself may retard erosion or control its course. In places, dikes have held up the overlying soil and rock material, but back-trickling water has softened the material beneath, and a cave has developed; or two caves may be present, one above the resistant rock layer and another below (figs. 18 and 54, head J-1 Walden's gully).

If the channel bringing water to a deep gully is floored with vegetation, the root mat commonly acts as a lip. The water runs off the hanging roots and falls to the gully floor without wetting the head wall. A firm sod cover may sag several feet and still serve to pour the water well out from the gully head and prevent any of the flow from trickling down the wall. Roots of trees and shrubs have somewhat the same effect and help retard gully-head erosion, though usually enough leaks through between them to moisten the weak parent material (fig. 49). The drip of water falling on sloping portions of the gully head from exposed roots and rootlets, carves drip pockets, and these develop into small rills. From time to time the soil between the roots is washed out and they are left bare and protruding. Portions of the root mat periodically fall from the bank, and blocks of the resistant soil mass cave with them.

SEEP CAVES

In a few of the gullies studied, the activity of the cutting head is due mainly to seepage. Gully-head cavities formed in this way are referred to as seep caves. The common association of gully heads with terrace water furrows or drainage ditches produces conditions favorable for seepage, because the concentrated and protracted flow of water in the man-made channels gives every opportunity for the ground to become saturated. In spite of these conditions it has been found that very few of what at first appear to be seep caves are actually caused by seepage. Studies made during heavy rains and at various intervals afterward indicate that, in most gully-head caves, not seepage but back trickle is of major importance. When the trickle stops, the walls of the cave soon become dry.

In a few gully heads, tension cracks a short distance back from the lip allow water to move downward rather freely and emerge as a seep or even a concentrated jet in the cave beneath. This was true of gully head B in the Foster's Tavern area (figs. 22, 23, and 90), which was observed periodically for 14 months. The tension crack gradually widened, thus allowing more and more of the water to go through to the cave and leaving less to pass over the lip. Figures 24 and 25 show the condition on rainy days. The water is entering the crack above and emerging from the roof of the cave below. The lip at this gully head is in an unusually thick and resistant B horizon in Cecil soil, and its form made only one major change in the 14 months in which it was studied. The upper walls of the seep cave lie in a moderately weak C-horizon material which gives way abruptly downward to a vulnerable C saprolite, as is shown by the distinct break of the cave wall in figure 25. Rapid removal of this lower material is mainly responsible for the enlargement of the seep cave.

Prolonged winter rains early in January (figs. 43 and 46) brought about the caving of the arch in the gully head. The channels along

FIGURE 22.—Seep cave in gully head B of the Foster's Tavern area, July 31, 1936. Water from the terrace channel percolates downward through the tension crack near the man's feet and emerges from the roof of the cave.

FIGURE 23.—The cave in gully head B, Foster's Tavern area, on January 14, 1937, after the arch had collapsed as a result of prolonged rains.

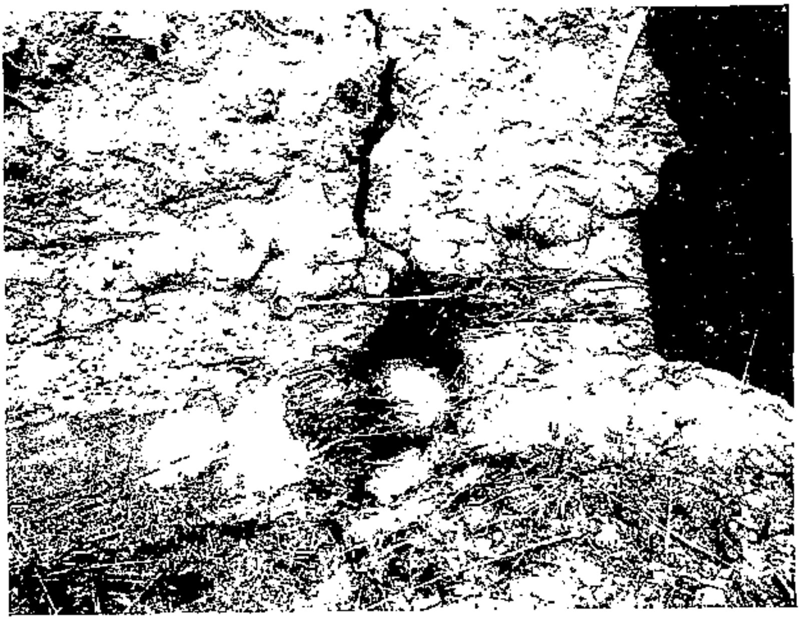

FIGURE 24.—Water flowing from left to right in the terrace channel passes downward through the tension crack to a seep cave in the wall of the gully shown at the right. The striped rod is marked in inches.

FIGURE 25.—Inside of the seep cave at head B of Foster's Tavern area. The seepage water emerges as a jet from the tension crack in the cave roof. Part of it falls to the floor and part flows down the walls as back trickle.

which water seeped through the tension crack and the large size of the cave are shown in figure 23. Until new tension cracks develop and seepage can again take place, this head will be of the true plunge-pool type.

A seep cave along the side wall of another gully had an opening about 3 by 3½ feet and was large enough inside to permit a man to stand upright (fig. 26). Water entered from a tension crack in the bed of an old road bordering the gully. The entire roof caved in during the heavy rains of October 1936.

The caves described in the preceding paragraphs carry water only in wet weather. Others which are fed by springs and are wet almost continuously are sometimes found. Figure 27 shows a seep cave which extends back some 10 feet into the wall in weak material at the base of the Worsham soil. Masses of soil have fallen from the roof of the cave although little or no water trickles down the face of this cut.

CLASSIFICATION OF ACTIVE GULLY HEADS

From the various gullies mentioned above it may be seen that gully heads of different types present somewhat different problems. The

FIGURE 26.—Opening of a seep cave in a gully wall. Water flowing downward from a tension crack in an old road adjoining the gully has formed a cave in which a man can stand upright.

FIGURE 27.—A seep cave 2½ feet high and 10 feet deep, in Worsham soil. This cave was formed by a spring; little or no water flows down the face of the gully wall.

types of gully heads found in Spartanburg County can be classified (1) according to vertical profile and (2) by horizontal plan or rim outline (fig. 28).

On the basis of their vertical profiles, gully heads may be classified into four types.

1. **Inclined:** Low heads entirely within one soil horizon, or higher heads in soils having approximately uniform resistance through all horizons. Inclined heads may be formed also by natural or artificial stabilization, one phase of which, usually, is sloping of the head.

2. **Vertical:** Rather unusual. This type of head may be entirely within one soil horizon or may be in material of uniform resistance; may have weaker material and cave at base concealed by fill except during storm periods; or may be a temporary condition representing step 1 of the gully-head cycle. Sometimes called box head (fig. 21).

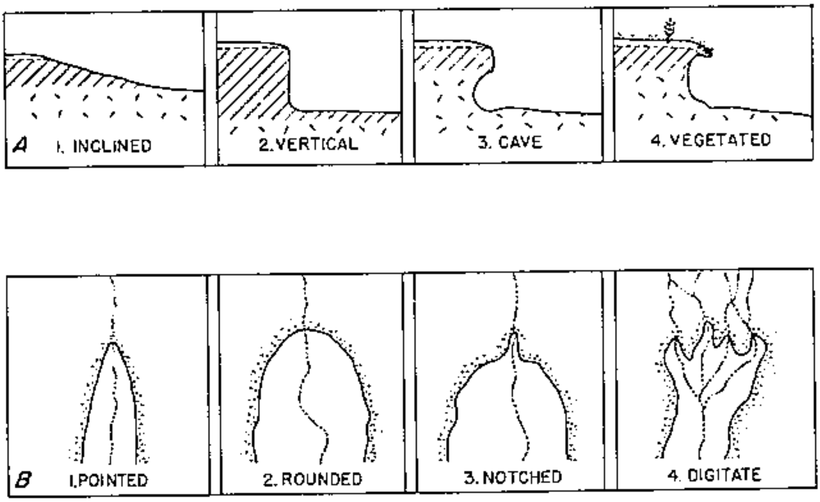

FIGURE 28.—Characteristic types of active gully heads: *A*, Longitudinal sections; *B*, plan views of the rims. Although pointed gully heads (*B*, 1) very commonly have inclined profiles (*A*, 1), and many rounded heads (*B*, 2) have vertical head walls (*A*, 2), any of the profiles shown above may be associated with any of the plan views of the gully rims.

3. **Cave:** The most common type of head in deep gullies where the soil horizons are of different degrees of resistance. A tough B horizon, dike, or layer of rock forms the lip. This type commonly passes through the cyclic changes shown in figure 21. It may be caused by back-trickle and plunge-pool action or by seepage.

4. **Vegetated:** An overhanging root mat or sod forms a spout and keeps the flow of water well away from the bank.

On the basis of rim outline the following types of gully heads may be recognized.

1. **Pointed:** Channel deepens and broadens gradually and uniformly from the narrow, pointed head; usually shallow.

2. **Rounded:** Semicircular, usually with steep or vertical walls.

3. **Notched:** Like rounded head but with sharp notch in the semicircle. This often indicates that the gully rim is in the resistant B horizon but that the channel has cut down into weaker material.

4. **Digitate:** Multiple head with members arranged like fingers on a hand.

Although this classification is based on the types of gullies in the Spartanburg area, many of the forms described can be found in other parts of the country.

MASS MOVEMENT

As the cutting head of the gully progresses up the channel, the segment immediately downstream from the active head enlarges rapidly. This portion of the gully, greatly deepened by plunge-pool scour and caving, continues to be active until the steep walls are sloped back and vegetation can gain a foothold. Water flowing in the gully softens and undercuts the banks. This causes large segments to cave or slump downward, blocking the channel or accumulating as a sloping talus at the base of the wall. Smaller particles break loose, roll or are washed down the wall, and are carried away through the gully channel. These processes are largely responsible for the rapid widening of deep gullies by which they quickly engulf the adjoining fields.

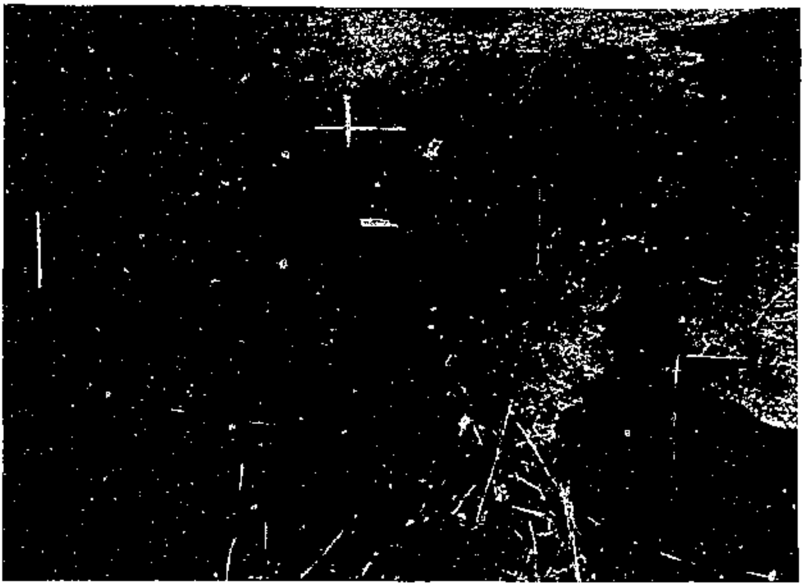

FIGURE 29.—Tension cracks parallel to the rim on the west side of basin A, Littlejohn's gully. (Photographed January 4, 1937, after 7 days of drizzling rain.)

When gully erosion cuts a deep trench into the soil and rock, the equilibrium of the neighboring soil is disturbed. Lateral pressures are no longer equal and there is a tendency for the soil to give or move slightly toward the side of reduced pressure—toward the gully. If the gully walls are steeper than the normal angle of repose for the material under existing conditions, they tend to cave or slough off until the slopes flatten to the angle of repose. Because of the relief of lateral pressure the upper parts of the gully walls have a tendency to lean and cave into the gully. The tension produced in this way is expressed in the field as vertical or steeply dipping cracks essentially parallel to the gully rim and a few inches to many feet back from the edge (figs. 24 and 29). As the cracks widen, owing to wetting and drying, heating, cooling, and freezing, the blocks bounded by them tend to break away and slide or fall into the gully.

Such movement may take place as slumping, in which a block of solid material, or an area of sloping debris acting essentially as a unit, slowly moves downward with backward rotation on a more or less horizontal axis parallel to the scarp. Columnar blocks, and long narrow wedges separated from the gully walls by tension cracks, often slip downward in this manner. Many of the irregular crescent-shaped depressions along streams are evidence of downward and outward movement by slumping (fig. 30). Slump movement is also common on a talus, or slope of loose debris, where material settles downward as fast as it is cut away from the base. Such slopes usually are broken by many transverse crevasses, and water making its way downward through these cracks aids in lubrication of the slump movement. Slips along gully walls sometimes follow old fault surfaces which were developed long before weathering had reduced the rocks to their present friable condition.

FIGURE 30.—Slumping in the light-gray Worsham soil along this small stream was the major cause of the large crescent-shaped depression at the right and of the smaller one on the left bank.

Caving is distinguished from slumping in that caved material tends to rotate forward as it falls. Tension cracks are present, at least in incipient form, on the upland surface along the margins of any steep-walled gully. As these cracks gradually widen, owing to heating and cooling, wetting and drying, or lateral frost thrust in the soil, the blocks are forced outward and, being no longer bound to the walls, fall vertically downward or plunge forward into the gully. It is not unusual for blocks containing many cubic yards to cave in this way (figs. 31 and 52).

The separation and falling of relatively thin sheets from the gully walls is referred to as spalling. Such sheets may be 4 or 5 feet in width and height but 6 inches or less in thickness. As they usually crumble to small fragments on impact they must be seen in action to be fully understood. A photograph of a large spall actually falling in a gully head is shown in figures 32 and 33. Caving and spalling are of great importance during the winter and spring months and during the later stages of run-off from a rain.

On sloping surfaces everywhere, the upper layers of the soil move slowly downhill by soil creep (p. 21 and figs. 8 and 9). This movement is ordinarily too slow to be perceptible and may amount to only several inches or a fraction of an inch per year. It is most active where the lower part of a slope is cut away, as where gullies or streams have carved a deep channel in a valley bottom. The rate at which creep would cause downhill movement of the soil and bring about a closing-in or convergence of gully walls varies greatly according to the soil, the slope, and the moisture content. No measurements of this effect are as yet available.

Soil creep is essentially a flowage within the soil layers though the creeping soil may, in some places, slide over the underlying parent material (fig. 10). Soil at the surface moves the fastest because changes of temperature, moisture, and frost conditions are at a maximum there. Movement decreases with increasing depth, and, unless slippage occurs, there is practically no movement at the base of the subsoil.

FIGURE 31.—Caved material in the upper end of basin B, Littlejohn's gully. (Photographed January 4, 1937, after 7 days of drizzling rain.)

Flowage of the rotten rock or parent material in the lower part of gully walls has sometimes been suggested as one cause of the rapid growth of gullies.[12] Brown [13] considered that this form of mass move-

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[12] BENNETT, H. H. SOIL EROSION AND FLOOD CONTROL. U. S. Dept. Agr. Graduate School Lectures, Jan. 31, Feb. 1 and 3, 1928. [57] pp. 1936. [Mimeographed.] See lecture 3, p. 6.

[13] H. M. Brown. Letter to T. S. Buie, regional conservator, Region 2, Soil Conservation Service, discussing hypotheses of gully growth considered during field trips in the vicinity of Spartanburg, S. C., May 11, 1934.

FIGURE 32.—Head A of Walden's gully, seen during the latter part of the rain of October 16, 1936. Note the thick B horizon of the soil and the large pile of fallen material in the cave head.

FIGURE 33.—The same head of Walden's gully a few minutes later. The white arrows indicate a large spall or slab of the clayey soil starting to fall. A smaller block is about to land.

ment was of major importance during certain stages in the growth of Piedmont gullies. According to this theory, layers of the C-horizon material low in the gully walls or beneath the gully floor flow plastically when they are saturated with water and loaded beyond a certain critical point. If the bottom of the gully is cut down close to the water table, very little surface water may be needed to produce saturation and plastic flow. If the gully floor is far above the level of underground water, more surface water may be required to bring the C material to the saturation point. Water flowing through a gully or stream may saturate the lower part of the walls. This process may be seen to be effective along the banks of certain small streams where saturation by seepage and surface water combined so lubricates the material in the lower part of the bank that it flows forward and downward and allows the overlying drier soil to settle downward usually in the form of slump blocks.

Outflowage of earthy materials in the lower part of the walls of gullies or ravines has long been considered an important phase of the ravine-building process in Sweden (*5, pp. 4–5, 9, 12; 6, pp. 9–10*). Plastic flow beneath the ground surface is known to have caused upward bulging of the bottom of cuts made for railroads, canals, and other engineering projects in the United States, and in some instances, movement has continued intermittently over a long period or until a state of equilibrium has been reached. Conditions in the weathered granitic and gneissic rocks in Spartanburg County are moderately well suited to produce plastic flow in the parent material. No conclusive evidence has been obtained that there is any deep-seated movement on a large scale, but shallower flowage such as that which produced the slump scarp pictured in figure 30 is fairly common where the ground is saturated.

Exposed surfaces of soil or rock tend to break up into small fragments owing to chemical alteration, wetting and drying, temperature changes, frost heave, and the swelling of mosses and algae after dry periods. Bare areas of clayey soil are particularly vulnerable and often develop a thin surface layer of loose crumby or fluffy character, which may be called a crumb mulch (fig. 34). This crumby layer is absorptive and is little affected by light rains, but it is readily removed by showers or rains of greater intensity (fig. 35). During dry weather the mulch crumbs on steep slopes roll and slide downwards, thus contributing to the gradual retreat of the gully walls.

Frost action not only loosens the surface layer of the soil but causes much downhill movement. In bare soils with a high clay content the top layer may be raised by the growth of spew frost or needle ice just below the surface. Water freezing in the clay forms a multitude of tiny ice needles which grow outward from the soil perpendicular to the surface (fig. 36). Other ice layers or lenses may form within the top few inches of the soil. As the needle ice grows, earth and pebbles are raised, sometimes to a height of several inches above the ground. When the ice melts, these are let down by gravity and come to rest farther down the slope (fig. 36). Even greater migration results from the downhill rotation of the ice crystals. Owing to their melting first at the base, the crystals fall down slope, carrying with them the overlying soil and pebbles, and on moderate to steep slopes the crystals and soil materials may slide or roll several feet farther. If freezing is repeated nightly and the needle ice melts again each day, the movement produced by this process can remove a considerable thickness of soil even in a single winter.

FIGURE 34.—A layer of crumb mulch 2 to 3 inches thick on the wall of a shallow gully in Louisa soil. A heavy rain 2 weeks before this picture was taken stripped the full depth of the mulch cover from part of this bank.

FIGURE 35.—Crumb mulch on the wall of a roadside gully. Seepage from the bank and cutting by water flowing in the gully have removed the mulch from the lower half of the wall.

FIGURE 36.—Crystals of spew frost or needle ice 3 inches high, formed on a slope of moist clayey soil on a night in February. Many of the crystals have melted at the base and have fallen forward, carrying their loads of soil and pebbles several inches or a foot or more down the slope.

WASHING OF WALLS

Water flowing down gully walls removes material by sheet erosion and rilling, but it has also certain minor protective effects which are usually overlooked. When crossing the impervious B horizon, which in the Piedmont soils is usually red, flowing water picks up a load of clay and silt. When the water reaches the more porous white to gray crumbly C material lower on the gully wall, much of the clay is deposited and forms a coating or paint usually less than one-sixteenth inch thick, which has somewhat the appearance of stucco (fig. 37). This clay covering sheds water fairly well, and the minute lichens and algae growing in the layer toughen it so that it is broken only by exceptional rains. Where this protective crust is penetrated by running water, the weak C-horizon material erodes with great rapid-

FIGURE 37.—In the upper corners of the picture are remnants of the paintlike coating of clay washed from the B horizon higher on the gully wall. Rainwash and crumbling of the dry material have removed the crust from the central part of the view.

ity, but the coating is soon replaced by the washing of additional clay from above.

A little noted but very common phase of clay painting on gully walls is the development of miniature mudflows (fig. 38). When flowing over loose, finely divided material, drops of water may pick up enough mineral matter to become viscous, and may then make their way down the walls as miniature mudflows, a phenomenon that has also been observed on the walls of gullies in Sweden (*5, pp. 11–12, fig. 7*). As an individual flow progresses, water is lost from the sides and mud is deposited at the margins, where it forms a pair of tiny ridges or natural levees which tend to confine later flows to the same channel. When the moisture has been absorbed or evaporated the flow solidifies and stops, leaving a bulbous ter-

FIGURE 38.—Miniature mudflows of red clay on a vertical gully wall cut in weathered granitic rock. The flows form tough ribs which help to prevent crumbling of the underlying material.

mination and a grooved track. Figure 39 shows several solidified flows with bulbous terminations formed where the gradient of the flows was decreased at the top of a small talus cone. Miniature mudflows are formed on steep slopes and on walls which are vertical or even tilt slightly forward, in which case they have much the appearance of dripping wax on a burning candle. The small mudflows shown

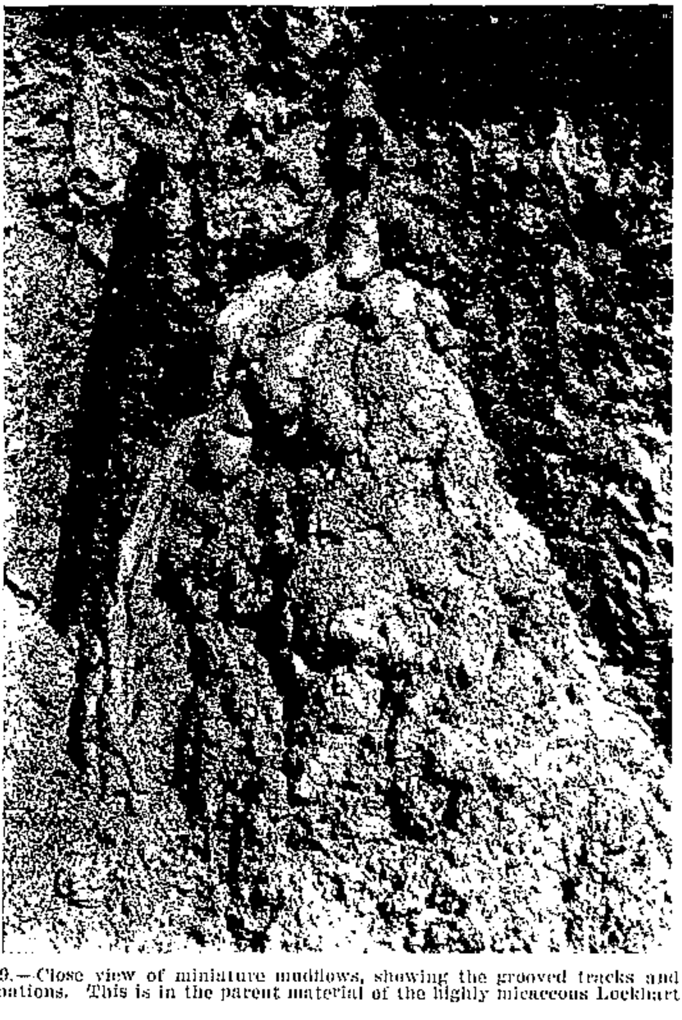

FIGURE 39.—Close view of miniature mudflows, showing the grooved tracks and bulbous terminations. This is in the parent material of the highly micaceous Lockhart soil.

in figure 40 were produced experimentally by allowing a steady drip from a gallon water jug to flow down a small channel and over the edge of a vertical gully wall in Lockhart soil. The pictures were taken at intervals of several minutes and show the natural levees and the way in which the flow shifted from one course to another when the terminal bulb became so large that it obstructed the channel.

Where the flow of water is more dispersed or where the wall is on the under side of an overhang, long, straight mudflows are rare

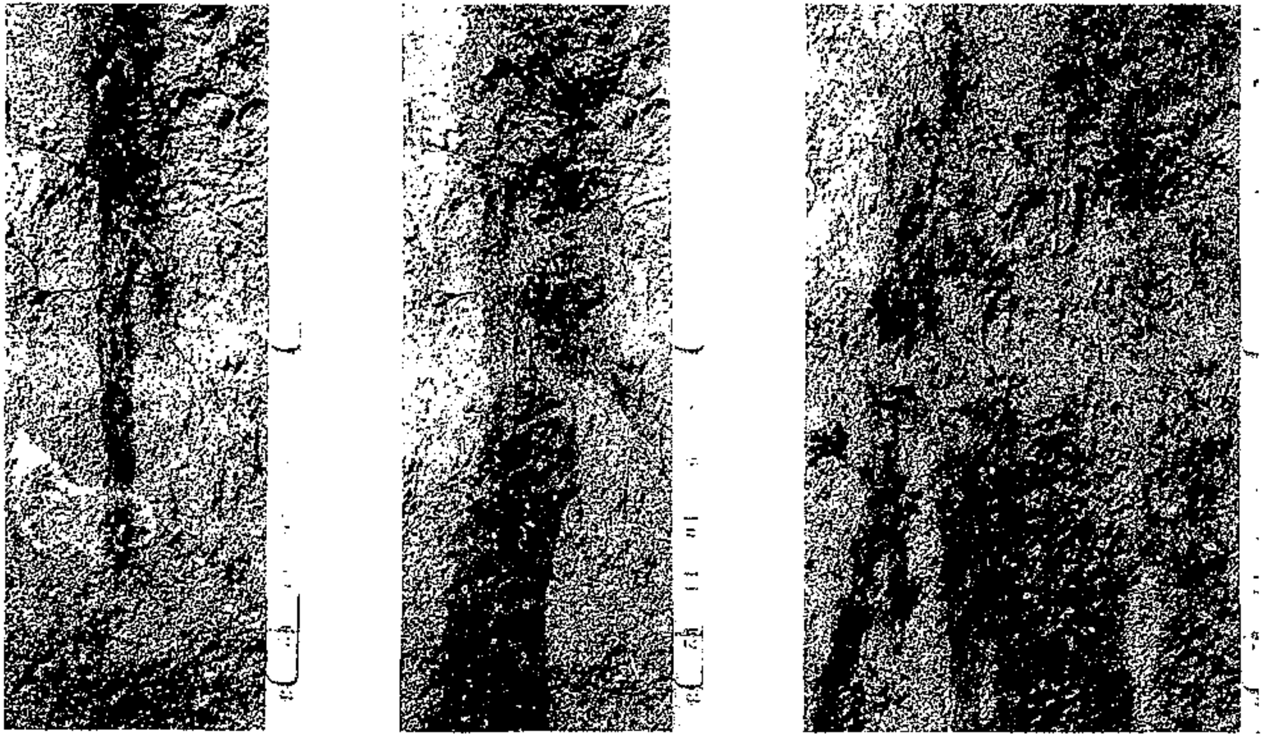

FIGURE 40.—Miniature mudflows produced experimentally on a vertical gully wall by allowing water to drip steadily on the upland surface and run over the gully rim. Successive pictures were taken at intervals of several minutes and show the development of natural levees and terminal bulbs, and the constant shifting of courses. The scale is in inches.

or absent. Instead the surface becomes covered with a multitude of tiny interweaving mud rills of irregular form and intricate pattern. Clay paint, mudflows, and mud rills are present not only on gully sides but often in gully-head caves as well. The protection given by these clay deposits helps to prevent the collapse of loose crumbly surfaces in dry weather, deflects particles of material falling from above, and protects the weak wall against the impact of raindrops.

CHANNEL CLEARING

The rapid enlargement characteristic of this stage of the gully-cutting cycle is dependent not only on headward erosion and wall failure but on rapid removal of the accumulated material from the gully channel. This can be accomplished only by heavy rains which produce run-off of considerable volume. Because of the seasonal character of such rains, gullies tend to become choked by debris during some parts of the year, but at the season of heaviest rainfall the accumulated material is removed. The talus which provides a buttressing effect to the gully walls is cut away, and the walls are prepared for another period of caving and slumping.

STAGE 3: HEALING

The stage of healing and readjustment, which follows the period of most active cutting, is a time of delicate balance in the regimen of the gully. If there are no unusually heavy rains to cause excessive washing, no drought years to weaken or kill the vegetation as it tries to get a foothold, and no human or animal interference in the area, this stage should progress smoothly, and the gully should approach rapidly a stabilized condition. There are, however, many possible interruptions, and the task of healing the gully may be set back any number of times. If the base level that controlled the development of the graded condition in the second stage is lowered or if some other factor causes renewed cutting, the whole gully may be rejuvenated and may revert to stage 2.

The beginning of the healing stage may be brought about in several ways. Natural advancement of the gully toward the drainage divide diminishes the upland drainage area. The proportion of the run-off which flows into the gully head is decreased, and more of the rain falls directly into the gully. Natural or artificial diversion of water from the drainage basin of the gully accomplishes a similar decrease in flow within a shorter time.

As headward erosion is reduced, down-cutting is retarded, and the walls can become graded to a gentle slope suitable for the growth of vegetation. During this stage the water channel remains much as it was in the more active period preceding, but the plunge pools are converted to long sloping heads, owing to the accumulation of material caved from the gully rim. Weathering and washing reduce the slope of the walls, but a low vertical rim may remain in the resistant material at the top of the soil profile. Vegetation begins to grow within the gully; first on the talus slopes, then in the bottom. As the plant cover increases and the root mat becomes denser, erosion is decreased still further, and more and more soil material and leaf litter accumulate in the gully.

STAGE 4: STABILIZATION

The final stage of the gully cycle is reached when the gully channel is graded to a more or less permanent local base level, when the walls have sloped back to approximately the angle of repose, and when vegetation has grown in sufficient abundance to anchor the soil, allow the development of new topsoil, and promote its accumulation. There is no sharp break between this stage and the preceding one. The period of healing is a necessary prelude to stabilization, and the one stage grades into the other.

In the Piedmont, large areas of abandoned gullied lands have healed and have gradually been stabilized by plants (fig. 62). The type of vegetation which takes root in the stabilizing gully and the rate of growth of the plant cover depend on drainage, the angle and direction of exposure of the slope, the soil type, and the sources of seed most easily available. In gully channels kept moist by a continuous flow of water from springs, valley trees such as alder, maple, tuliptree, sour gum, and willow appear. In drier portions of the gully channel and on the talus slopes and walls, vegetation such as pine, sumac, mimosa, blackjack, and post oak becomes established. As a result of the caving and slumping of blocks of soil from the gully rim, grasses, vines, and small woody plants are transplanted naturally to the gully floor and slopes. Honeysuckle, Bermuda grass, young pines, sumac, chinaberry, mimosa, and cultivated plants such as the Himalaya blackberry, rambling rose, peach, and privet have been observed transplanted in this manner in the Spartanburg area.

Barring further active gully erosion, stabilized gully areas will gradually become regenerated, but many centuries will elapse before they develop a new soil at all comparable to that of which they were robbed by a few short years of unwise cultivation.

A stabilized gully should be able to resist normal flow of water, but there is always the danger that excessive concentration of flow may cause renewed cutting or rejuvenation in the old channel. Increase in run-off on the gully watershed is a likely cause of trouble. Even if the gully has worked headward to the drainage divide, stabilization may be upset in other ways. Adjacent gullies eroded to a lower level may cut sideward or headward and intercept or capture the drainage of the stabilized area. This process occurs in nature on a large scale in river captures. It is exceedingly common in gully erosion, and examples of past and impending capture may be seen in many of the gullies described in this bulletin (figs. 69 and 90).

As long as any water flows through the gully there is always the possibility of the cutting out of both the gully floor and its stabilizing vegetation by the upstream migration of a knickpoint or overfall. This must be considered in the construction of check dams, and ample precautions must be taken to protect the dam farthest down the channel against undermining by a headward-migrating knickpoint (p. 74 and fig. 41).

Stabilization, either natural or artificial, is never truly permanent. Constant vigilance is needed to forestall renewed cutting in areas which have once been seriously eroded. Check dams and other

FIGURE 41.—Unless precautionary measures are taken, the knickpoint shown in the foreground will continue to migrate upstream and soon will undermine the log check dam.

control structures must be inspected and maintained systematically if their usefulness is to continue (*9*).

GRADE

During stage 1 the gully was confined to the A and B horizons. The channel was irregular and its grade depended largely on the slope of the surface or on that of the terrace or ditch along which the gully had cut. In the second stage, or period of headward cutting with its plunge-pool erosion and wall caving, the gully grew rapidly both downward and laterally. The depth to which the channel could cut was controlled in part by the resistance of the soil and rock material and in part by the level of hard barriers farther downstream.

Any stream or watercourse tends to deepen its channel until its slope is just steep enough to carry the sediment or load which is delivered to it. If there is an excess of energy over the amount needed to transport the load the channel is cut deeper or degraded. If, on the other hand, the load is too large for the stream to transport, some of the material is dropped, and the channel is built up or aggraded. In a stream having a moderately continuous flow an almost perfect graded condition may be attained. In intermittent streams or in streams having a large range between low water and flood stage the grade may change repeatedly.

Gullies, generally speaking, are intermittent stream courses although the lower ends of many of the deep Piedmont gullies contain a more or less continuous flow from small springs in the channel floor. During a heavy rain a gully channel may be deepened several feet by the removal of material which has fallen or washed into it or by the scour of the current on the solid gully floor. Between rains the caving of blocks from the walls may alter the gradient of the channel and form barriers which must be removed before grade again can be attained. Near the head of an active gully where much of the material thus added to the channel consists of blocks of the resistant B horizon, the gully channel is apt to be steeper. If the C horizon is gravelly or contains an abundance of rock fragments, the general gradient will be steeper than if the material added to the gully bottom is finely divided. The gully channel is deepest when run-off is at a maximum. As the rain slackens and run-off is lessened, some of the material is deposited and the headward portions of the gully floor are built up. When the flow ceases, the angle of the floor is somewhat steeper than the true grade.

In the gullies studied in the Spartanburg area a wide range of grades was found. Gradient was seen to be dependent on many factors such as the position in the gully, character of the soil material, and degree of activity of the gully (fig. 63). The lower end of Cox's gully (p. 115) near Switzer, S. C., is floored with a long sand train having a gradient of only 3 percent. One of the cutting heads (head B) which brings in a heavy load of sediment but not much water, has a gradient of more than 11 percent and has built a sand fan entirely across the main channel where it enters the gully (figs. 42 and 80). The other major head (head A) carries proportionately more water and less sediment, but most of its load is dropped where the flow is impounded by the sand fan of head B (fig. 42).

During stage 2 of the gully cycle, when headward cutting is active, the gully steadily approaches a graded condition, but as long as active downcutting of the channel is in progress there is little opportunity for stabilization of the walls. Deepening of the channel constantly steepens the side slopes, and vegetation has little chance of gaining a foothold. The change from the active cutting stage to the healing stage, then cannot come until the channel has attained, at least temporarily, a graded condition.

FIGURE 42.—View southward down basin B of Cox's gully toward the broad sandy flat, where the main channel has been filled, or aggraded, to a depth of 8 feet.

Even after the floor of the channel has ceased rapid down-cutting, the gully walls continue for a time to cave and wash away and gradually work back to a more gentle slope. Decrease of erosive activity allows more rapid growth of vegetation. Fewer plants are washed out, and gradually the walls attain a good plant cover. The natural pioneer plants that spring up as volunteer growth in gullies which are beginning to heal can be supplemented by the planting of selected erosion-resistant species.

BASE LEVEL

The fundamental principle that streams carve their own valleys and that tributaries enter the trunk streams with accordant junctions was first expressed about 1800. This principle, known as Playfair's law, is well recognized today, and its corollary is also true, namely: When there is a change in level of the trunk stream, tributaries tend to adjust themselves to the new level. If the major stream is cut deeper, its tributaries deepen their channels accordingly; if, on the other hand, the major stream is dammed or otherwise has its level raised, the tributaries deposit material in their channels and build up to the new level. This principle applies not only to major drainage systems but also to small streams and gullies and even to rills developed by sheet erosion.

Many large gullies are graded to the level of a permanent stream into which they empty. The level of the stream, in turn, is controlled by a still larger body of water, or by a barrier which forms a rapid or fall. When the base level of a stream remains fixed for a long period of time a graded condition can be attained, not only on the main stream but on its tributaries. A stable lake level similarly allows streams entering the lake to become graded.

Changes in the level of streams and lakes may take place in a number of ways. Stream levels may be raised naturally by damming of the channel by landslides, fallen trees, brush, or ice, or artificially by the work of man. Lake levels may be raised in the same way by increasing the height of the outlet. Water levels may be lowered by (1) destruction of a barrier or dam which forms the local base level; (2) increased erosion, owing to greater volume of water or faster run-off; or (3) clearing of vegetation along the stream channel or lake outlet, thus allowing faster movement of floodwaters (*26*).

If the lowering of base level is gradual, the result in a tributary gully or stream valley may be a slow uniform down-cutting. More often, though, the change in base level is rapid. The main stream cuts downward quickly but the tributaries, having a smaller volume of water, do not quite keep pace. Rapids or waterfalls develop where the tributaries enter the main stream.

KNICKPOINTS

Falls or breaks in the grade of a stream or gully profile are spoken of as knickpoints. Upstream migration of a knickpoint may deepen a gully or stream channel by a number of feet, destroy much of the healing which has taken place, and temporarily return that segment of the channel to stage 2 or to what we may call a subdivision of stage 3 of the cycle of gully cutting.

Similar waterfalls or rapids may be present within a fairly inactive gully and if held up by tree roots, fallen trunks, patches of sod, or resistant rock materials, may remain at the same site without advancing headward for many months or years. If the soil or parent material contains layers of unequal resistance to erosion or if a mat of roots covers the channel of the gully, the knick is usually vertical or overhanging. In these cases the more resistant soil, rock, or vegetable matter holds up the top of the step, and a cave may develop in the weaker material beneath. The headward advancement of this step, as erosion continues, is accomplished chiefly by repeated breaking off of the lip and the caving in of the sod and trees when the old gully floor is undermined. If the material is homogeneous, or if little vegetation is present to toughen the gully floor, the knick is commonly less abrupt and may be a rapid or a series of small steps.

Old knickpoints in a gully may renew their activity or new knickpoints at weak places in the gully floor may be initiated if the rate of cutting in the gully is increased. If additional water is diverted into a gully by rearrangement of natural drainage, by construction or alteration of road drains or terraces, or by the breaking over of poorly maintained terraces, erosion may be accelerated. Removal of vegetation within a gully or on land in the drainage basin above the gully by clearing, burning, or overgrazing may likewise produce more rapid run-off and greater damage by erosion. Removal of absorbent topsoil from the gully watershed leaves an erosion pavement (*28*) of stony or clayey subsoil which sheds water rapidly and allows little to soak in (fig. 16).

The erosion hazard of active knickpoints is seen clearly in the Spartanburg area, as well as in other parts of the country, where gullies which for a long time were apparently stable have renewed their activity and are again cutting both headward and downward. Vegetation is being undermined, and the slope of the gully walls is becoming steeper. The area is reverting to an earlier stage of the gully-erosion cycle.

RATE AND AMOUNT OF GULLY EROSION

It is well known that although some of the Piedmont gullies have been growing for many decades, others have formed in a much shorter time. Information as to their rate of cutting or period of development, however, is rather scarce. Many factors control the rate of gully formation. The size and slope of the drainage basin, the land use, the character of soil, and the depth and shape of the gully head all are important. Meteorological conditions such as total precipitation, intensity of precipitation, the seasonal relations between intense precipitation and frost and cropping of the land, and the rain pattern itself all affect the resultant erosion.

In the study of the rate and amount of erosion of gullies in the Spartanburg area, recording rain gages were installed close to the gullies being observed, as mentioned in the section on climate. Stakes were set on the upland surface at regular intervals from the gully rim, iron rods were driven in the gully heads and walls, and maps, sketches, and photographs were made periodically to record the amount of erosion. The studies included not only changes in gullies or gully systems as a whole, but in individual gully heads and small segments of the walls.

SIZE AND CHARACTER OF DRAINAGE AREAS

It will be seen from the detailed topographic maps which were prepared for the gullies that there are great differences in the areas drained by individual gully heads. Area alone, however, does not control the rate of cutting. The slope of the drainage basins is a vital factor and can be estimated from the topographic maps. The type of land use in the drainage area may make extreme differences in the rate and amount of run-off. Rain falling on a paved highway, for example, runs off immediately and almost completely. Barren land that is eroded down to the B horizon in clayey or gravelly soil gives the most rapid and complete run-off of any soil area, and, depending upon the intensity of the rainfall, this may be as much as 95 percent. Such areas of eroded B material are present around several of the gully heads here described (fig. 16). The relative rates of run-off for various tilled crops such as small grains planted broadcast or drilled, for open cultivated crops such as corn and cotton, for cultivated lands on A, B, and C horizons of various texture and structure, for orchards, for forests, and for grassland on different slopes have been studied by agricultural colleges and erosion experiment stations throughout the country and have been shown to vary widely.

The depth and shape of the gully head also control the rate of erosion. If the head is shallow and entirely within a tough B horizon, as in stage 1 of the gully cycle, erosion is relatively slow. Deeper plunge-pool heads, the lips of which cave owing to undermining, may erode with extreme rapidity.

METEOROLOGICAL FACTORS

The annual precipitation in an area does not necessarily bear any close correlation with the rate of gully erosion. If the precipitation comes as slow drizzles throughout the year or as light rains during the period of maximum ground cover, the land may erode very little. If, one the other hand, precipitation is intense, the destruction may be rapid even though the annual total be small. For this reason average rainfall means little as an indication of regional erosion hazard. To say that an area receives an average of 50 inches of precipitation a year does not mean that erosion will be more severe there than in an area of 20 inches of precipitation or any less severe than in one of 100 inches average annual precipitation.

In the same way the customary method of tabulating rainfall by a daily total is unsatisfactory as an indication of erosion hazard. Only under unusual circumstances would the rainfall for each hour of a 24-hour period be approximately uniform. It is far more likely that the day's total would be made up of one or more periods of heavier rainfall separated by periods of drizzle or complete lack of precipitation. On a rainfall record running from 8 a. m. to 8 a. m. a rain lasting from 7:30 a. m. to 9 a. m. would be divided into 2 days although the entire storm lasted only 90 minutes and occurred on a single calendar day. Such a storm would appear on the record no differently from two separate rains, one of which may have occurred in the middle of the morning of the first 24 hours and the other about dawn at the end of the second 24-hour period. Such records give no indication of the ability of the rain to erode. In studies of soil erosion, the storm rather than the daily precipitation must be taken as the unit of rainfall, and precipitation records so far as possible should be continuous, so a sto show actual intensities rather than accumulated totals. Rain sequence is also a significant factor in erosion hazard. A shower falling on soil thoroughly wet from prolonged rains is likely to have a high percentage of run-off, whereas a rain coming without preliminary soaking of the ground has a better chance to be absorbed.

The periodicity and character of the storms in the Spartanburg area from July 10, 1936, to July 9, 1937, and their effect on gully erosion are shown in graphic form in figure 43. The record of precipitation was taken with recording gages of the weighing type, which register for both rain and snow.[14] The amount of precipitation and its intensity are shown by the heavy solid line, which is comparable to the tracing made by the recording pen of the gage. The daily total is indicated by the bar graphs along the base line.

The meteorological situation responsible for the rain is also shown. During the summer months many of the rains are convective and usually occur along a cold front. Some are thundershowers; others are instability rains unaccompanied by thunder or lightning. In contrast to these are the prolonged, widespread warm-front rains, which are seen to be more common during the winter and spring months. These terms, warm front and cold front, apply to the character and position of the air mass responsible for the rains (fig. 44). A warm-front rain, for example, is formed where a mass of warm air actively overrides a passive mass of colder air. In doing so the warm air rises and is cooled until condensation takes place. The precipitation that results is generally more or less prolonged and extensive. A cold-front rain is produced where a mass of cold air at the earth's surface pushes forward beneath a passive body of warmer air, forcing the warmer air aloft and again causing precipitation by cooling of the warmer air. Cold-front showers, however, are characteristically of short duration and spotty distribution. Thunderstorms are frequent along cold fronts during the summer months. Convective storms of the instability type may result from the heating of the land and lower air during the warm daylight hours even though not controlled by frontal conditions. The positions of warm and cold fronts can be interpreted from the standard daily weather map of the United States Weather Bureau. A study of these fronts and of the relation of rainfall to the cold and warm air masses is a marked aid in interpreting the potential damage to be caused by the storms.

The erosion hazards created by these two types of rain, cold front and warm front, are sufficiently different to demand further explanation. Cold-front rains in the Spartanburg area are shown in figure 43 as occurring frequently from July to September and less often in the colder months. The intense nature of these rains is shown by the steep gradient on the intensity graph. (See August 7 and 16 and September 3.) Their spotty distribution, however, shows only when records from a number of stations are available. In figure 45, *A*

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[14] The record from July 10 to October 22, 1936, was taken from the Nesbitt gage, maintained cooperatively by the U. S. Geological Survey and the Soil Conservation Service. The record for the period after October 22 was obtained from the Layton gage, installed and maintained by the Section of Climatic and Physiographic Research of the Service.

the rainfall of August 8 for the Barry and Nesbitt gages is plotted by ½-hour periods. (See fig. 6 for location of the stations.) Although the Barry gage is only 8½ miles northwest of the Nesbitt gage, the rainfall at the Barry gage started sooner, was almost five times as heavy, and lasted more than twice as long. On September 3 (fig. 45, *B*), in another cold-front thunderstorm, the rainfall at the Nesbitt gage started sooner, was more than three times as heavy, and lasted longer than at the Barry gage. Records from other gages (nonrecording type) within 10 or 15 miles show even greater divergence.

The rains of October 15–16 were of the warm-front type probably complicated by convective showers. They were much more widespread than those of August and September and showed less variation in intensity between stations. Figure 45, *C* shows the close similarity in intensity and timing of that rain at the Barry and Nesbitt gages. Although in its wide distribution this rain is characteristic of the warm-front type, its high intensity indicates that it was due to a combination of causes. More characteristic warm-front rains occur in the winter months. The rain of January 1 to 3, 1937, for example (fig. 43), shows a much gentler gradient, which indicates a lower intensity. The records of individual gages (fig. 46, *A*) show marked similarity in the pattern of this rainfall, not only for stations within 14 miles south and east of Spartanburg but also at another gage at Lancaster, S. C., 70 miles to the east. The steadiness of the rainfall, which let up only for short periods during the 2½ days, is typical of the warm-front type. Another characteristic warm-front rain came on February 20 to 21, 1937, (figs. 43 and 46, *B*). The timing of the fall was uniform throughout the Spartanburg area and was similar, although slightly delayed, at Lancaster.

Because of the differences in the types of rainfall predominant at different seasons, the rate and manner of enlargement of gullies varies markedly from one part of the year to another. The winter and spring are essentially times of wall caving. Summer and fall are characterized by channel clearing. The prolonged, drizzling, warm-front rains of November, December, January, and February, saturate the ground and cause a maximum of caving from the gully rim but rarely have sufficiently rapid run-off to carry much of the material down the channel. In contrast to these the intense cold-front storms of July, August, September, and October, and the occasional tropical cyclones of the same period give heavy run-off, which clears out the debris-choked channels and removes the blocks of caved material at the base of the walls. No study could be made of tropical cyclones in action as none passed through the area during the observation period.

The rapid growth of the deep, caving gullies of the Piedmont results from the combined work of these seasonal processes. Caving and slumping of the gully walls without removal of the material would be a self-limiting process. The gully would, in time, become so choked with its own debris that further caving would be impossible. This condition is sometimes approached in the spring months when the gully walls are well buttressed by piles of fallen material, reaching up to or above the base of the B horizon and preventing the enlargement of the caves in the C horizon, which prepare the

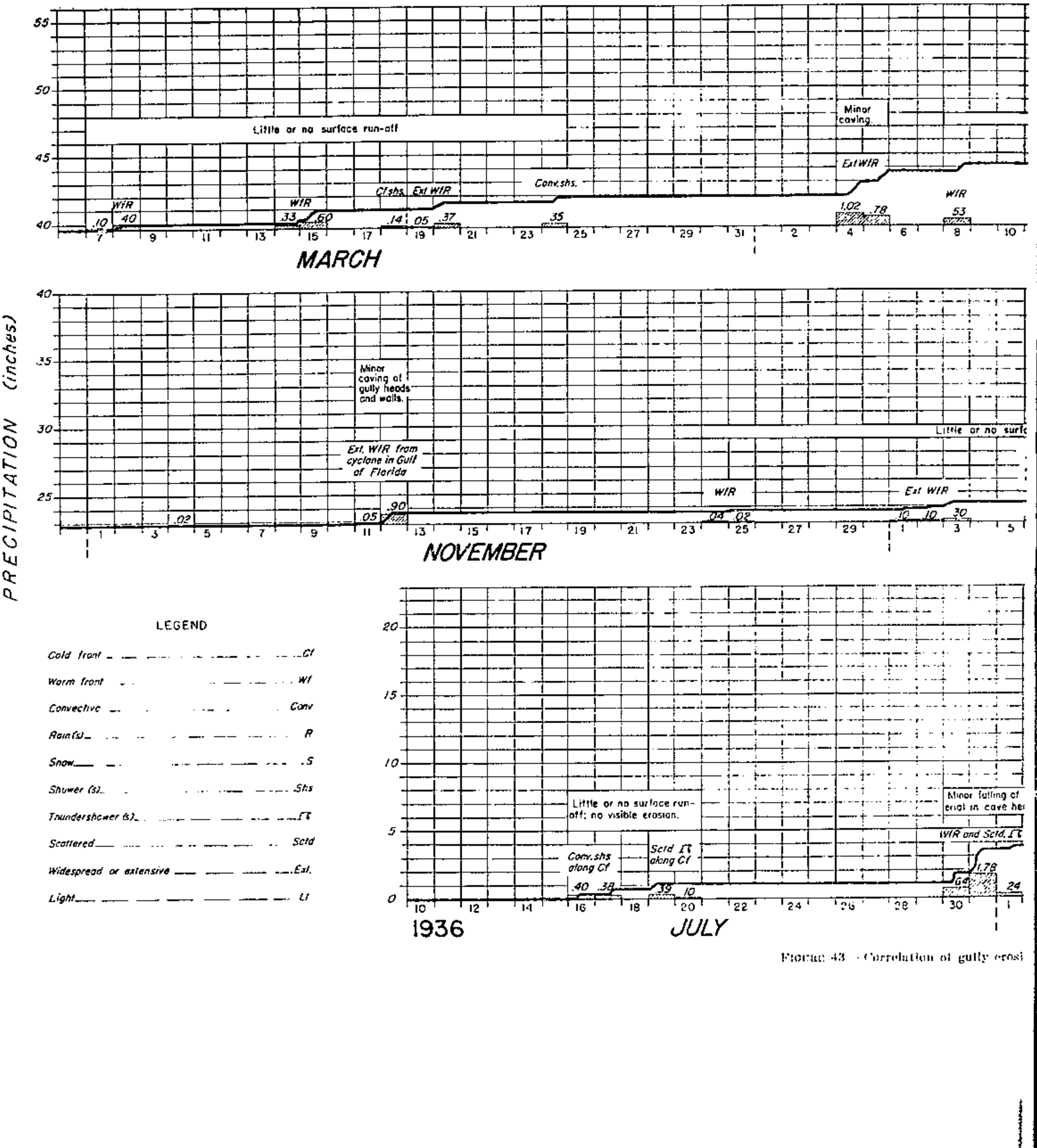


FIGURE 43.—Correlation of gully erosi

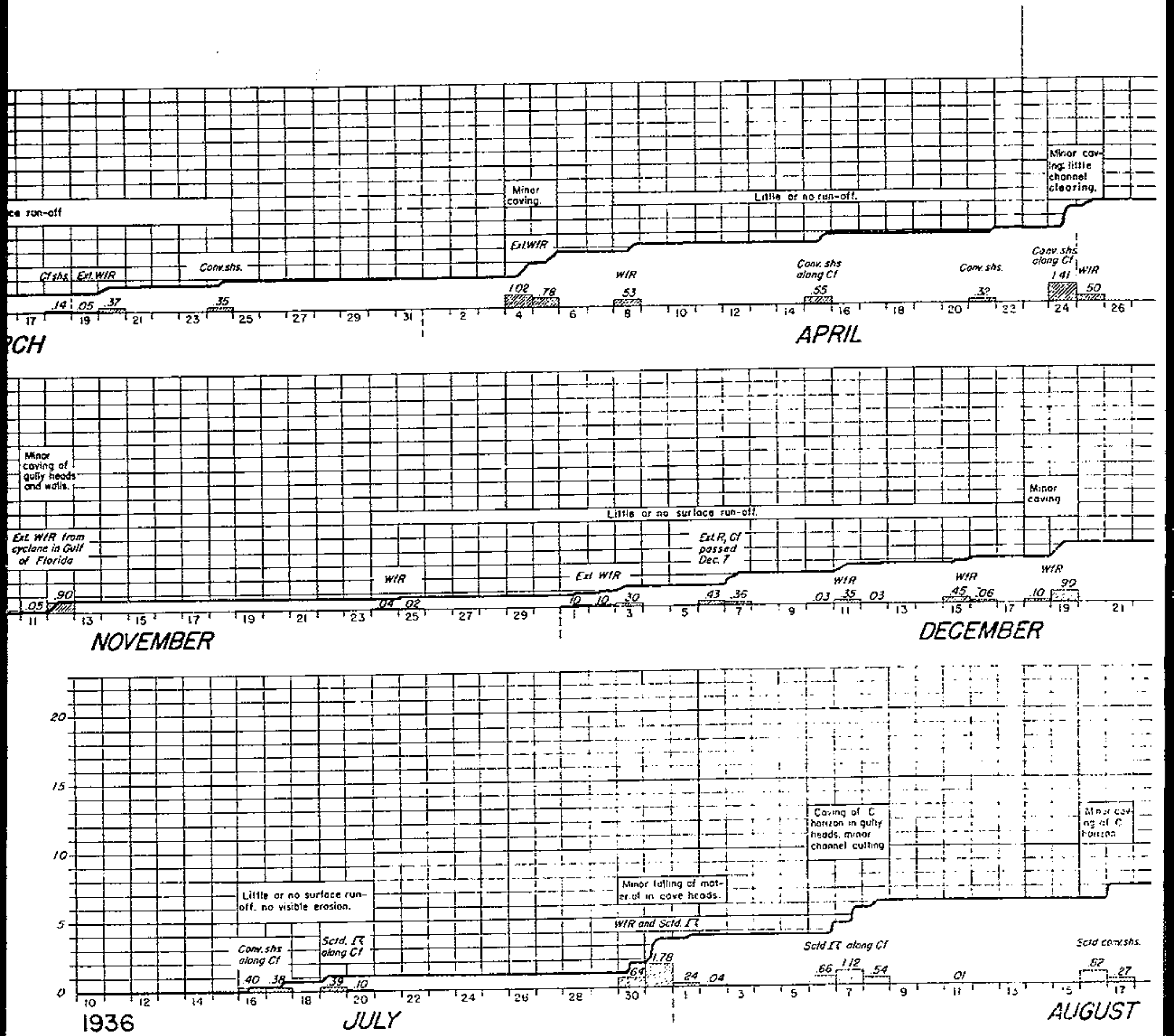
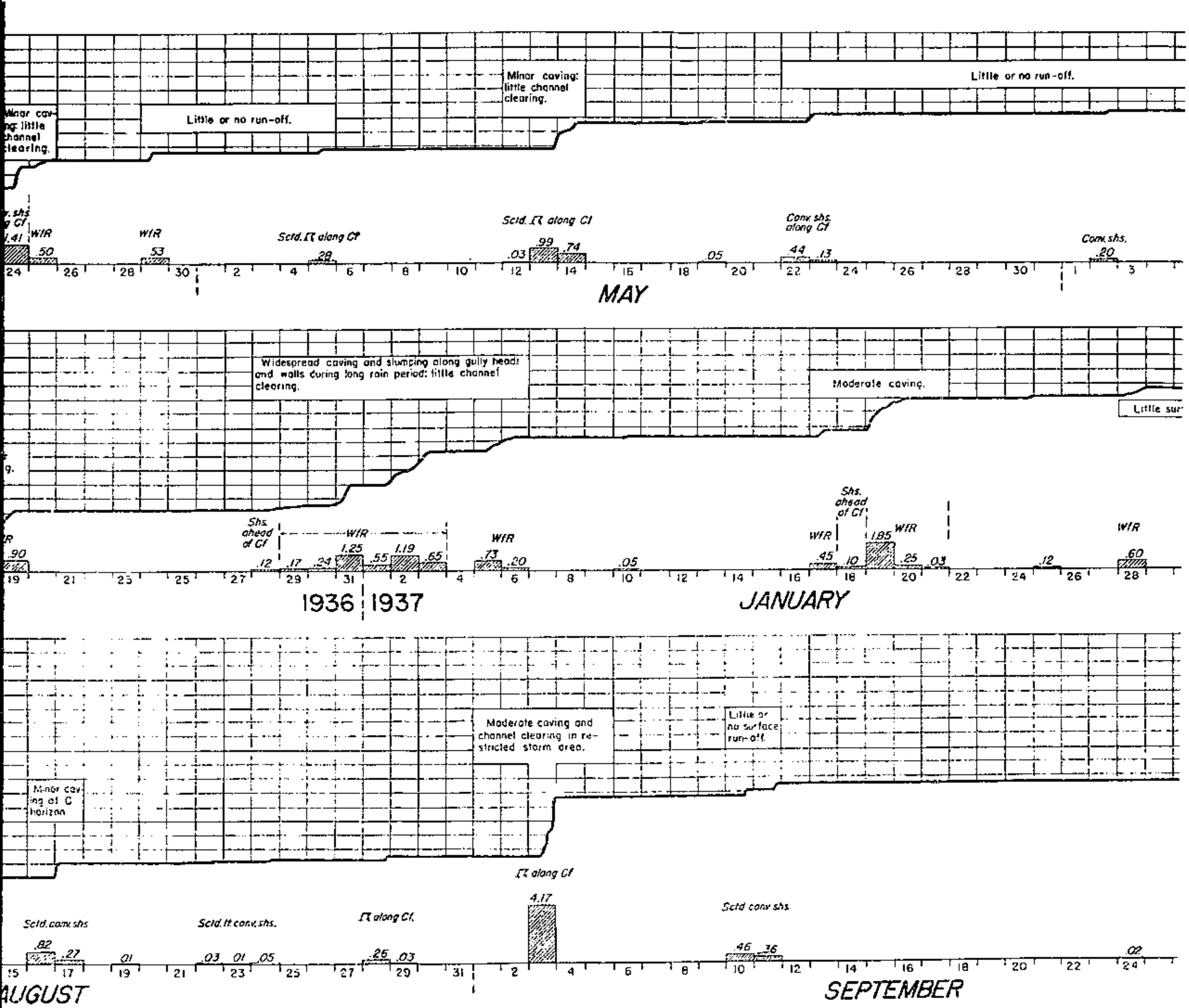
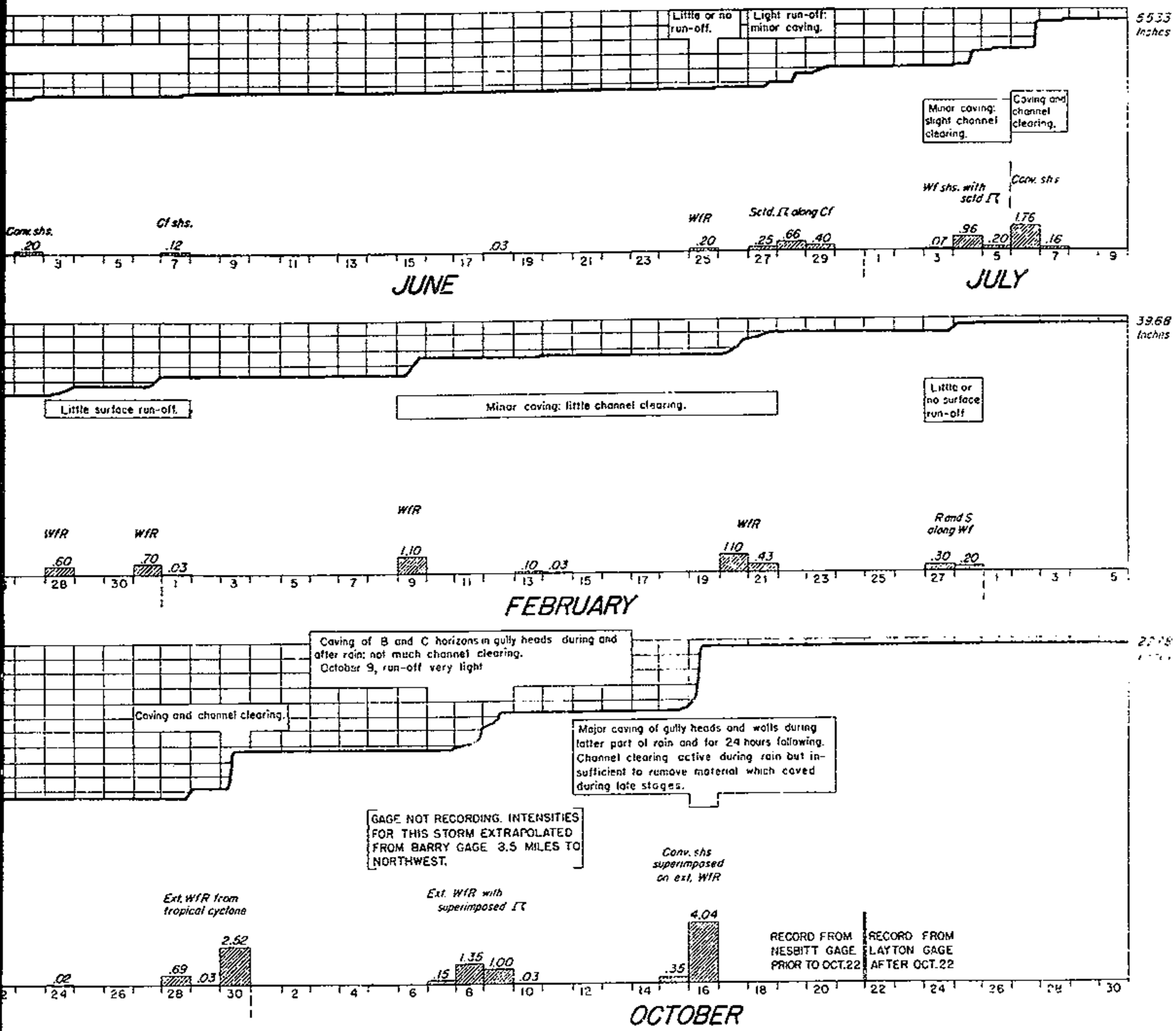


FIGURE 43.—Correlation of gully erosion and precipitation near Spartanburg, S. C., from July 10, 1936 to



ly 10, 1936, to July 9, 1937 The heavy solid line indicates the amount and intensity of precipitation its time of occurrence, and its duration Daily totals are shown by the



e shown by the bar graphs along the base line.

way for major caving of the gully rim. Accumulation of slopes of fallen material is thus one of the best protections against gully enlargement. When channel clearing washes away the debris from the base of the gully walls, the C horizon is exposed to removal by trickling waters or is free to flow slowly forward as a plastic body.

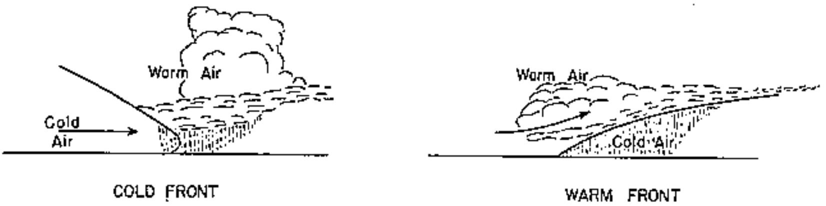


FIGURE 44.—Vertical sections through a cold front and a warm front, showing the distribution of rain in each. The vertical scale is greatly exaggerated.

Either type of removal leaves the overlying resistant soil without adequate support and prepares the way for additional caving from the gully rim. Although caving is most characteristic of the winter season, it can take place at any time of the year. It is not caused solely by drizzling rains, but may result from heavy showers if they are sufficiently prolonged to cause thorough saturation, or if they chance to follow soon after other rains which have partially soaked the ground.

OBSERVATIONS ON EROSION OF GULLY HEADS AND WALLS

During an observation period of almost a year, some of the gully heads of the Spartanburg area showed little or no change. Others receded 10 to 15 feet within a few months but were practically dormant for the remainder of the year. The seasonal variation in gully activity suggests that by careful timing of gully-control measures man might take advantage of the work already done by nature. If water is diverted from a gully at a season when much material is collapsing from the walls the necessity for artificial filling can be avoided. In the absence of flowing water the caved material will remain in place and form slopes on which vegetation can gain a foothold. This is the first step toward ultimate stabilization.

LAYTON'S GULLY

One of the most extreme cases of rapid enlargement was in the lower segment of Layton's gully (fig. 58 and p. 101). When this gully was visited on July 11, 1936, there was evidence that the main channel below J, the junction of the two tributaries, had been eroding rapidly. That part of the gully followed the course of a natural stream through mixed woods and had cut 10 to 15 feet below the old valley floor. The recent renewal of cutting in the main channel was caused by water from the west tributary, which drains an area of 1.15 acres of severely eroded corn and pea fields that have an average slope of 13 percent.

Little change took place in this part of the gully from June 11 until the storm of October 8 and 9 (fig. 43). Head J, where the

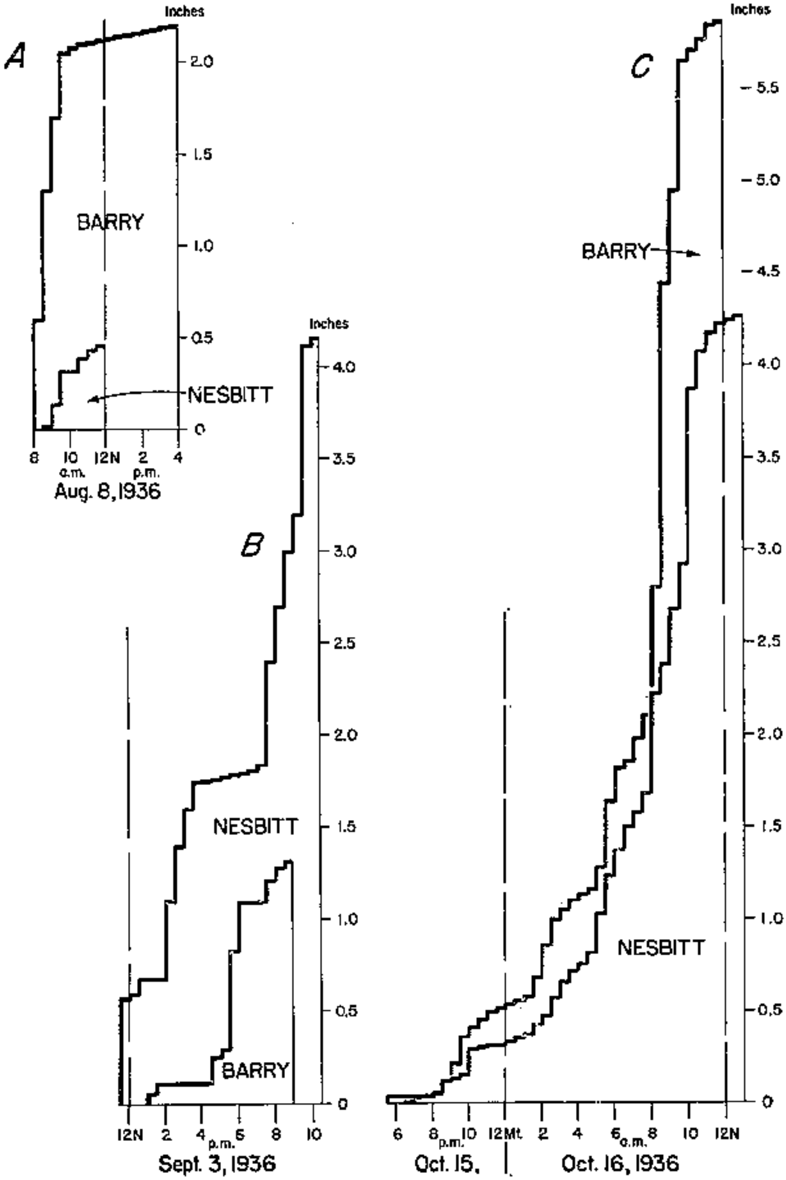


FIGURE 45.—*A* and *B* are characteristic of the action of local thunderstorms along cold fronts; *C* represents a warm-front storm probably complicated by convective showers. Note the greater similarity of the rainfall at the two stations in *C* than in *A* and *B*.

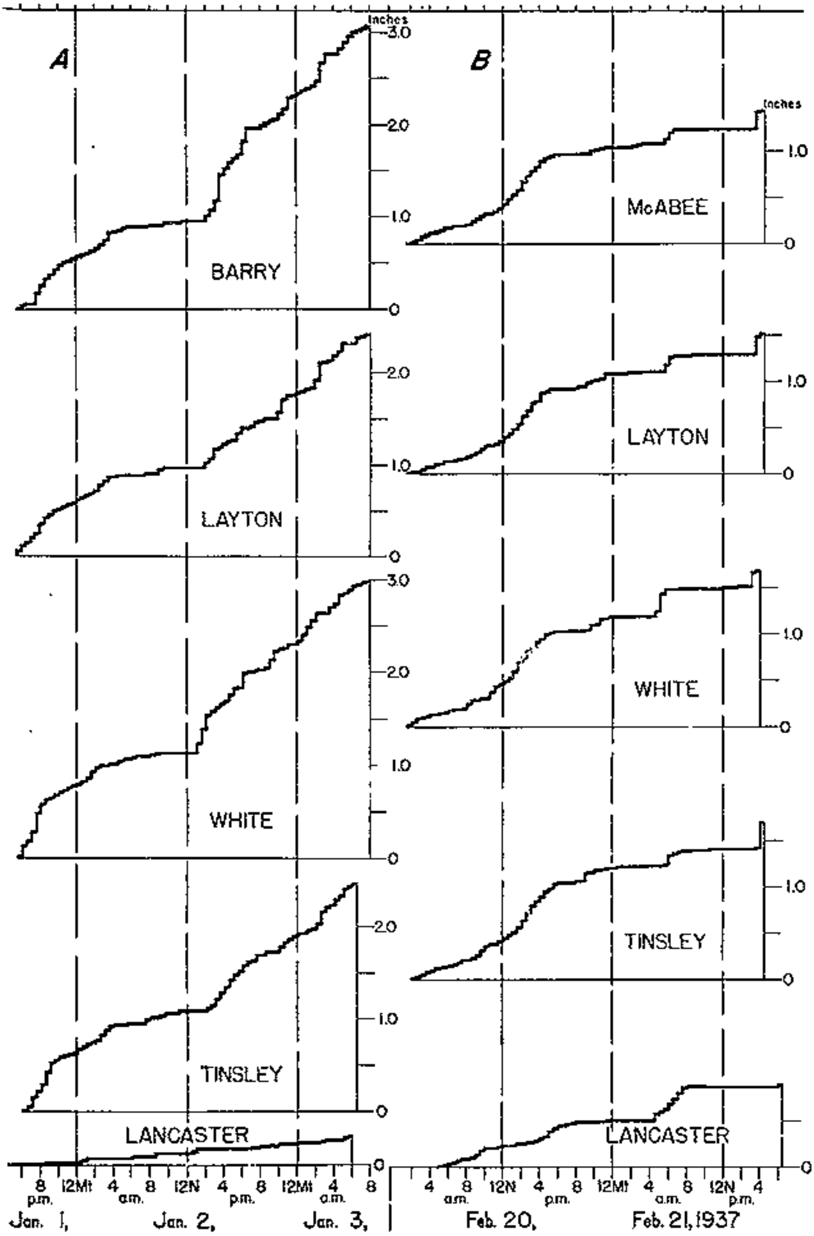


FIGURE 46.—Characteristic widespread winter rains along warm fronts. The records of all five gages are very similar although the station at Lancaster is 70 miles east of the other four. The vertical and horizontal scales of this figure are half as large as those of figure 45.

west tributary enters, was cut back slightly during that rain, and a small amount of caving took place. The changes were relatively slight, however, and conditions remained much as they were during the summer (figs. 47, 49, and 51). On October 15–16 the area received a rain of unusual intensity. The gage at the Layton gully had not been set in operation at that date, but at Nesbitt's gage, 3 miles to the southeast (fig. 6), 4.39 inches of rain were recorded in 20 hours (fig. 43); 2 inches of the rain fell in 2 hours. The intensity at the Layton gully area may have been somewhat higher. A standard gage 1.5 miles northeast of the gully received 5.53 inches, another standard gage 4 miles west received 6.25 inches, and a recording gage 5½ miles northwest of the gully caught 5.87 inches, 3.63 inches of which fell between 8 and 10 a. m. on the 16th. As a result of this rain, the narrows in the lower channel of the Layton gully were entirely cut away (fig. 48), and the active head (J), where the west fork enters the main gully, receded some 15 feet (fig. 50). Caving of the walls increased the 19-foot width of that part of the gully to 31 feet (fig. 52). The tough soil of the B horizon along the western rim caved in blocks several tons in weight, which plunged forward and landed on the gully floor in an almost inverted position. Approximately 1,500 square feet of wooded land along the gully rim caved during and immediately after this heavy October storm (fig. 53). Such large volumes of caved material can be worn down and washed away only by powerful rains. Most of the fallen blocks in the Layton gully remained for many months, their buttressing effect giving the walls partial protection against further caving.

WALDEN'S GULLY

Head A of Walden's gully cut back about 50 feet between January 1934 and September 10, 1936, at which time the water was diverted by a drainage ditch (figs. 53 and 69). Prior to the diversion, this head drained several acres of land, but after construction of the ditch the drainage was reduced to the immediate area of the gully head, which totalled only some 1,400 square feet. At this head of the gully the B horizon is unusually thick and massive and at some seasons forms a very deep overhang (fig. 54). When wet, however, the clayey material softens and caves off in blocks. On October 8–9 the area received a rain which was recorded at a gage 1 mile to the north as 4.20 inches in 40 hours, 1.40 inches of which fell between 6 and 8 p. m. on October 8. On October 9 this gully head showed much fresh caving and the process was still continuing although the water going over the lip was almost imperceptible. Small pieces of the wall were dropping almost constantly, and larger spalls a foot or more across and several inches thick occasionally broke loose and fell.

The rain of October 15–16 produced even more marked effects and was largely responsible for the caving shown on figures 53 and 54. The Barry gage, 1 mile north of the gully, recorded 5.94 inches of rain in 18 hours. A total of 3.67 inches fell from 8 to 10 a.m. on October 16, with a maximum intensity of 2.43 inches in a single hour. In spite of the lack of flow over the gully rim, owing to di-

FIGURE 47.—View upstream toward the narrows, 10 feet deep and 4 feet wide, in the lower segment of Layton's gully, July 11, 1936. The channel is cutting in the floor of an old wooded valley, the slopes of which have been little changed since the Revolution.

FIGURE 48.—The same view on December 4, 1936. Most of the widening of the channel was caused by the intense rain of October 15–16.

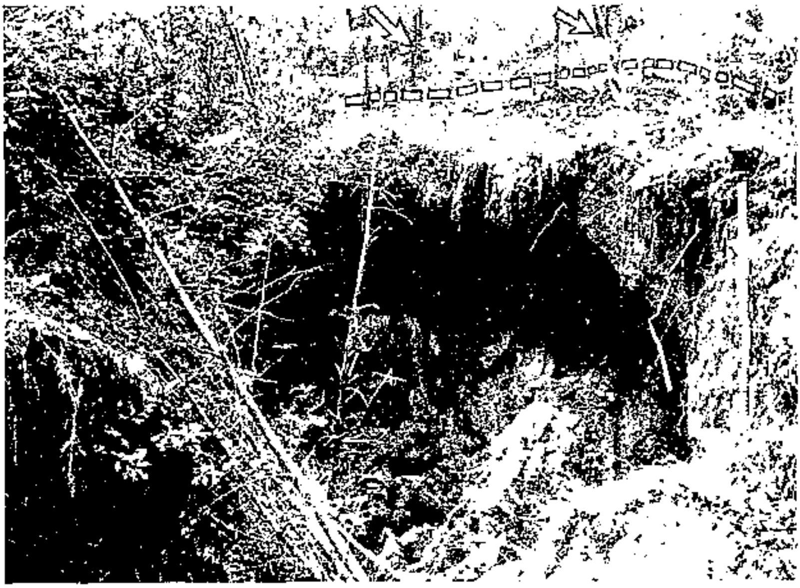


FIGURE 49.—Cave and plunge pool where water from the west fork enters the main channel of Layton's gully. August 4, 1935. The red B horizon 6 feet thick overlies weak gray rotten rock.

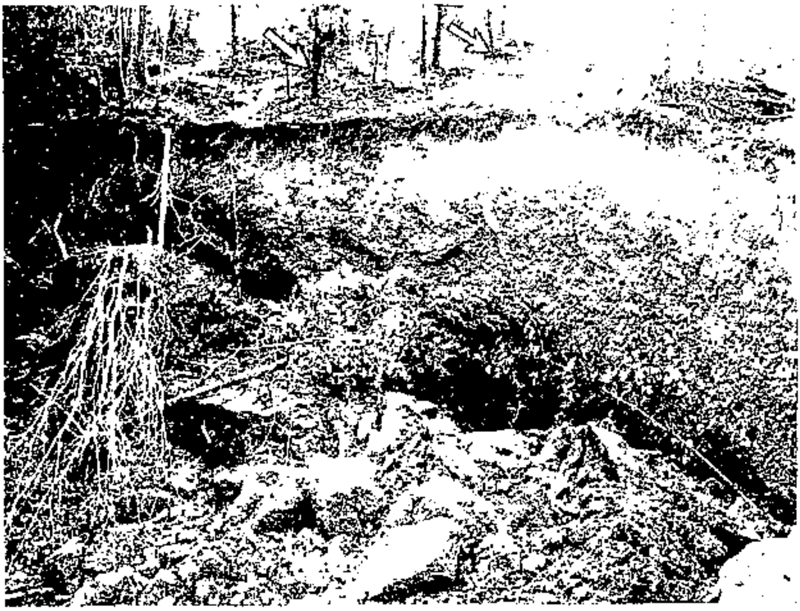


FIGURE 50.—The same area on December 4 after the rim had receded 15 feet by caving. The dotted line on figure 49 shows the approximate extent of the caved area. Arrows indicate the same trees in each picture.

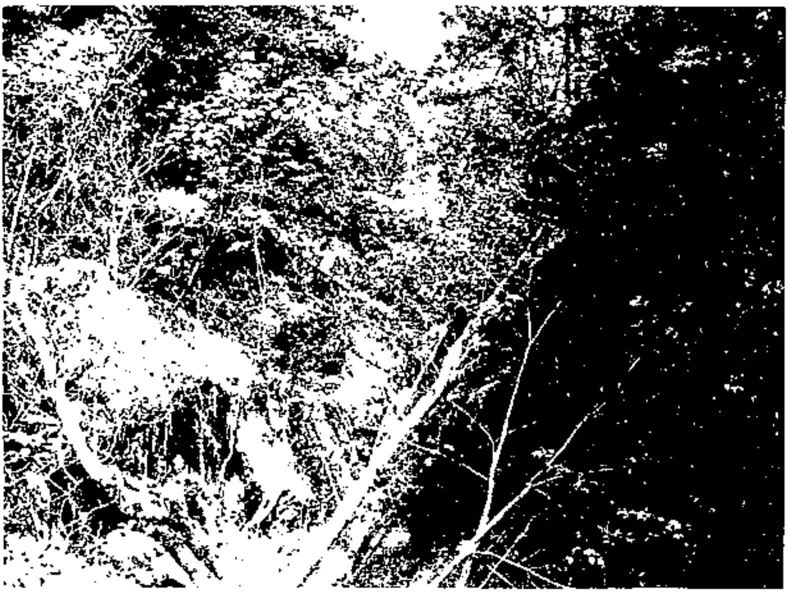


FIGURE 51.—View down Layton's gully from a projecting point on the east side of basin 3. Taken August 1, 1936.

FIGURE 52. Essentially the same view on December 1. Both walls caved extensively as a result of the heavy rain of October 15-16. Caved blocks of B-horizon soil at the left center contain several cubic yards. The tree in the left foreground in figure 51 tilted over to the opposite side of the gully when caving occurred, as is shown in this picture.

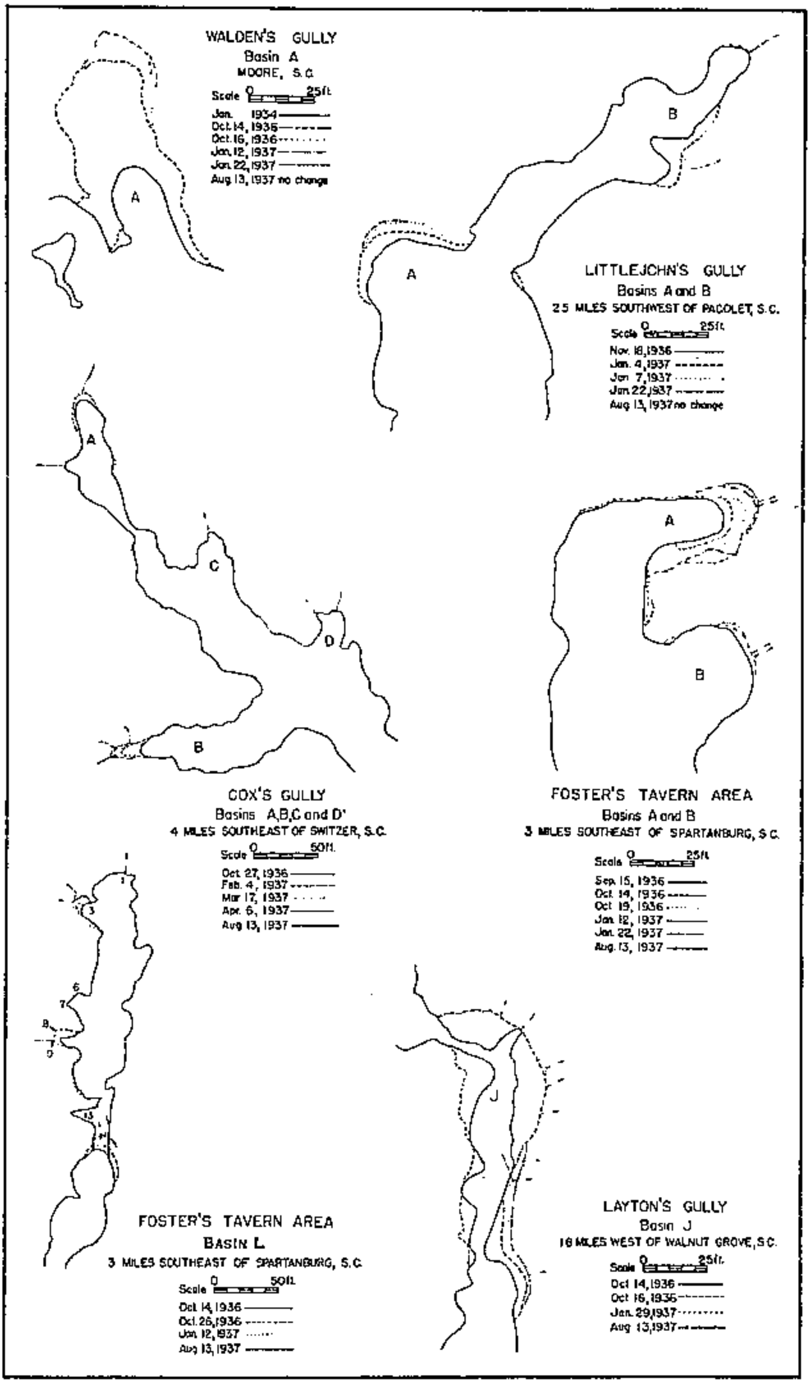


FIGURE 53.—Maps showing areas of rapid rim caving on six gullies in Spartanburg County, S. C., October 1936 to August 1937.

version of the water, there was enough rain to saturate the soil and caving was active. The falling of a large spall or slab of soil from the thick B horizon in the gully head is seen in figures 32 and 33. The crack behind this block could be seen widening for a minute or more before the actual caving caught by the camera took place.

Because of the absence of any flow over the rim, caved material accumulated on the gully floor until, by January, this gully head, instead of being a vertical drop of more than 20 feet, had a scarp only 6 feet high, from the foot of which stretched a long incline of fallen material (fig. 54). Healing of the gully head is in progress, and vegetation is rapidly establishing itself.

Heads J–1 and J–8 of Walden's gully (fig. 54) have also receded but have been less active than head A.

LITTLEJOHN'S GULLY

Head A in the Littlejohn gully drains an area of 6.13 acres, most of which has lost a large proportion of its topsoil and is now idle (figs. 77 and 78). The greater part of the water flowing over this head comes from rain falling on the north side of the road and reaches head A through a culvert. From October 24 to January 4 head A caved back 5 feet. By January 12 it had receded 4 feet farther, and by January 22 a total of 10 feet of the rim had fallen (figs. 29, 53, and 54). There were no rains of unusual intensity during this 3-month period. The heaviest came on November 11–12 and brought 1.31 inches in 25 hours, at a maximum rate of 0.25 per hour, as recorded at the Tinsley gage 2¼ miles to the northwest (fig. 6). Several rains of 0.6 inch or less fell during the first 3 weeks of December; one on the 19th totaled 0.90 inch. Most of the caving resulted from precipitation that fell between December 29 and January 6, during which time rain was received every day except January 4. These rains were of the widespread low-intensity type characteristic of warm-front conditions. The maxima for a 24-hour period were 1.42 inches on December 30–31 and 1.54 inches on January 1–2. The highest intensity was 0.63 inch for 1 hour 50 minutes, or a rate of about 0.34 inch per hour.

Head B–4 of Littlejohn's gully caved 5 feet between October 24 and January 4, and 3 feet more by January 7 (figs. 53 and 54). Most of the caving resulted not from intense rains but from thorough soaking by the slow general rains of December 28 to January 6, which totaled 5.72 inches. Between January 7 and early April little or no caving took place although 1.89 inches of rain fell on January 19, 1.08 inches on January 28, 0.95 inch on February 9, 1.22 inches on February 20, and 1.15 inches on April 4 and 5. The reason these rains did not cause further caving on head B–4 is that caved material was accumulated higher than the contact of the B and C horizons and had to be removed before further undermining and caving could take place.

COX'S GULLY

Caving of the heads in Cox's gully was not rapid until, owing to a terrace break, head B (figs. 55 and 80) began accelerated cutting.

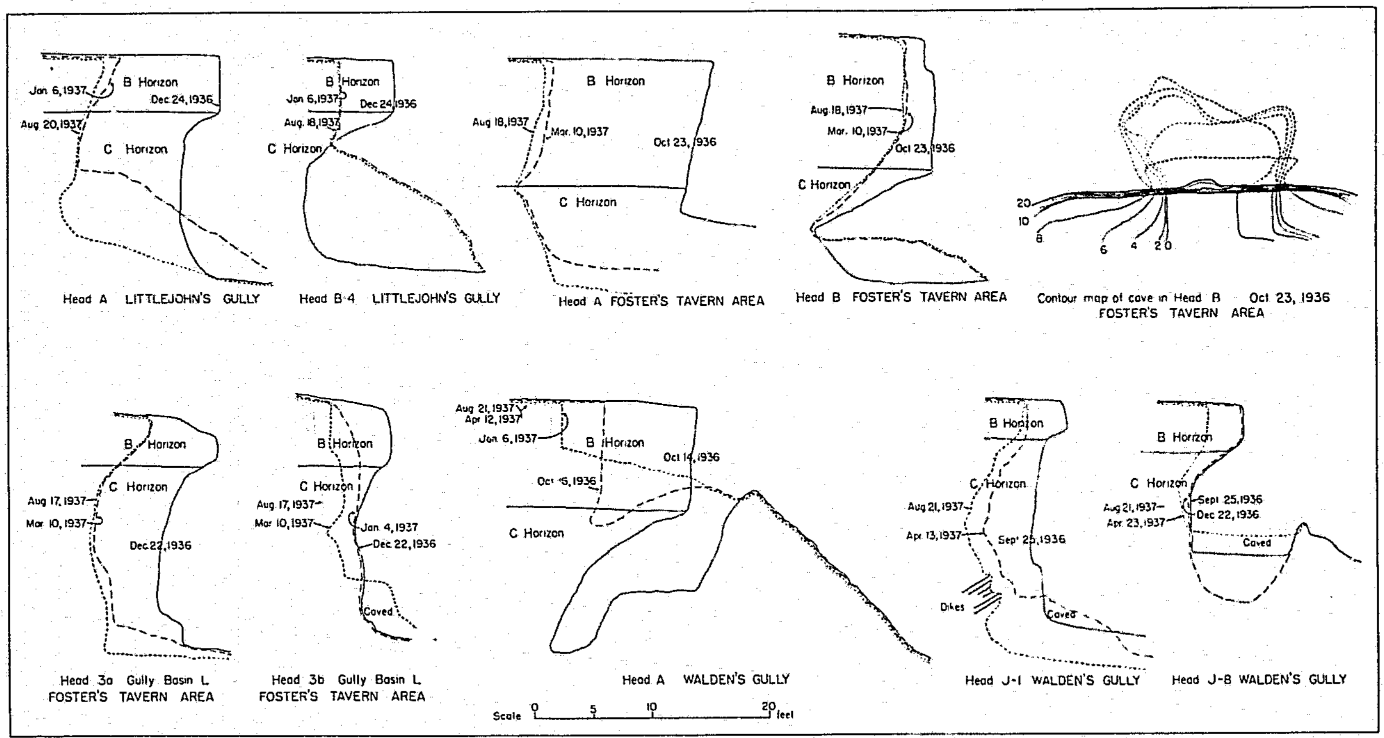


FIGURE 54.—Vertical sections and map showing rapid caving of gully heads. Note the extensive caving in the winter months and the small amount of change in the spring and summer.

From October 27, 1936, to February 4, 1937, this head receded 14 feet by caving (fig. 53). By March 17 it had progressed to 17 feet beyond its October position, and by April 6 to a total of 20 feet. It then remained more or less inactive until the latter part of June, but by August 13, 2 additional feet of erosion had taken place. This head of the gully drains an area of 1.46 acres, 0.28 acre of which was formerly pine woods. Clearing of this woodland during the spring and summer of 1937, however, increased the rate of run-off and the erosion hazard at the gully head.

Head A receives water from a road culvert and an idle field of 1.68 acres, but this head cut only 6 feet between October 27, 1936, and February 4, 1937, and had made no further progress by the following August 13.

FIGURE 55.—Head B of Cox's gully, March 26, 1937. This branch of the gully grew headward 20 feet between October 27, 1936, and April 6, 1937.

FOSTER'S TAVERN AREA, GULLY BASINS A, B, AND L

Active caving in gully basins A and B (figs. 53 and 90) is instructive in that the rate of cutting changed markedly when the sizes of the drainage areas were altered. Until about October 1, 1936, head A drained only 0.15 acre, but at that time construction of a small loose-rock dam along a property line increased to 6.5 acres the area draining through that head and decreased the flow to head B. A short intense rain, which at stations a few miles away totaled 2.5 to 3 inches, was responsible for most of the caving which occurred between September 15 and October 14, 1936. Head A was enlarged some 4 feet during that period but head B showed little change. From October 14 to January 22, head A grew rapidly, but from that time until August 13 it was only slightly active.

Head B of the Foster's Tavern gully area formerly drained some 8.14 acres, but diversion to head A, about October 1, 1936, reduced the area to 1.77 acres. When observed first, on June 10, 1936, head B had a height of about 19 feet, and a tension crack 18 inches back from the lip allowed part of the flow of water to move downward and emerge as a jet in the roof of a large seep cave beneath (figs. 24, 25, and p. 53). Except during unusually heavy rains most of the water passed downward through the crack and little went over the lip. As a result, the head showed no noticeable change in outward appearance from June 1936 until January 1937 (figs. 22 and 23) although the cave was becoming steadily deeper and broader during this time. Even the heavy rain of October 15–16 made no obvious change in this gully head (fig. 53). The long period of slow saturating rains from December 28 to January 6, however, enlarged the crack, and the weakened arch over the cave collapsed (figs. 23 and 53). Other minor caving has taken place since, but no major changes had occurred when the gully was last observed on August 13, 1937.

No rain gage was in operation in the Foster's Tavern area until October 22, 1936, but from the records of gages 6 to 12 miles south and southwest it is estimated that more than 4 inches of rain fell at the gully in the storm of October 15–16. In the period from December 28 to January 6, 6.34 inches fell in a series of long drizzles accompanied by occasional more intense showers. The slow saturating rains caused much of the caving of the side walls. Heavier showers of 1.33 inches in 8 hours on December 31, when 0.3 inch fell in a ½-hour period, and 1.88 inches in 18 hours on January 2–3 washed out a little of the accumulated material and accelerated caving of the heads and walls.

Sufficient survey data are not available for an accurate calculation of the volume of material removed from this gully, but it is known that approximately 0.017 acre, or 740 square feet, of land along the gully rim caved off in the period from November 1, 1936, to February 1, 1937. The average depth of material lost was approximately 20 feet, making the volume removed some 550 cubic yards. Nearly all of the run-off was from clean-cultivated terraced fields on slopes of less than 5 percent. The percentage run-off for this area is probably very similar to that for fallow land on a 5-percent slope on Cecil clay, which has been found by Diseker and Yoder (*8, p. 13*) to range at least from 37 to 87 percent, depending largely on the intensity and duration of the rain and the soil moisture at its start.

The entire gully at basin L (Gross' gully No. 1) has been cut in less than 10 years, and several of its heads continue to grow rapidly (figs. 18, 53, and 54). The gully follows a fence line and was developed from a more or less linear ditch which carried the water from the terraces down the slope. Head 3, a multiple head which now drains an area of 1.118 acres, caved back 7 feet from October 14, 1936, to January 12, 1937, but only an additional one-half foot in the following 7 months (fig. 56). Heads 8 and 9, which together drain only 0.222 acre, caved 4½ feet from October 14 to January 12 and only one-half foot additional by August 13 (figs. 54 and 95).

The overfall or knickpoint at the head of the lower basin in the main channel of gully *L* moved headward 4 feet between October 14 and October 26, another 6 feet by January 12, and 2 feet additional between January 12 and August 13. This overfall is capped by a tenacious clay (fig. 57, *A* and *B*), but erosion of the weak saprolite beneath allows it to be undermined, just as in original cave heads around the gully rim. Collapse of the lip and side walls results (fig. 57, *C*). The peculiarities of the soil which have produced the resistant lip in this gully are discussed on page 133.

GROUND-WATER RELATIONS

The natural position and contour of the water table are determined largely by climate, topography, local geologic conditions, and the character of the soil profile. The water table, or top of the ground water, normally parallels the surface of the land but is less irregular. It lies deeper below the surface on hills, but closer to the surface in valleys or other depressions, and thus has somewhat lower relief than the land. Where the topographic surface meets or intersects the water table, water appears above the ground as a spring, stream, lake, or marsh. Streams fed by springs give definite indication of the level of the water table. Especially in regions of low rainfall, however, streams may be purely surface phenomena unrelated to ground water.

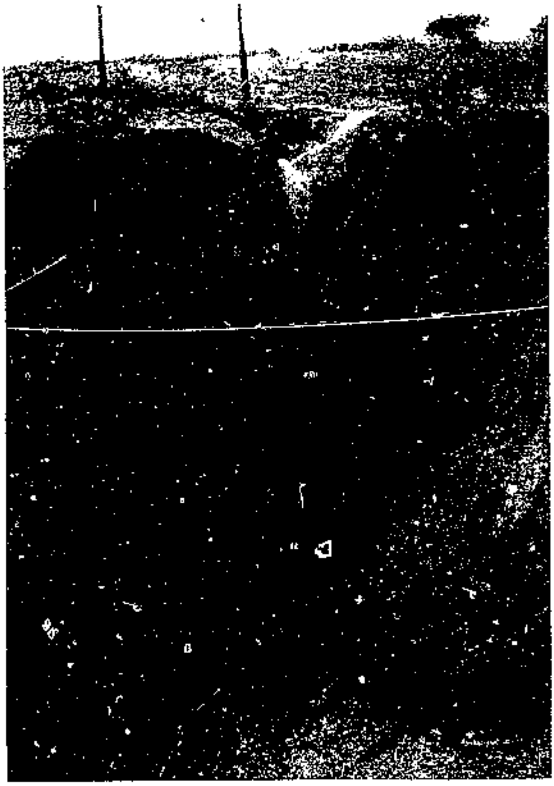


FIGURE 56.—Head 3 on the west side of gully L, Foster's Tavern area, during a rain on October 8, 1936.

Accelerated erosion brings about important changes in ground-water conditions. Removal of the A horizon by sheet erosion in-

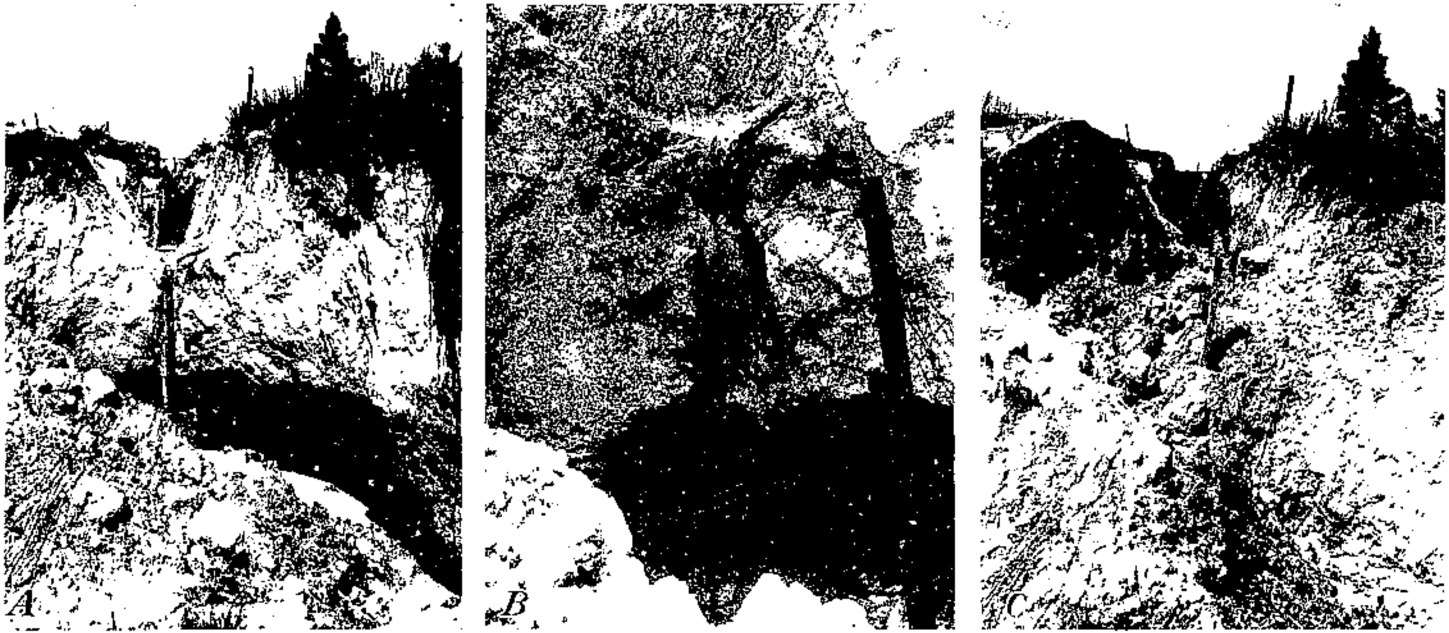


FIGURE 57.—Knickpoint or overfall in gully L, Foster's Tavern area. *A*, October 3, 1936; material fallen from the wall at the left has forced the current to undercut the bank at the right. *B*, October 8; water flowing over the knick during a heavy rain, cutting back the lip and enlarging the plunge pool at the base. *C*, April 7, 1937; same view as in *A*, after the collapse of a large area of the wall at the right.

TB 633 (1939) USDA TECHNICAL BULLETINS UPDATA

PRINCIPLES OF GULLY EROSION IN THE PIEDMONT OF SOUTH CAROLINA

IRELAND, H.A., SHARPE, C.F.S., EARGLE, D.H. 2 OF 2 creases the rate of run-off and thereby reduces the chance for water to percolate downward into the soil. A lowering of the water table results, making the land less suitable for the growth of vegetation. When rills and gullies develop, the water is drained away even faster and the water table is lowered to, or even below, the level of the gully floor. Plants that require an abundance of water weaken and die, and their place is taken by more xerophytic vegetation which can withstand the drier conditions. In the Spartanburg area pine is probably the most persistent tree under these circumstances, and the tops of dry spurs and islands in many of the gullies are covered with pine needles, lichens, a few hardy weeds, and scattered colonies of pricklypear. Vegetation of this sort gives far less protection to the ground than a good sod or a luxuriant forest growth. For this reason, lowering of the water table makes for progressive expansion of the eroded area wherever gullying has once been started. Depletion of the vegetal cover for many feet back from the gully rim reduces the resistance of the soil to erosion.

Where ground water is abundant, springs may emerge along the gully walls. In most gullies in the Spartanburg area the upper end of the channel is dry, but springs may maintain a small flow through the lower portion, as in the Layton, Walden, and Barry gullies, and in several of those in the Foster's Tavern area.

Within the gully, the level of ground water may be at or above the floor, may be in sediment deposited on the floor, or may lie in undisturbed soil or rock several feet below the gully bottom. In the Piedmont the soil locally has an important effect on the height of the water table. The tight clayey B horizon of the Cecil and related soils is almost impervious and not only retards the downward percolation of water but in some places appears to act as a capping layer, which prevents the escape of water trapped beneath. Sections showing the position of the water table in the deeply filled floor of Cox's gully are presented in figure 83. The situation there is characteristic. Toward the upper end of the gully the water table is several feet below the gully floor, but in the lower portion, below the entrance of basin B, ground water is found in the sandy fill and the level rises with reference to the graded surface of the fill in each section farther down the channel.

Lowering of the water table is shown in another way. The lower ends of many of the deep gullies of the Spartanburg area exhibit in their walls gray unoxidized Worsham soil, the upper surface of which is interpreted as the former level of ground water. In parts of the Foster's Tavern area the surface of this gray soil is 15 or more feet above the gully floor. Such conditions are evidence that gullying and accelerated stream trenching have greatly exceeded the natural rate of erosion, and the slow processes of soil formation have been unable to keep pace. The gray Worsham soil is, in most places, rather resistant and retards the development of large gullies.

The effect of ground water in producing a thick resistant soil beneath drainageways on hillsides is an important factor in determining the vulnerability to gully erosion. Owing to the more continuous presence of water and probably also to the effect of creep, the B horizon of the soil in draws or drainage lines is often unusually thick. If the slope is low and the water table is near the surface the soil may be of Worsham type. In any case, the greater thickness of the subsoil makes the area more resistant to erosion, and this principle may well be utilized in selecting locations for terrace outlets. Although outlet ditches on any part of a slope may cut at first with equal speed, those down natural drainageways may be expected to be more permanent, and the deeper subsoil there should give better foundations for any rigid baffles or dams which may be required.

REPRESENTATIVE EXAMPLES OF GULLY EROSION

The forms and processes of gully erosion described in the preceding pages have been observed in many gullies throughout the Piedmont of South Carolina and adjoining States. The detailed studies on which actual rates and dynamics of gully cutting have been determined, however, were made in the vicinity of Spartanburg. Mention has been made freely of these gullies and of the information gleaned from them, but their descriptions have not been presented in full or as complete units. Much may be learned by studying the life history of individual gullies—following their growth from insignificant rills to large and destructive chasms. The early history of many gullies is obscure. The origin of some of them, however, can be traced back to the early nineteenth century. Alternate periods of gully growth and dormancy can be followed through ante bellum times, the Civil War, the reconstruction period, and on into the twentieth century, the World War, and the present. Case histories of nine representative gullies of the Spartanburg area are presented here. Four of these gullies drain into the same stream and are intimately related. They are described collectively as the Foster's Tavern gully group, after which the characteristics of the individual gullies are discussed separately.

METHODS FOR THE RECONSTRUCTION OF GULLY HISTORY

The history of the initiation and enlargement of the gullies described in this bulletin has been worked out from information obtained within the gully itself, from local physiography, and from accounts of the property owners and nearby residents. Most helpful in this regard is the evidence gained from the ages of trees growing in and around the gully. Stumps of recently cut trees were examined wherever available and the annual growth rings counted. Few recent stumps were found, so the oldest and generally the largest trees growing on the floor and walls of each gully were bored with an increment borer, which shows the complete series of annual rings from the outer bark to the center of the tree. In this way the age of the trees can be determined; and by adding 2 to 5 years, the estimated time for the trees to take root after erosion, the minimum age of that part of the gully can be computed. The oldest trees are found uniformly in the lowest and oldest end of the gully. The upper end of an active gully is usually bare, or supports only a few small pioneer plants.

Information gained from the larger trees growing within the gully can be correlated with that obtained from borings in trees growing on the gully rim or on islands of the upland surface which have been completely isolated by gully cutting. Lowering of the level of ground water where a gully cuts close to a tree or erosion of the soil from around some of the roots is clearly recorded in the growth rings. As the tree's growth becomes stunted, the new rings added each year are much narrower than those added formerly. The period of active cutting of that part of the gully, then, is known to have been between the time of stunting of the trees on the rim and the beginning of the growth of trees on the gully floor. The history may have been complicated, however, by one or more cycles of recutting. When erosion was renewed, the vegetation in the gully was cleared out, the gully deepened, and new trees grew, after which the gully became stabilized.

Physiographic evidence from the gully pattern, and the character of individual basins, heads, and drainage channels within the gully, help in the reconstruction of the history and can be correlated with evidence from tree rings and from human accounts.

Human history provides a check of the data obtained from tree rings and aids in adding details, especially for recent decades. Dates of terracing and of building or altering roads and ditches have been valuable in working out the history of some gullies. Dates of retirement of the land or of land abandonment because of gullying or sheet wash can be verified in many instances from the vegetation record. From these various sources it has been possible to date, with a fair degree of accuracy, the beginning of gullying and some of the stages of gully advancement.

In the following pages each gully or gully group is represented by a large-scale topographic map and by a map showing vegetal cover and land use. Maps of erosion features in and around two of the gullies are also included. The vegetation and land-use maps show the relationship of gully cause and gully cutting to the ecology and the man-introduced changes in the area. The degradation of the areas bordering the gullies and the encroachment of erosion onto cultivated land are also seen. The age and diameter of trees into which borings were made are indicated. Maps of erosion features show the present state of activity of the gullies and the character of the erosion now going on. The areas of active erosion, in red, are chiefly on steep gully walls where the erosion processes are the most violent and where the material is the most vulnerable. Areas where erosion now is retarded by vegetation or is not sufficiently active to remove accumulating pine needles and leaves are mapped in orange. This classification includes also areas in which erosion proceeds slowly owing to the gentleness of the slopes and the small size of the drainage area. Sheet wash and rill wash, however, are active even on very low slopes, especially where vegetation has not yet gained a foothold. Other colors on the erosion-features maps indicate areas of active caving and stabilized areas. Outside of the gully rim are shown old normal valleys and cultivated and uncultivated upland. Prominent knickpoints in the gully channels are indicated by crosses.

The parts of the gully system are divided according to drainage basins, designated by letters. Active heads within some of the basins have been numbered, that is, Walden's gully, basin J, head 4 would be designated as Walden's gully J–4.

LAYTON'S GULLY

The Layton gully lies 1.8 miles west of Walnut Grove School on the north side of the road from the school to the village of Moore (fig. 6). Although not so old as many of the other gullies in this area, Layton's gully has passed through several distinct stages in its development and shows a marked contrast between portions which are now temporarily stabilized and others which are cutting with phenomenal rapidity.

GEOLOGY AND SOILS

The bedrock at Layton's gully varies from injected mica schist to coarsely crystalline, porphyritic, gneissoid granite or diorite. The schist is probably a facies of the Carolina gneiss and the invading igneous material resembles the Yorkville granite. Petrographic examination of a fresh rock specimen from a ledge in the stream to which Layton's gully is tributary shows it to be a porphyritic quartz diorite (table 6). Over most of the area both schist and granite are weathered to a depth of at least 25 or 30 feet.

Owing to the complex nature of the bedrock and its variability even within small areas, the soils at the Layton gully are basically of a somewhat mixed type, and differential erosion has produced further variations. Although formerly mapped as Louisa clay loam and sandy clay loam (*17*), these soils would now be classed as Lockhart. Neither the porphyritic quartz diorite nor the injected schists are sufficiently resistant to form effective barriers to erosion in the gully area. Both types of bedrock weather to a weak friable parent material which erodes very easily and produces cave heads beneath the more resistant B horizon. The Lockhart soil, because of its thin solum, the friable nature of its subsoil, and its micaceous parent material, is even more erodible than the Cecil. West of the lower end of the gully is a small area of Worsham soil, but this is of little consequence in the gully history.

TOPOGRAPHY AND DRAINAGE

The Layton gully has its head at a break in the drainage ditch along the north side of the topsoil road (fig. 58).[15] From there it extends northward some 675 feet, in which distance it drops 90 feet and attains a maximum depth of 19 feet. It follows the course of an old intermittent drainageway and is incised in a gently rounded hillside with an average slope of 13 percent. The gully is essentially linear in form but is developing a trellis pattern in its upper end as the various heads are being extended laterally along terrace water furrows (fig. 15).

The total drainage area is 4.39 acres, divided as follows:

	Acres
Upper segment (basins A and B, to section 3-3')	0.50
Middle segment (basins C to H, to section 9-9')	1.57
Lower segment (basins J and K)	1.17
West fork (basin L)	1.15
	4.39

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[15] The topographic maps of Layton's, Littlejohn's, Cox's, and Barry's gullies were made by Oscar D. Price; the topographic map of Walden's gully was made by H. A. Ireland, and that of the Foster's Tavern area by H. A. Ireland, J. C. Owen, and O. D. Price.

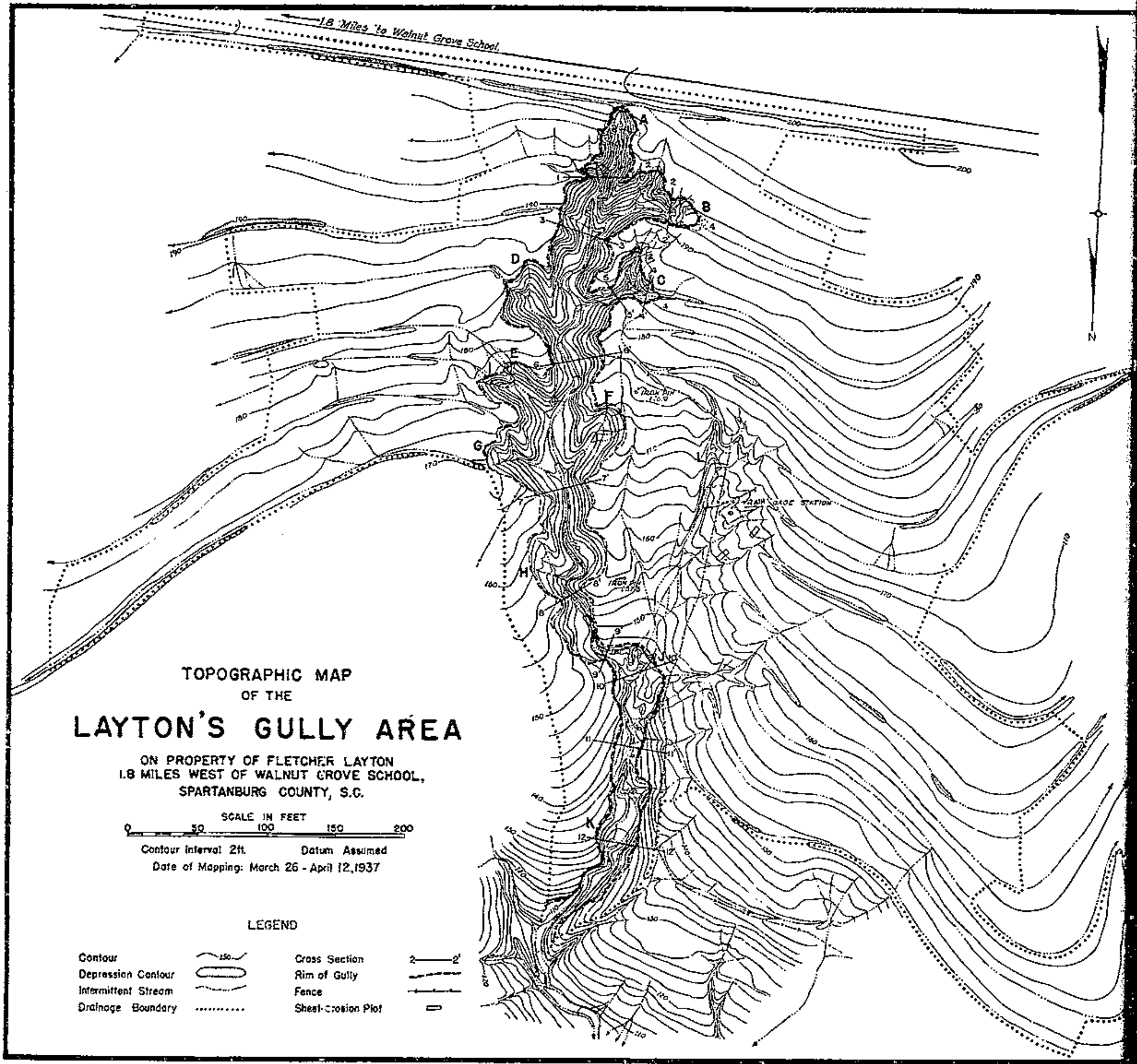

FIGURE 58.—Topographic map of the Layton's gully area.

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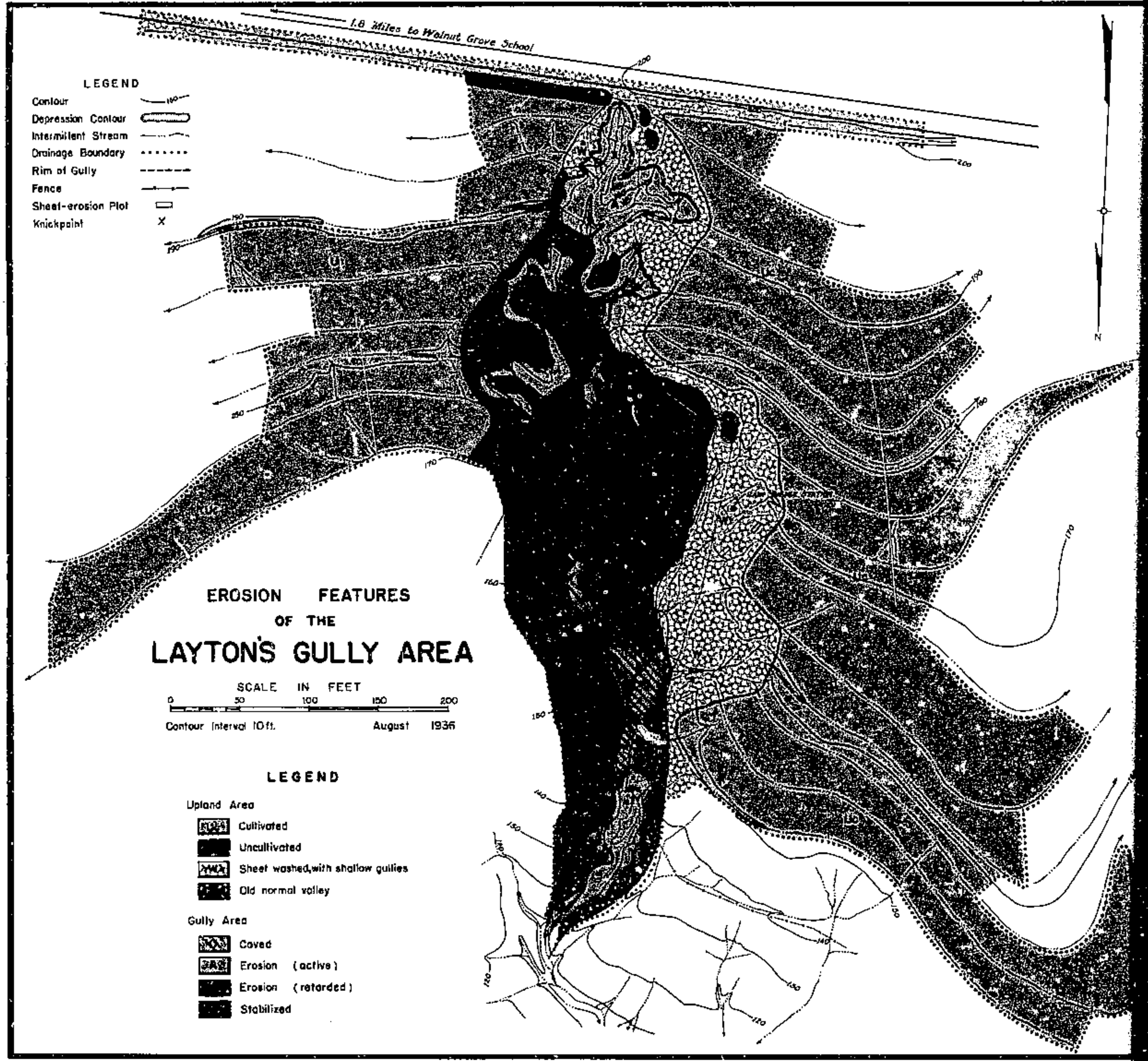


FIGURE 59.—Erosion features of the Layton's gully area.

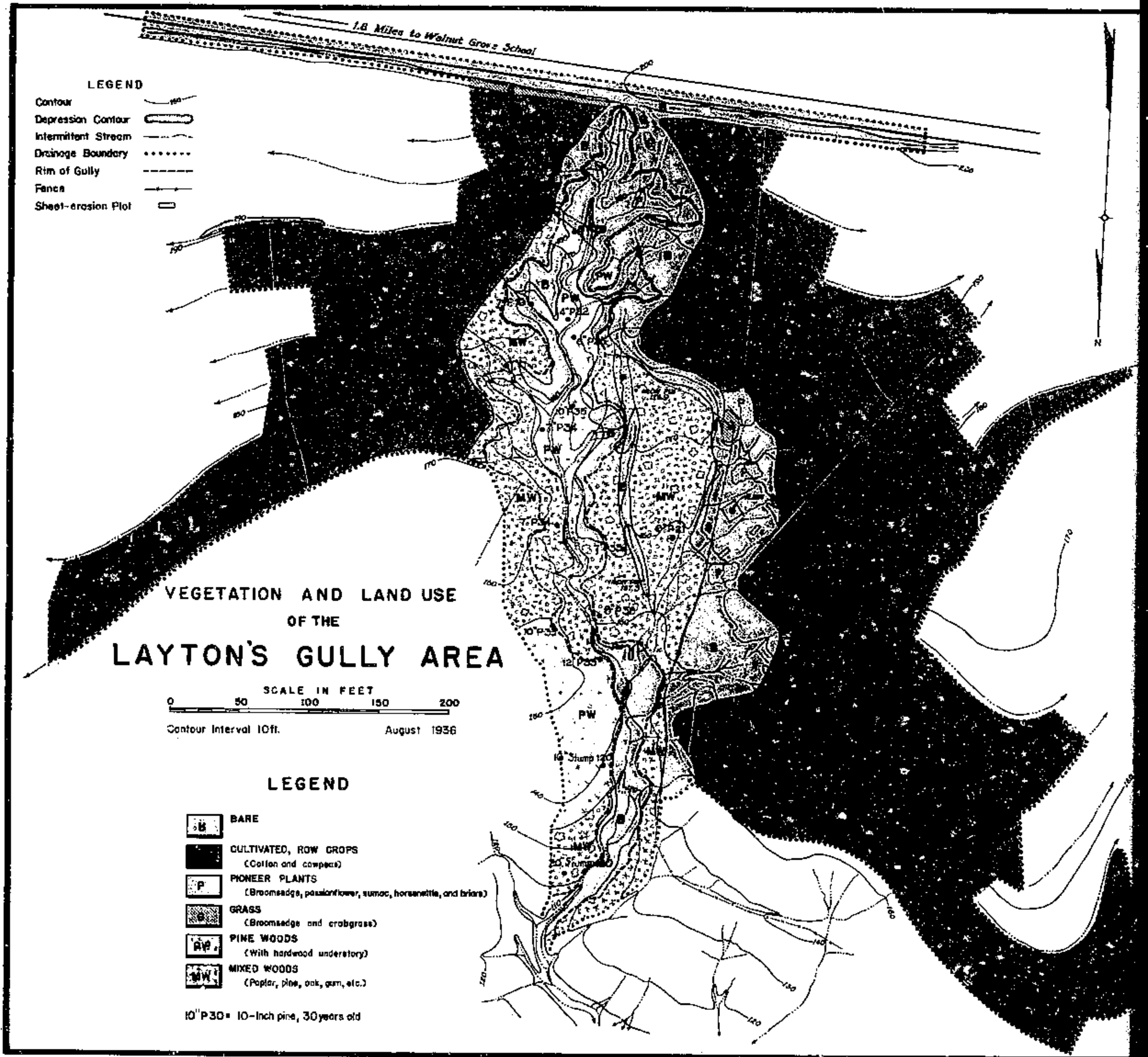


FIGURE 60.—Vegetation and land use of the Layton's gully area.

DEVELOPMENT OF PRESENT DRAINAGE

When the present owner acquired this property, some 30 years ago, the most active head of the gully had advanced to a point 90 feet from the road. The location of the head at that stage can be identified in the field today by the character of the gully walls (fig. 59) and by the age and distribution of the vegetation now growing there (figs. 60, 61, and 62). The fields on both sides of the gully were terraced and there were two terraces between the gully head and the road. It appears that the gully was essentially stable at that time, as the walls were well vegetated and the cross section was a broad **V**. The middle portion supported mostly saplings only a few years old, but the lower course (fig. 60) lay through a small wood lot containing a number of white oaks which were then 90 to 130 years old. That part of the valley was broad and open. The slopes were so gentle that wagons could be driven across them, and from the position of the ancient oaks it would seem that the valley had been much the same since before the Revolution. The surface soil along the valley sides may have been thinned somewhat by sheet erosion and creep but much of the topsoil remained because of a thick cover of forest duff. The B horizon of the soil was abnormally deep along the axis of this valley, owing partly to downhill movement by soil creep (fig. 49).

The recent acceleration of erosion at this gully, according to the property owner, dates back 20 to 23 years. About 1914, the land was let to tenants. Within 2 years the terraces above the gully head had broken over, and the gully had started cutting rapidly toward the highway. The tenant farmers apparently paid little attention to the terrace break-overs and also allowed the development of many washes in the fields. Between 10 and 20 years ago the white oak timber in the wood lot was sold, tree by tree, thus removing much of the protection of the slopes in the old valley.

A few years ago the owner repaired the terraces, reversing the flow of some of them so less water would be carried into the main gully. He filled the minor gullies, some of which were said to be 5 or 6 feet deep. This work undoubtedly retarded cutting of the main gully.

Recently, probably since 1935, the west fork (figs. 58 and 63) started rapid cutting owing to the breaking of terraces or because of the cropping system used. By July 1936 the lower segment of the gully had been converted from a broad **V**-shaped valley to a deep **U**-shaped gash. The bottom was literally ripped out of this old well-vegetated valley, and a steep-walled barren channel which enlarged rapidly by caving and slumping was produced (fig. 47).

PRESENT EROSION CONDITIONS

For convenience in discussion, the gully has been divided into four sections, each having different but fairly uniform erosion conditions.

UPPER SEGMENT

The upper or headwater segment, that closest to the road, is a little more than 90 feet long and extends about to the position of cross section 3–3′ (fig. 58). This portion of the gully, consisting of basins A and B, is less than 23 years old and occupies an area that was formerly terraced and cultivated. It is now almost barren of vegetation and is actively eroding (figs. 59 and 61). The walls are retreating by washing, crumbling, slumping, and caving. Individual cutting heads are progressing by plunge-pool action, by washing, and, where weak C-horizon material is softened by back trickling of sheets of water along the vertical or overhanging walls, by caving. Seepage is of little or no importance. Caved material is removed from the gully channel only when heavy rains cause abundant run-off.

The largest cutting heads in this upper segment are all of plunge-pool type with a lip of tight B-horizon clay overhanging a cave developed in the C material. Head A–1 at the highway ditch (fig. 61) receives the most water of any of the three large heads and drains about 0.19 acre. Unless protective measures are taken it eventually will undermine the road and project gully branches along the road ditches, presenting serious trouble for the highway-maintenance staff. It has cut very little in the last year, however, and the road may not have to be moved for some time. Head B–4 on the second terrace on the west side (fig. 64) is wider and lower. It drains an area only one-fourth as large but is eating headward much more rapidly. From August 1936 to August 1937 this head broadened 6 feet and extended up the water furrow about an equal distance. The owner has helped to retard the cutting of the head by regrading the terrace which leads to it so as to reverse the flow and drain the run-off from the fields away from the gully. Head B–2 drains only some 600 square feet but is very active (figs. 61 and 63). This marked activity of heads having only small drainage areas is one of the outstanding features of this upper segment. Drainage from areas of 25 square feet, or even less, forms a well-marked channel down the gully wall and in many cases develops a small-scale cave head.

More rapid deepening of basin B than of basin A has produced a small knickpoint about 3 feet high, which is moving upchannel in basin A. Some attempt has been made to stabilize the gully walls and channel by planting honeysuckle, but owing to the rapidity of erosion the vegetation has not grown well and has had little effect as a control measure.

MIDDLE SEGMENT

The middle segment receives directly the drainage of 1.57 acres in addition to the 0.50 acre draining into it from basins A and B. It extends from cross section 3–3′ to section 9–9′ and comprises some 350 feet of fairly well stabilized gully much older than the upper segment. In this stretch, the stabilized character of the floor and walls and the age of the pines and tuliptrees now growing there (figs. 59, 60, and 62) indicate that the channel has existed for at least 35 years and that in the past filling has about kept pace with downcutting. Portions of this segment show recent cutting which is now dormant. In other parts fresh scarps and small terraces indicate active erosion.

Except near the head, the middle segment receives little water from the west side. On the east side it drains a much larger area, including one terrace more than 350 feet long planted in clean-tilled cotton.

FIGURE 61.—View headward from cross section 3 in the upper segment of Layton's gully showing the barren walls characteristic of active erosion. Head A-1 is at the left, head B-2 at the right.

FIGURE 62.—View down the channel in the middle or stabilized segment of Layton's gully between cross sections 6 and 7. The larger trees are 32 to 35 years old.

The cutting heads are of various types. In basin C several small but very active plunge pools receive the waters from the third terrace on the west side. These plunge pools (C–2, C–4) advanced 2½ to 4 feet from August 1936 to August 1937, but deepening of this basin has been more marked than headward erosion of its rim. In the summer of 1936 the plunge pools were only 5 to 7 feet deep, and the walls of the basin sloped downward to the floor, the lowest part of which stood 4 feet above the trunk channel of the gully. By the summer of 1937 the heights of the plunge pools had increased greatly, and most of the basin floor had been lowered almost to the level of the main channel. Basin C is by far the most active head in this stretch of the gully. Only one typical plunge pool, E–1 (fig. 63), is found on the east side of this segment of the gully, as most of the water enters by steeply inclined channels. Head E–1 differs from those in basins A, B, and C in that the lip is formed of a tangled mass of sod and tree roots which overhang and protect the gully wall, thus preventing rapid lip erosion.

The stabilized condition of the middle segment of the gully will soon be disturbed. The lower part of this stretch has numerous small falls or knickpoints developed as a result of rejuvenation of the lowest segment of the gully. The youngest and largest of these was formed when run-off from the storm of October 15–16, 1936, caused excessive erosion of the main gully below the junction of the tributaries. At the start this knickpoint was 2 feet high but by August 13, 1937, it had migrated upstream 42 feet and had increased to a height of more than 4 feet (fig. 65). Headward movement of this step is certain to continue unless protective measures are taken or unless it encounters a resistant dike or other rock barrier. Complete recutting of the walls will follow this deepening and all trace of the present stabilization will probably be removed (p. 74).

WEST FORK

The west fork drainage flows in a much shallower channel than the main gully and at the present time includes the run-off from 1.15 acres. Most of this is planted in cowpeas, but about one-fifth is scrubby, mixed woodland which has grown up since that area was removed from cultivation 15 to 20 years ago. About one-eighth to one-tenth of the drainage area is bare ground from which the topsoil and some of the subsoil has been stripped by sheet erosion and shallow gullying (fig. 66). Part of the flow in this fork is derived from the fourth terrace on the west side, drainage from which, apparently, at one time entered the main gully near head F.

The channel of the west fork is much younger and less well developed than that of the east or major branch of the gully. It is nowhere more than 6 or 7 feet deep and for at least half its length is not incised at all. The water spreads out over a wooded slope and flows in a group of poorly defined interweaving courses to the lip of gully head J. Part of the water comes from a tributary which flows down the spur between the two gully forks, following the course of an old obscure farm road (fig. 58). Drainage of the upslope portions of this old road has been captured by basins B, C,

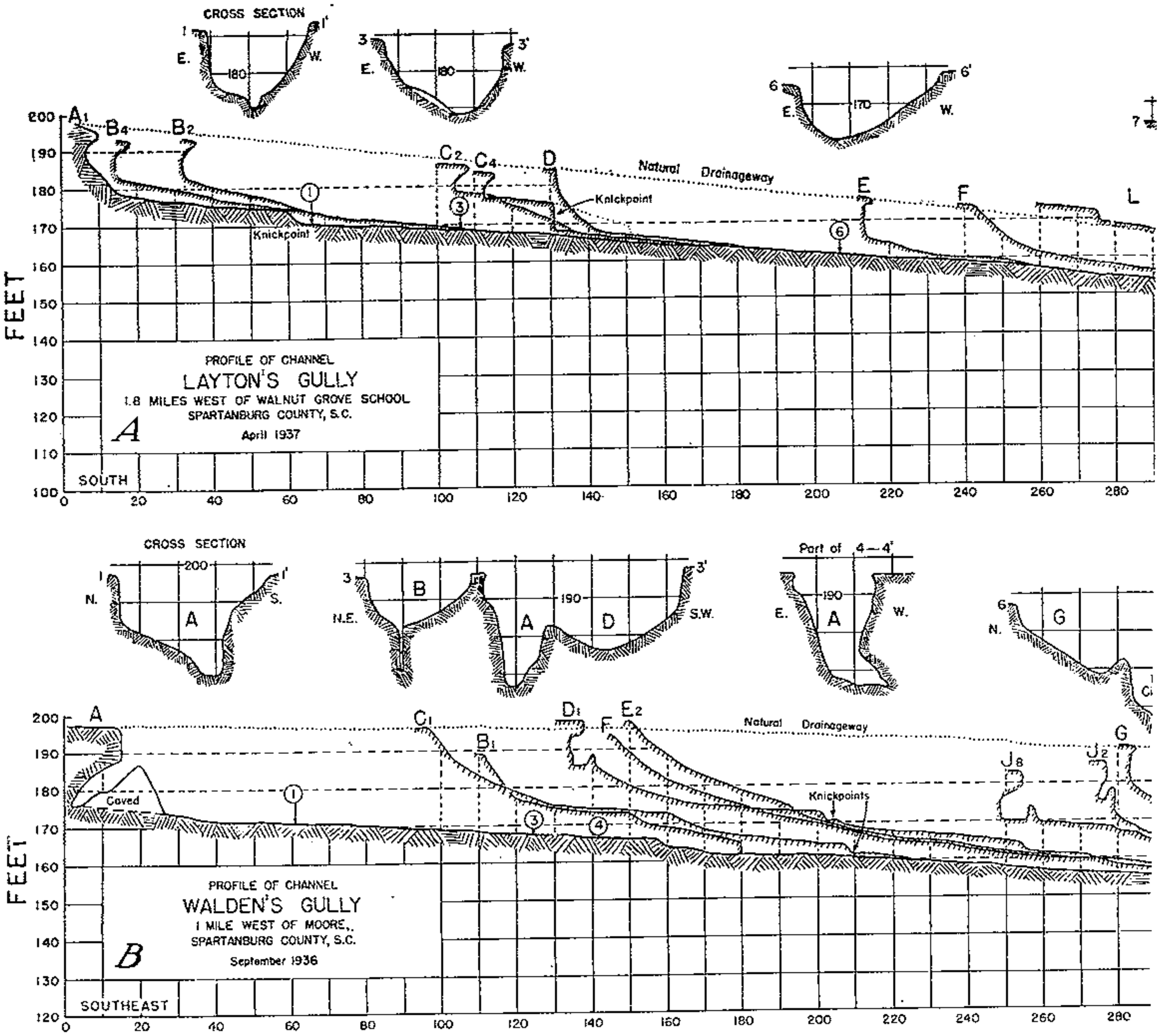


FIGURE 63.—Longitudinal profiles of the main channels and important tributaries of La

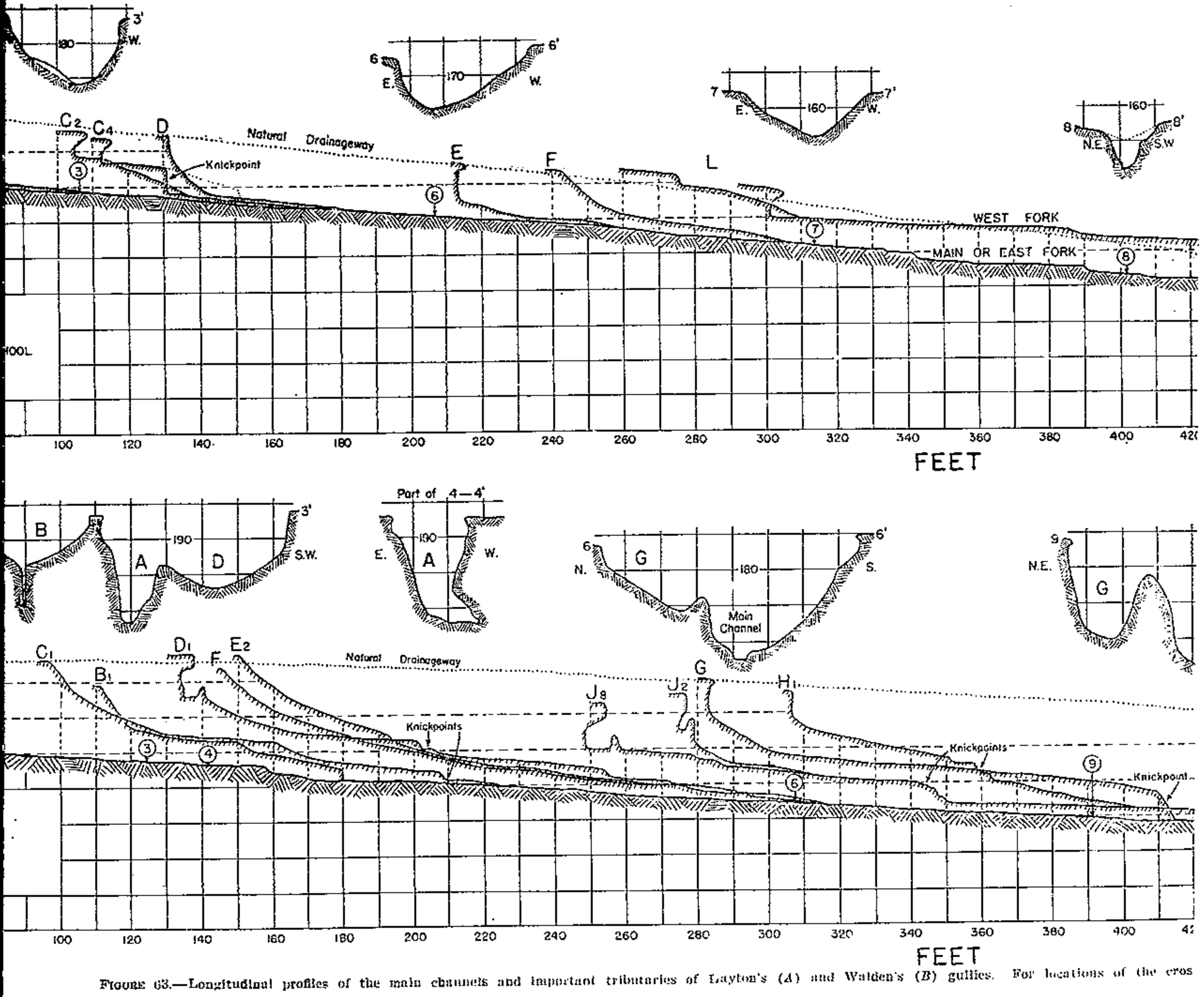
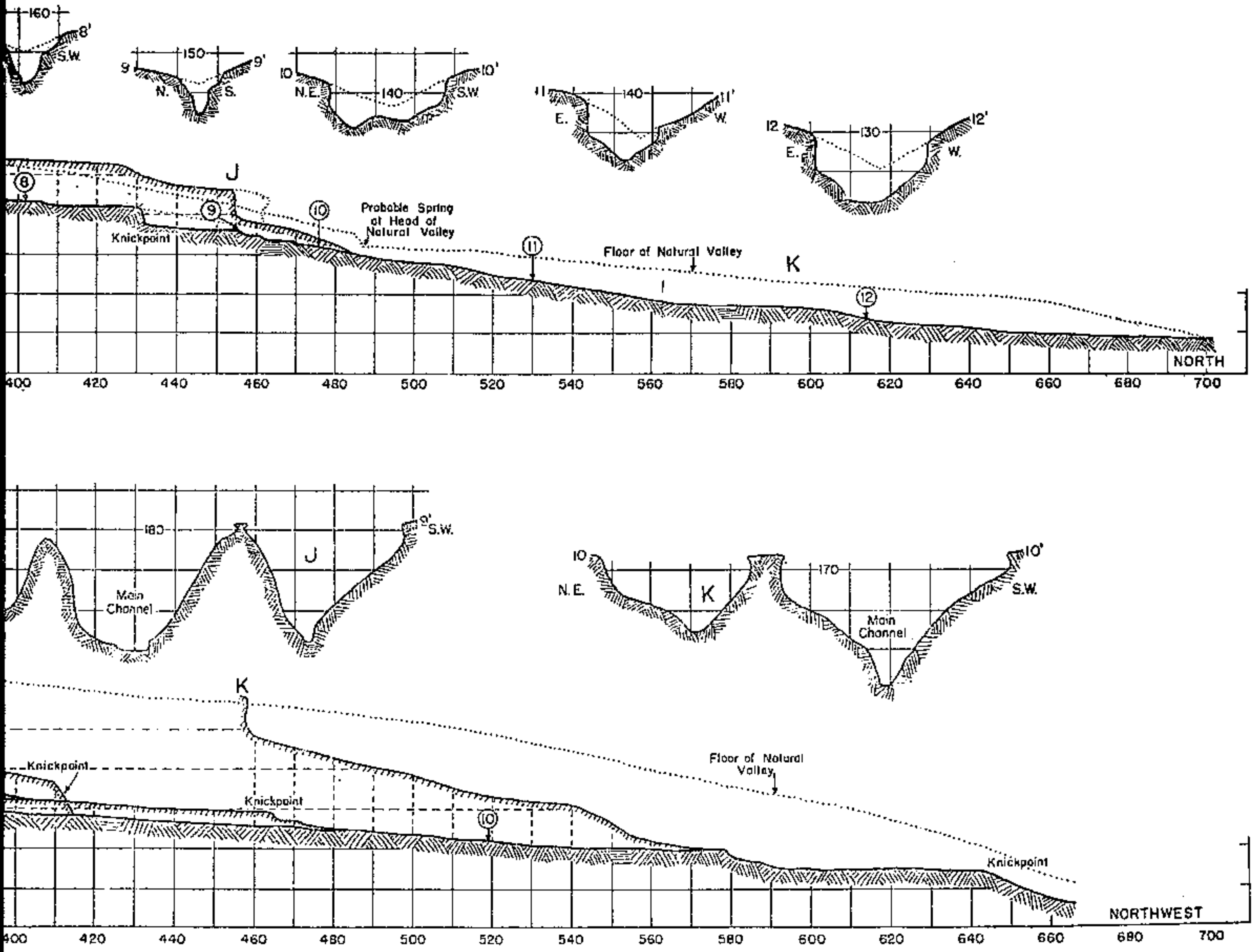


FIGURE 63.—Longitudinal profiles of the main channels and important tributaries of Layton's (*A*) and Walden's (*B*) gullies. For locations of the cros



of the cross sections and knickpoints, and the arrangement of tributaries, see figures 58 and 69.

and F, working headward from the deeper east branch. The greater part of the water draining through the west fork comes from the sloping fields and bare land to the west. Because of the high angle of slope, the steep terraces, and the poor vegetal cover, run-off from this area is very rapid, and the west fork of the gully is enabled to cut vigorously. Head J, where the west fork plunges to the floor of the downstream segment of the gully, grew headward 12 to 15 feet by cutting and caving during the storm of October 15–16, 1936 (p. 82 and figs. 49 and 50). Unless artificially controlled, head J may be expected to move headward up the west fork at a rate of 10 or more feet per year.

FIGURE 64.—Head B–4 on the west side of Layton's gully. Although this head drains less than 100 feet of terrace it has cut about 6 feet in a year.

LOWER SEGMENT

This downstream stretch, extending for some 225 feet and draining an area of 1.17 acres in addition to all the upstream segments, shows clearly a valley-in-valley form consisting of an old gentle-sided valley, in the bottom of which has recently been cut a deep, steep-walled gully, which is rapidly enlarging (figs. 47, 48, and 63).

Accelerated erosion of this section appears to be caused mainly by water coming down the west fork and not down the larger eastern branch of the gully. A considerable amount of run-off enters this lower segment directly from the eroded field on the west side. Water from many small channels plunges over that rim of the gully, but, owing to the rapid caving and slumping of the walls, there are few well-developed plunge pools. A marked contrast exists on the east side, where the drainage area is about one-fifth as large but is chiefly in pine woods. No well-defined channels enter the lower gully on that side.

Heavy rains in October 1936 brought about drastic changes in the upper end of this gully segment, deepening the channel and causing rapid caving. Both rims of the gully were well wooded, but the walls were so deeply undermined that large blocks caved, carrying the trees and shrubs with them (figs. 51, 52, and 53). The recent enlargement of this gully has been described on pages 79 and 82 of the section, Rate and Amount of Gully Erosion.

PRESENT VEGETATION AND LAND-USE CONDITIONS

In 1936, as shown on figure 60, the cultivated area surrounding the gully was almost entirely in cotton and cowpeas. The cotton, growing on the east side of the gully, was clean-tilled and well cared for. The cowpeas, growing in the field west of the gully, made a very poor showing. They were not cultivated, and the field grew up heavily with various weeds, including horsenettle, passionflower, and crabgrass. There was a small patch of corn in the northwestern corner of the area.

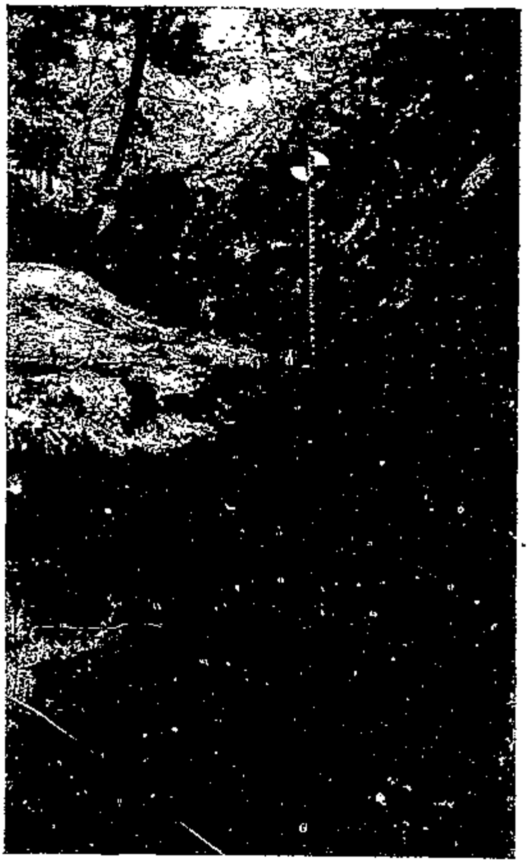


FIGURE 65.—Knickpoint 4 feet high in Layton's gully between cross sections 8 and 9. Three stages in the deepening of the gully may be seen: (1) The gently sloping walls in the background, (2) the moderately deep present channel beyond the level rod, and (3) the newest channel in the foreground below the knickpoint.

The gentle slopes near the tops of the hills have in general a sandy topsoil 4 to 6 inches thick. On a few scattered spots, as along the roadside, remnants of the A horizon are held in place by coverings of broomsedge, lespedeza, and weeds (fig. 67). Lower down, where the slopes are steeper and erosion has done more damage, large areas of the B horizon and some of the B to C transition zone are exposed. Scattered growth of pioneer vegetation is found in these areas.

All of the gully except basins A, B, and C is bordered by woods and, except for the parts now most active, the area within the gully itself is also wooded. The many trees in the temporarily stabilized middle segment differentiate it distinctly from the

FIGURE 66.—Almost 3 feet of soil has been stripped from around this ash sapling in the area drained by the west fork of Layton's gully.

more recently cut headward portion (figs. 60–63). Pine, tuliptree, sourwood, dogwood, maple, oak, ash, and hickory are common, and some of the pines and tuliptrees have been shown by boring to be 30 to 35 years old.

The area of mixed woods, between the fence, which parallels the west fork of the gully, and the long narrow bare strip, which was once a farm road, was formerly cropland. It was abandoned about

FIGURE 67.—View eastward across basin A of Layton's gully. Several inches of topsoil still remain in the grassy strip along the roadside. The cottonfield at the left has eroded far down into the subsoil.

20 years ago, when the field to the west, where the rain gage now stands, began to wash too badly to cultivate.

Along the lower segment of the gully, pine and mixed woods have replaced a stand of mature white oaks, stumps of which are still in a fair state of preservation.

This gully area shows clearly that a wooded region will resist erosion from the surface downward but has little protective effect when attacked from beneath as by undercutting from a deep gully. In the lower segment, trees 6 inches or more in diameter have been undermined and have fallen into the gully (fig. 51). Saplings project at various angles from caved blocks. Many trees along the side of relatively inactive portions of the gully have tilted outward from the bank but have become stable again, and their upper parts have resumed vertical growth. Roots of trees partially undermined by gullying aid in protecting the bank, sometimes for a period of years (fig. 75).

Even if the gully does not undercut the trees, lowering of the ground water as a result of gullying interferes with their normal development (p. 93). Borings in pines close to the rim of the gully show a permanent retardation of tree growth 20 to 21 years ago, caused apparently by the cutting or deepening of that portion of the gully. At the lower end of the middle segment the effect of the unfavorable conditions may be seen in the comparison of two pines, both of which are 30 years old. The one on the edge of the gully is 6 inches in diameter and the other, only 6 feet farther up the slope, is twice as large. Prior to the recent renewal of active erosion, pines grew very well on the C-horizon material of the gully slopes and floor. Washing of A- and B-horizon soil over the C material on some of the slopes undoubtedly aided tree growth. The pines plotted on the map (fig. 60) show diameters of as much as 12 inches for a 33-year-old-tree.

PROBABLE FUTURE DEVELOPMENT

Unless artificially controlled, this gully will in time undermine the road and force its removal to a new location. Headward migration of the 4-foot knickpoint up the east fork will deepen the channel, causing the wooded side slopes to cave, and the healing process will have to start anew to adjust the walls to the lower level of drainage. Accelerated cutting will continue until a new grade is established. Head J will continue working up the west fork at a rapid rate until it emerges from the woods. Even faster erosion may then result. More agricultural land will be destroyed by gullying, particularly the area between heads A and L.

Ordinary rigid check-dam construction would be of little use in this gully owing to the weak, crumbly nature of the bedrock. Diversion of the water and sloping of the banks might be advantageous, but would introduce the possibility of developing an equally bad gully from the diversion ditch. Layton's gully offers an excellent site at which to study the operation of plunge-pool heads and might well be worth some experimental construction for gully-head control. Retardation of erosion at a few critical points would at least postpone the rapid enlargement of this gully.

WALDEN'S GULLY

The Walden gully, on the property of J. H. Walden, 1 mile west of Moore, is one of the most spectacular in Spartanburg County. Its deep canyonlike channels are incised as much as 35 feet below the evenly sloping upland, portions of which have been completely isolated and left as islands surrounded by steep, vertical, or even overhanging gully walls. Several of the cave heads are still active, and channel erosion continues to undercut the walls (figs. 68, 69, and 71). Other parts of the gully, however, have been naturally or artificially stabilized. This gully illustrates well the complex history by which such features are developed. Successive stages of cutting and stabilization are well shown; capture of slowly eroding heads by more active ones is illustrated; and the beneficial results of diverting water away from the head of the gully are seen.

GEOLOGY AND SOILS

The bedrock of this gully area is a felsic gneiss consisting mainly of quartz and a high percentage of large feldspar crystals. It is porphyritic in places and is cut by many small quartz veins and pegmatite dikes. Few of these, however, are thick enough to form resistant barriers in the channel. The zone of weathered rock or saprolite, the parent material for the overlying soil horizons, is deep, and in no place has the gully cut down to firm, resistant bedrock (fig. 7).

The soil of the entire upper portion of Walden's gully is Appling sandy loam. Much of the topsoil is still present in the fields and pasture land around the gully but has been disturbed by plowing. It has an average depth of about 8 inches except in a few places near heads H and J (figs. 70 and 71) where the topsoil has been entirely removed by sheet wash and shallow gullying. The subsoil or B horizon is a firm, light-red to yellowish-red clay of unusual thickness. Near head C it is 129 inches deep and in several other places measures more than 100 inches. This apparent over-thickening of the clayey subsoil is found beneath several of the channels entering the gully and suggests the effect of soil creep or more efficient eluviation beneath the drainageways. The red and yellow mottling, characteristic of the lower horizons of the Appling soil, is not pronounced in this gully area.

Immediately downstream from the lowermost head of the gully (head K) the Appling soil grades into Worsham, which has a dark-gray topsoil and a subsoil, yellowish at the top and underlain by light-gray resistant material. This resistant soil layer is even thicker than the B horizon of the Appling soil, and is underlain at about 200 inches by friable saprolite or decomposed rock. Uphill from the area of Worsham soil the upland has an average slope of about 8 percent. The Worsham area forms a distinct shoulder or narrow bench, at the outer edge of which, about 100 feet from the permanent stream, there is a marked break in slope. From this break to the stream channel the hillside slopes at about 30 percent.

FIGURE 68.—Walden's gully. Head A, in the left foreground, was cutting actively until a few days before this picture was made. Construction of a small ditch has prevented water from entering this head, and caved material can now accumulate on the gully floor. Water was diverted from head C, at the right, many years ago, and the head is partially stabilized.

FIGURE 69

FOUND AT END
OF BULLETIN.

DEVELOPMENT OF THE PRESENT DRAINAGE

The history of the development of this gully has been worked out from the age of vegetation in and around it, from the physiography of the gully area, and from accounts of farmers living close by.

Walden's gully appears to have started about the middle of the last century. By 1855 it was about 20 feet deep and extended upslope to slightly above the shoulder of the hill (fig. 72). At its upper end the valley probably had two indistinct heads, one near the point where the gully head K is now, the other at a corresponding position in the basin of the main channel. Springs very likely contributed some of the water in this channel, as the lower portion of the present gully still carries an almost continuous flow. Above the gully head, shallow drainage lines collected the run-off and poured it into the growing depression.

Some time before 1860 the upland area was cleared of natural vegetation and was planted, only the steep slope between the shoulder of the hill and the permanent stream being left in woods. Evidence that the land, now deeply gullied, was once cultivated may be seen in the distinct line which separates the surface soil, disturbed by cultivation, from the underlying undisturbed soil, which is mostly of the B horizon. Such a line is present on all or most of the islands of the upland which now remain in the gully (fig. 68). Through this field flowed the water from a roadside ditch that drained several acres of farm land north of the gully. As erosion progressed, the gully lengthened, following the drainage lines, and by 1875 the two heads had extended 50 to 100 feet upslope from the position they occupied in 1855. The northeastern head, now referred to as basin K, has changed very little since 1875. Retarded by the resistant Worsham soil, erosion could proceed only slowly at this portion of the slope. Continued abrasion, however, finally wore through the Worsham material. As erosion reached vertically downward into the saprolite, and upslope to the weaker Appling soil, the rate of cutting was greatly accelerated, and caving of the walls became more important (fig. 73).

By 1895 the gully head had moved 100 to 150 feet upslope along what is now the main channel, basin G had been cut to approximately its present length, and the tributary channels D, E-F, H, and J had been started (fig. 72). The headward extension of basins G and K was stopped by the construction of a diversion ditch and embankment, and natural stabilization of the heads by vegetation then began.

Terracing first became common in the region around Walden's gully at about this period. No direct evidence is available, but local residents think that the area around the gully was terraced about 1895 to 1900. The terraces collected the run-off of the slope and directed it toward the gully, thus increasing the flow down the channel and causing faster erosion. Terraces drained into what have become basins C, F, H, and J. Drainage through terrace breaks about 1895 to 1905 is thought to have been responsible for the cutting of basins D and E. Basin A was initiated by a later terrace break which probably occurred between 1905 and 1915. By 1915 basin C had reached approximately its present size, and vegetation had started the process of stabilization. It appears that formerly head

C had carried the overflow water from the road ditch, but that about 1915 natural or artificial diversion added that water to the drainage of basin A. As the gully heads approached the drainage divides of the terraces, they received less and less water; activity diminished and stabilization was approached. Heads E and F have gradually healed and have reached a fair degree of stability (fig. 74), but although D and H are close to the divides and are no longer actively eroding, they are still bare.

In the period from 1915 to 1938, basin A was carved and the head of basin D was undercut and captured, thus forming the large islands. The rapid erosion of basin J began about 1915, when a break in the terrace leading to head H allowed that water to drain into the east side of basin J. Rapid deepening of the main channel during this and earlier periods left basin G as a hanging valley with its mouth 10 feet higher than the trunk channel and separated from it by a knife-edge divide (figs. 63 and 69). The upstream end of this divide is being undercut at the present time, and if this process continues, the upper portion of basin G will be captured.

Walden's gully is of compound form (fig. 15). Heads working up the slope have tended to produce a dendritic or branching pattern. Erosion cutting headward along terrace water furrows, since 1900 or 1905, has carved lateral tributaries to the gully, thus giving part of it a trellis pattern. As gully tributaries dissected the land, the areas between them were withdrawn from cultivation and by 1916 had begun to grow up in broomsedge and small pines. Later erosion completely isolated several of these areas and left them as large islands within the gully.

PRESENT LAND USE AND EROSION CONDITIONS

When studied in the late summer and early fall of 1936 only 3 basins, A, B, and J, out of a total of 10 were active. A comparison of the maps made in 1936–37 (figs. 53 and 69) and the aerial photographs taken in 1934 shows that head C did not change its position during that period, but that basin A cut headward about 55 feet in 2½ years. Head C, for many years, has been partially stabilized with honeysuckle and small saplings of pine and tuliptree. Head A, on the contrary, has been barren (figs. 68 and 70).

On September 10, 1936, a ditch was dug by the landowner, diverting away from head A all the drainage from the road and from the upper terrace. The flow was directed across a well-sodded slope draining into an adjoining gully several hundred feet farther north (fig. 69). Since that time the large cave head in basin A has disappeared, the roof of the arch has fallen in, and there has not been sufficient flow of water through the gully to remove the caved material (pp. 82, 87 and figs. 32 and 33). The healing process has started, and several kinds of grasses and honeysuckle are taking root on the long slope of caved material. The diversion of the water was very simple and required only a few hours' labor with a shovel. The result may be the stabilization of this basin of the gully and protection of the highway against erosion.

For a few years before September 1936, basin A was the most rapidly eroding part of the gully, and down-cutting of the channel

FIGURE 10

FOUND AT END

OF BULLETIN.

FIGURE 71

FOUND AT END

OF BULLETIN.

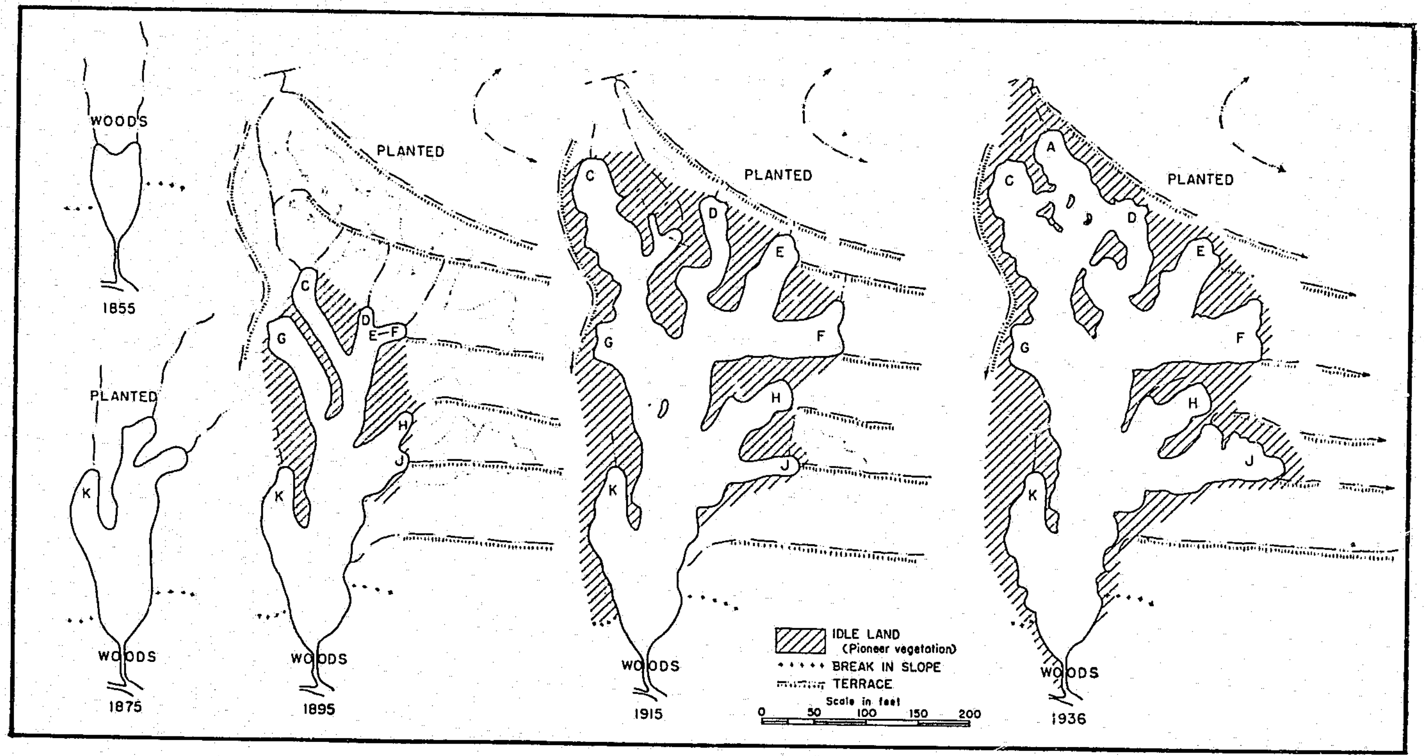


FIGURE 72.—Reconstructed history of Walden's gully, 1 mile west of Moore, S. C.

FIGURE 73.—Deep undercut in weak saprolite on the west wall of the main channel of Walden's gully, along the line of section 4–4′. Although the rock structures are preserved, the wall material is soft and porous.

draining that branch determined the grade for other basins near the head of the gully. The outlet from basin B, for example, has been incised so quickly, to keep pace with the down-cutting of the main channel, that it is now 12 feet deep but only one-half foot wide (fig. 63, Walden section 3–3′, and fig. 69). Basin B has a very small drainage area and although it will eventually become graded to the main channel this process will take a long time.

In 1937 basin J, with eight cutting heads, was the only basin of the gully which was eroding rapidly (fig. 71). Although the total area

FIGURE 74.—View up the channel of basin F, Walden's gully, now partly stabilized by vegetation. The largest tree is 18 years old.

drained was less than one-seventh acre, caving was very active and the flow of water was sufficient to remove the caved material. The head J–1, on the east side of basin J, is very likely to cut through the neck of the upland spur dividing basins H and J, thereby isolating the end of the spur as another large island within the gully.

The other five basins of the gully are relatively stable. Some erosion takes place in all of them, but its progress is slow. The relation of the basins to the slope has an important effect. Those lying transverse to the slope, such as F, H, and J, have their up-slope walls cut by the erosion of water passing over the rim, whereas the down-slope wall, affected only by rainwash and caving, is more favorable for the development of a vegetal cover. Walls of gully basins cut in wooded areas may be protected temporarily by the root mats of trees (fig. 75).

FIGURE 75.—The root system of this large oak has been effective in retarding erosion of the projecting point on the northeast side of the gully, 15 feet southeast of section 10–10′.

The channels of several of the basins contain steps or knickpoints, most of which have developed in the main channel and have worked headward up the tributaries. Some of these are 2 to 5 feet high and make the channel a series of steps (figs. 63 and 71). Many of them were started by periods of excessive erosion, some of which may be correlated with individual storms or times when cultivation was intensified in response to high prices or increased demand. The knickpoints in basins H and J, at about equal distances from the H-J fork, suggest the propagation of the same period of deepening up both tributaries (fig. 63, Walden profiles H–1, J–2, and J–8). Knickpoints in channels D–1 and C–1, at about the same distance from the gully mouth, may also have resulted from the migration up both channels of a knick which originated in the main gully. Rapid cutting of a large gully north of Walden's gully has lowered the channel of the stream to which both are tributary. A knickpoint 8 feet high recently has worked about 40 feet up the Walden main channel. If this knick continues to move up the channel, marked deepening of all the tributary basins must be expected.

No gully can be considered truly stabilized until it has been graded to a permanent base level, either natural or produced artificially by the construction of substantial check dams. These dams themselves must be protected against undermining by knickpoints or their life may be very short (*9*). (See pp. 74–75 and fig. 41.)

LITTLEJOHN'S GULLY

The Littlejohn gully, on the farm of E. N. Littlejohn 2½ miles southwest of Pacolet and 10 miles southeast of Spartanburg, shows the rapid destruction of an old road by gullying (figs. 6 and 76).

The bedrock at this gully area is essentially a hornblende gneiss heavily injected by granite and cut by many pegmatite dikes. Remnants of the gneiss, now badly disintegrated, are prominent in the head of the channel designated as basin A (fig. 77). Fine-grained and porphyritic granites, together with pegmatites, constitute the walls in basin B, which follows the line of the old road. The gneiss, granite, and pegmatite all are weathered to the full depth of the gully and offer little resistance to erosion. The soil in the areas of gneiss and fine-grained granite is a Cecil clay loam, from which most of the topsoil has been removed by sheet wash. The subsoil, or B horizon, a tough clay of moderate thickness, forms the uppermost 4 to 6 feet of the gully walls. The soil from the porphyritic granite, which occupies the area east and northeast of the gully (fig. 78), is of the Lockhart series. The topsoil has been removed from most of the area covered by this soil type throughout the watershed, and near the gully much of the subsoil, too, has been eroded away.

The Littlejohn gully is cut into a smooth hillside sloping less than 10 percent. Most of the run-off comes from an abandoned field of 5.9 acres north of the highway. That area once was terraced, but since its abandonment many of the terraces have broken and the fields have grown up in broomsedge, plums, persimmons, briars, and

FIGURE 76.—Littlejohn's gully, looking across basin A and up the course of basin B which follows the old road. The new road is at the left.

other pioneer plants (fig. 78). Drainage from this area is collected north of the highway and reaches the gully by way of a culvert underneath the road.

This gully is somewhat less than 40 years old. It developed where water from road ditches and terraces was concentrated in a small natural valley. Accelerated erosion deepened the natural channel and developed a cave-head gully which advanced headward up the valley and into the road ditches and terrace outlets. Until about 1929 the old road could be used, but since that time 175 feet of the roadbed has been cut away by gullying to a depth of 24 feet below road level. Cutting of road ditches down through the base of the B horizon, especially in areas of Lockhart soil, converts the ditches to destructive gullies. Rapid incision of the ditches occurs, and in many places lateral cutting that undermines the road results. Roadside drains extending downward into the C horizon are commonly several times deeper than their width in the resistant B material. In the C horizon, however, they broaden again, which gives them a bulbous enlargement at the base. As portions of the B horizon are undermined and cave away, the ditch or gully assumes a more normal shape with vertical or sloping walls.

Little water now passes along the old road into basin B. If the flow were large, erosion would be very rapid because the subsoil has been removed and the heads in the upper part of basin B are cutting directly in the C horizon. This condition does not allow the development of cave heads, as there is no resistant material to form an overhanging rim. Erosion is probably somewhat slower than it would be if an overhang existed and caving and back trickle were operative.

Construction of the new highway, 60 feet north of the old one, diverted drainage from head B but has increased greatly the flow into head A and has caused rapid growth there. According to the owner, this head cut 30 feet in a single year. Actual measurements made in 1936–37 showed 10 feet of cutting in a little over 2 months (p. 87 and figs. 53 and 54). The head of basin A is now within 25 feet of the road and, unless brought under control, will force relocation of the road within a few years (figs. 76 and 77). The main channel of the gully and basins A and B are barren of vegetation, and the walls are retreating rapidly (fig. 78). Caving is active at the head of basin A (fig. 29), around the mouth of basin B, and on the south side of basin B, where drainage of 0.37 acre from a single terrace has developed a prominent cave head (fig. 31). Water from this terrace is responsible for most of the recent erosion in basin B.

An unusual feature of this gully is the large step or shoulder, about 75 feet long and 25 feet wide, on the west side of basin A. The shape of this mass and the position of slumped and caved blocks on its surface suggest that at some former time the gully channel lay along the top of the shoulder, but that the channel was abandoned, owing possibly to the capture of the drainage by a more active tributary.

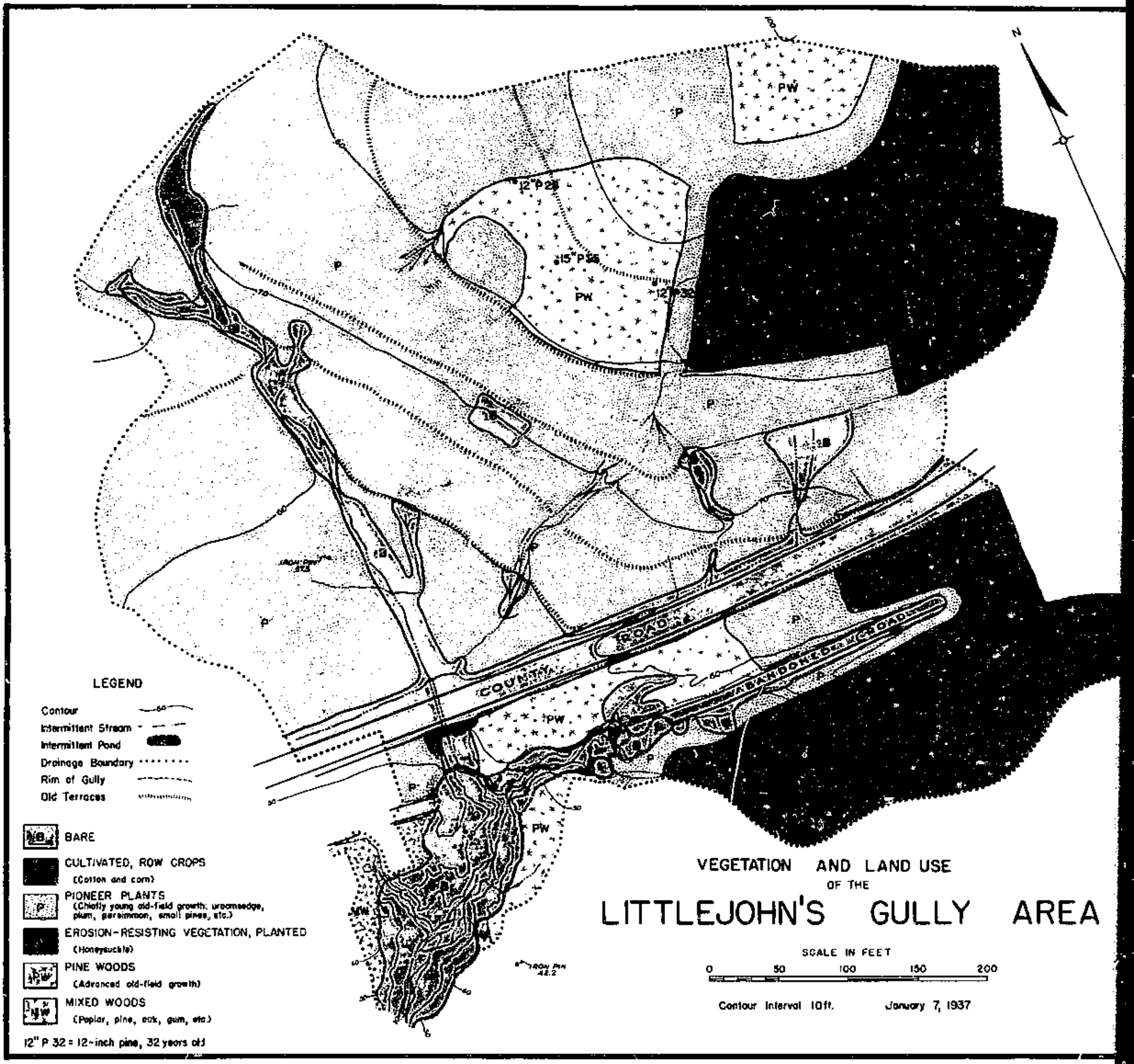


FIGURE 78.—Vegetation and land use of the Littlejohn's gully area.

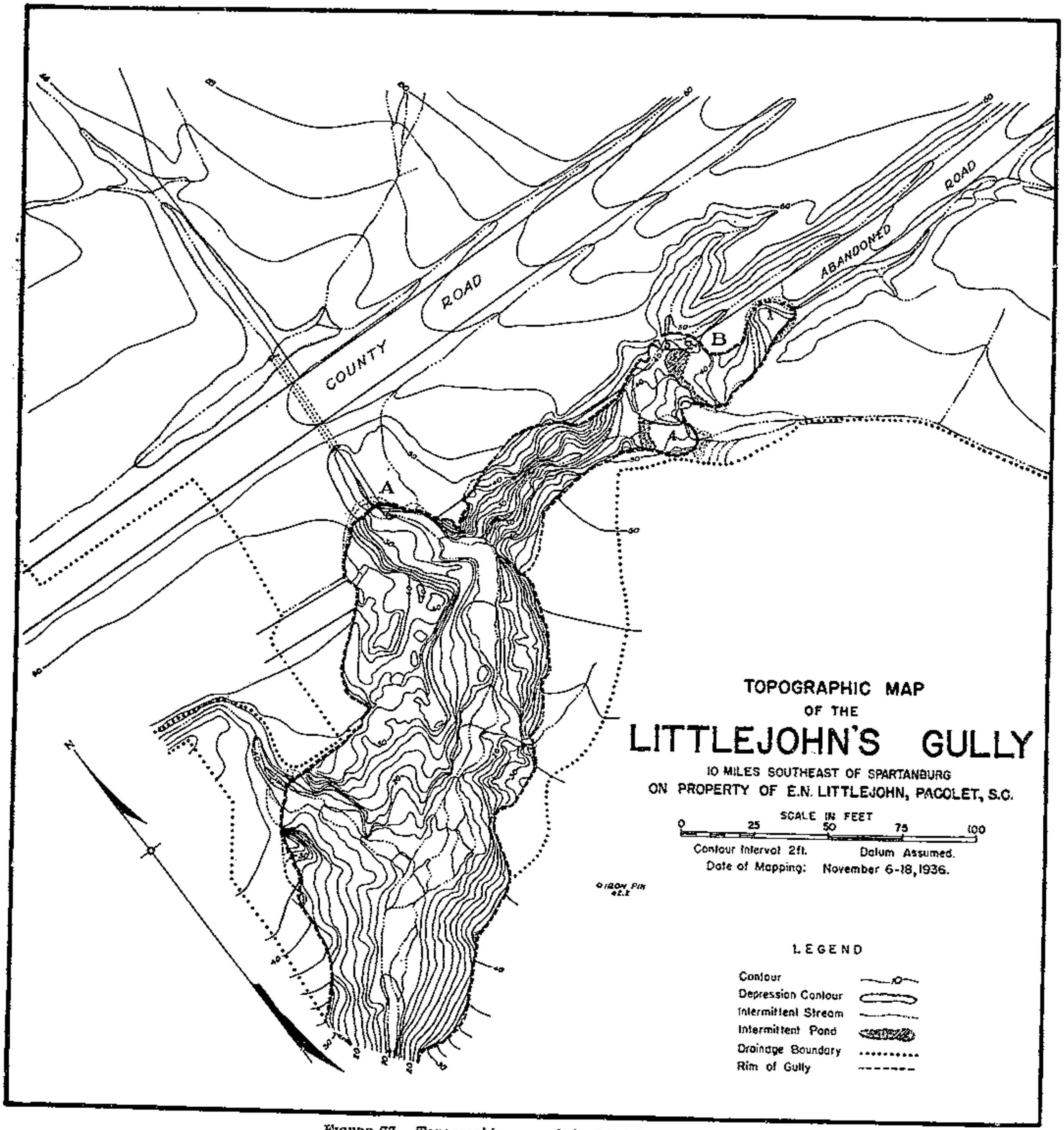


Figure 77.—Topographic map of the Littlejohn's gully.

COX'S GULLY

The Cox gully, located on the property of A. J. Cox, 4 miles southeast of Switzer and 16 miles by road south of Spartanburg (fig. 6), differs markedly from the other gullies here described in that its channel has aggraded to a depth of several feet. Owing to the intense activity of two important gully heads, large quantities of erosional debris are provided, but except in very heavy rains there is insufficient flow of water to carry the material to the lower end of the gully. A large volume of sediment has accumulated in the channel, buried the growing vegetation, and constantly raised the level of the broad, flat gully floor (figs. 42, 79, and 80).

HISTORY AND SETTING

The serious erosion in and around this gully is intricately related to the agricultural history of the area, which is one of the earliest developed farming districts in the county. The land was granted to John Patten by the first Governor of South Carolina about 1785 and is believed to have been put into cultivation shortly thereafter. A large brick plantation house was built about 1800 and apparently became the center of a small community, as the adjacent crossroads is known to have had its own post office. The big house, now in a bad state of disrepair, stands about 200 yards from the present head of the gully (figs. 80 and 81). The old road which crosses the gully area was present in 1820, as is shown on the Spartanburg County map in Mill's Atlas of 1825 (*22*). Serious gullying forced the abandonment of the original road about 1922, and a new one was constructed farther up the slope.

The Cox gully area is underlain in part by mica schist and in part by a highly feldspathic granite gneiss. Where the rock is deeply decayed, as at gully heads A and B, the parent material is extremely weak and friable. Where somewhat less badly weathered, the rock is still relatively resistant. The soils vary according to the underlying parent material. In most of the area they are of the Louisa series. Some of the soil resembles the Lockhart, but is classed as Louisa because of the greater depth of the B horizon, its deeper red color, higher plasticity, and greater resistance to erosion. At the falls in the main channel below head A (fig. 79, section 5–5′), part of the tough topsoil or B horizon appears to be semistratified and attains a maximum depth of 12 feet, lying directly on fairly resistant bedrock, which forms the falls. This narrow rocky portion of the channel is a local base level below which basin A cannot erode rapidly. Deep pot holes are present in the rock at the falls, but even so this barrier can be expected to control the deepening of basin A for a long time to come.

The Cox gully is incised into what was originally a shallow valley with gentle slopes ranging from about 15 percent along the channel to 3 percent near the divide. It extends from near the old plantation house southwestward to Ferguson Creek, one of the major tributaries of the South Tyger River. Rills and shallow gullies caused by terrace breaks, improper terrace outlets, and road drains, in the absence of adequate soil-conserving practices, are closely spaced in the area above the deeper gully. The surface of the abandoned road has been lowered 10 feet, and ditches bordering the road have cut into the weak C horizon. The main gully down the center of the old valley may have been formed as much as 50 years ago, but later became temporarily stabilized by a thick growth of vegetation. More recently, head A of the main channel and head B on the north side have renewed active cutting.

PRESENT LAND USE AND EROSION CONDITIONS

Early in 1937 when the vegetation and land use around this gully were mapped (fig. 80), the 2.14 acres in cotton was the only part of the drainage area which was under cultivation. Much the greater part has at some time been cultivated but has later been abandoned. Old-field pine covers 3 acres. The trees on the badly eroded steeper slopes north of the gully show by their age that cultivation of that portion of the land was discontinued nearly 80 years ago. Near the outer edge of the woods, however, the trees are younger, thus suggesting gradual encroachment on the cultivated fields as the margins of the tilled land became eroded and were abandoned from cultivation. This process is still going on, as is shown by the small strip of pioneer plants above gully head B. Since the gully was mapped, however, an area of pine woods around that head has been cut for cordwood and the land returned to cultivation.

One-half acre was abandoned when the old road was rerouted some 15 years ago. Part of this is growing up in broomsedge and small pines, but about 0.13 acre immediately upslope from gully basin A is bare, because erosion is too rapid to allow vegetation to gain a foothold (fig. 82). East of the new road a field of 1.17 acres has recently been taken out of cultivation and is raising a thin cover of pioneer vegetation. One-half acre between the roads has been idle for a longer time and has been planted to black locust and loblolly pine by the Soil Conservation Service. The downstream part of the valley has a cover of mixed woods, either because of the better supply of moisture there, or because the area may never have been entirely cleared.

The main channel of Cox's gully, lying along the axis of the old valley, averages about 10 feet in depth, but the tributaries, which cut into the steeper side slopes, are somewhat deeper. In the last few years basin A has advanced completely across the old road and now has tributary heads where each road ditch enters (fig. 82). The principal drainage into this basin is from abandoned fields, pine woods, and the old and new roads. At the lower end of basin A the channel narrows to about 1 foot and then drops 5 feet to the floor of the graded portion of the gully.

Basin B, the tributary draining the cultivated field north of the gully, has the most active and rapidly advancing gully head studied in the Spartanburg area (pp. 87–89 and figs. 53 and 55). Between October 27, 1936, and April 6, 1937, this head advanced upslope 20 feet. If this rate were to continue, it would take only a few years for head B to destroy the field which it drains. Head A, unless checked, will advance upslope and undermine the relocated road as it did the old road.

FIGURE 79

FOUND AT END

OF BULLETIN.

FIGURE 80

FOUND AT END

OF BULLETIN.

FIGURE 81.—This large brick plantation house near Cox's gully was built about 1800. Now, with the lands eroded by sheet wash and gullying, the house has reached a very dilapidated condition.

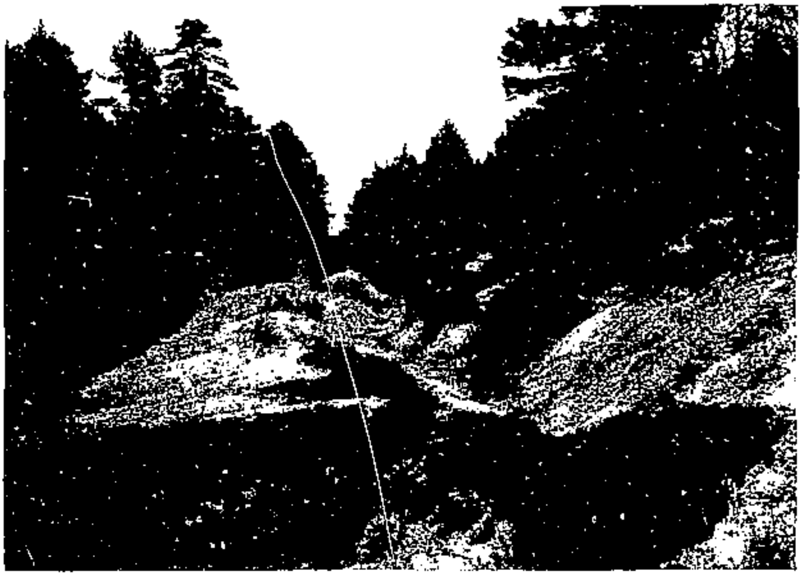


FIGURE 82.—View across head A of Cox's gully and northeastward up the old road, showing the deep erosion and barren surfaces.

THE GRADED CHANNEL

Deposition and removal of sediment from the channel of Cox's gully depend on the character and intensity of the rainfall. The run-off from a light rain occurring after a dry period, sinks rapidly into the deep sand train on the gully floor, and material carried by the flowing water is deposited. Raising of the gully channel by this process has buried some of the younger vegetation, and the sediment has encroached many feet on the larger and older trees. During a period of about 2 months in the spring of 1937 material washed from gully heads A and B built up the level of the main channel by an average of more than 15 inches.

Deposition may continue intermittently for many months, gradually raising the level of the gully floor. An exceptionally heavy rain, or one coming at a time when other showers have saturated the fill in the valley floor, however, can cut away much of the fill material and carry it along to be deposited in the downstream end of the gully or to be poured into Ferguson Creek. Other factors affecting the establishment of grade in the gully include the thick mat of honeysuckle which covers the floor and climbs into the trees in the lower end of the valley and the deposits, like natural levees, formed by Ferguson Creek during flood stages. Sedimentary deposits of this sort where the sand fan at the mouth of Cox's gully enters Ferguson Creek appear to have raised the temporary base level of the gully. Recent cutting out of brush along the shores of Ferguson Creek (designated as a "drainage project") may in time bring about accelerated erosion of the stream banks, removal of the lower end of the gully fan, and a lowering of the gully base level with consequent removal of the fill.

A series of borings into the fill in Cox's gully was made on seven ranges across the main channel and on two ranges across the tributary channel, basin B, along the lines of cross sections 6, 8, 9, 11, 12, 13, 14, 15, and 16 (figs. 79 and 83). In each range, holes were drilled at 1-foot intervals within 5 feet of the gully walls and at 2-foot intervals across the remainder of the section. The character and thickness of the fill, the size and position of the buried gully channel, and the relation of the water table to the gray unoxidized parent material were noted. Most of the borings passed through coarsely laminated, fine- to coarse-grained light-colored quartz sand, containing mica and feldspar, and having a layer of fine red clay at the top of each lamina. The sands are redder and more clayey at the base, where they are in contact with the red oxidized micaceous clay of the old buried gully walls. Below the red clay is the gray micaceous saprolite of the parent material. Where the saprolite lay more than 9 feet below the surface it could not be reached by the auger used for the boring.

In sections 6 and 8 (fig. 83), the top of the unoxidized saprolite coincides with the ground-water level and is lower than the bottom of the old gully channel. This indicates that oxidation causing the red color in the clay takes place only above the level of ground water. In section 9, the ground-water level is above the saprolite but still below the old gully floor.

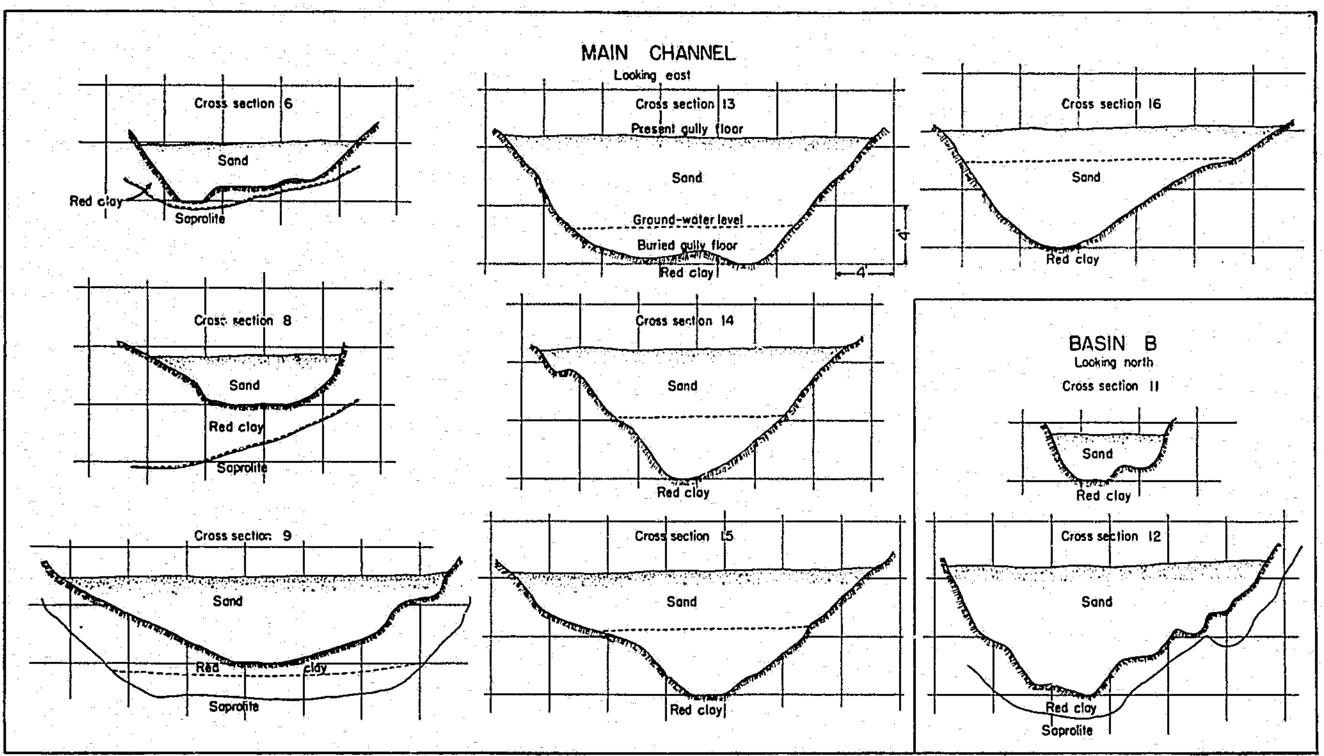


Figure 83.—Cross section of Cox's gully, showing the position of the water table and the character of the material beneath the present gully floor.

No water was encountered in the borings along sections 11 and 12 across basin B. This results probably from the fact that effective subsurface drainage of water into the main gully channel has lowered the ground-water level on the adjacent slopes. It appears that the level was formerly at the top of the saprolite.

In sections 13, 14, 15, and 16 the surface of the ground water is in the sedimentary fill above the old channel and is essentially horizontal. It comes closer and closer to the surface in successive sections down the channel and about 150 to 200 feet downstream from section 16, ground water is at the surface, as shown by the moist, swampy conditions. The level of ground water varies from day to day and from season to season according to precipitation and evaporation and may at times rise into the red clay even at the upper end of the channel as at sections 6 and 8. The elevation is controlled in part, also, by the thickness and porosity of the sedimentary fill in the old gully. Recent changes in water level have not lasted long enough to cause deoxidation. The red color of the clay is related directly to an average level of ground water and has been produced by oxidation during a long period of time. The abundant ground water in the channel of Cox's gully has helped the growth of vegetation, thereby aiding in building up the sand fan and bringing about the graded condition of the gully channel.

BARRY'S GULLY

The Barry gully, on the farm of R. H. Barry, 2 miles northwest of Moore, shows how by simple and inexpensive measures a farmer can retard the growth and control the shape of a gully. Water from an area of 18.5 acres drains to the gully, but careful farming has helped to prevent excessive run-off. Lespedeza followed by small grain is used in fallow fields. Where cotton is grown, an interrow of oats is used for winter cover. Bermuda grass and cowpeas now occupy considerable parts of the area, and no land is bare except along the roads and on parts of the gully floor. The flow of water approaching the gully is dispersed to some extent by a 2.7-acre Bermuda grass pasture (figs. 84, 85, and 86).

DEVELOPMENT OF PRESENT DRAINAGE

The gully has developed along the axis of a small, wooded, natural valley, which headed at a spring lying in a broad semicircular depression in the slope (fig 87). It is cut in Appling soil, comparatively resistant to a depth of 10 or 15 feet but underlain by decomposed granitic rock which is more vulnerable to erosion than the soil horizons above. The land of the gently sloping drainage area was cleared and farmed long before the Civil War. Continued cultivation and planting of many clean-tilled crops, however, so increased the run-off that a gully was initiated at the streamhead. By 1917 this gully had deepened and had developed a vertical head or plunge pool which had advanced some 200 feet into the Bermuda grass pasture (fig 87). Enlargement took place chiefly by the caving off of large blocks of the tough Appling soil, but the material, being of fairly uniform resistance, did not develop overhanging cave heads.

The gully not only had destroyed a considerable area of the pasture, but by advancing toward the road threatened to divide it in

FIGURE 84

FOUND AT END

OF BULLETIN.

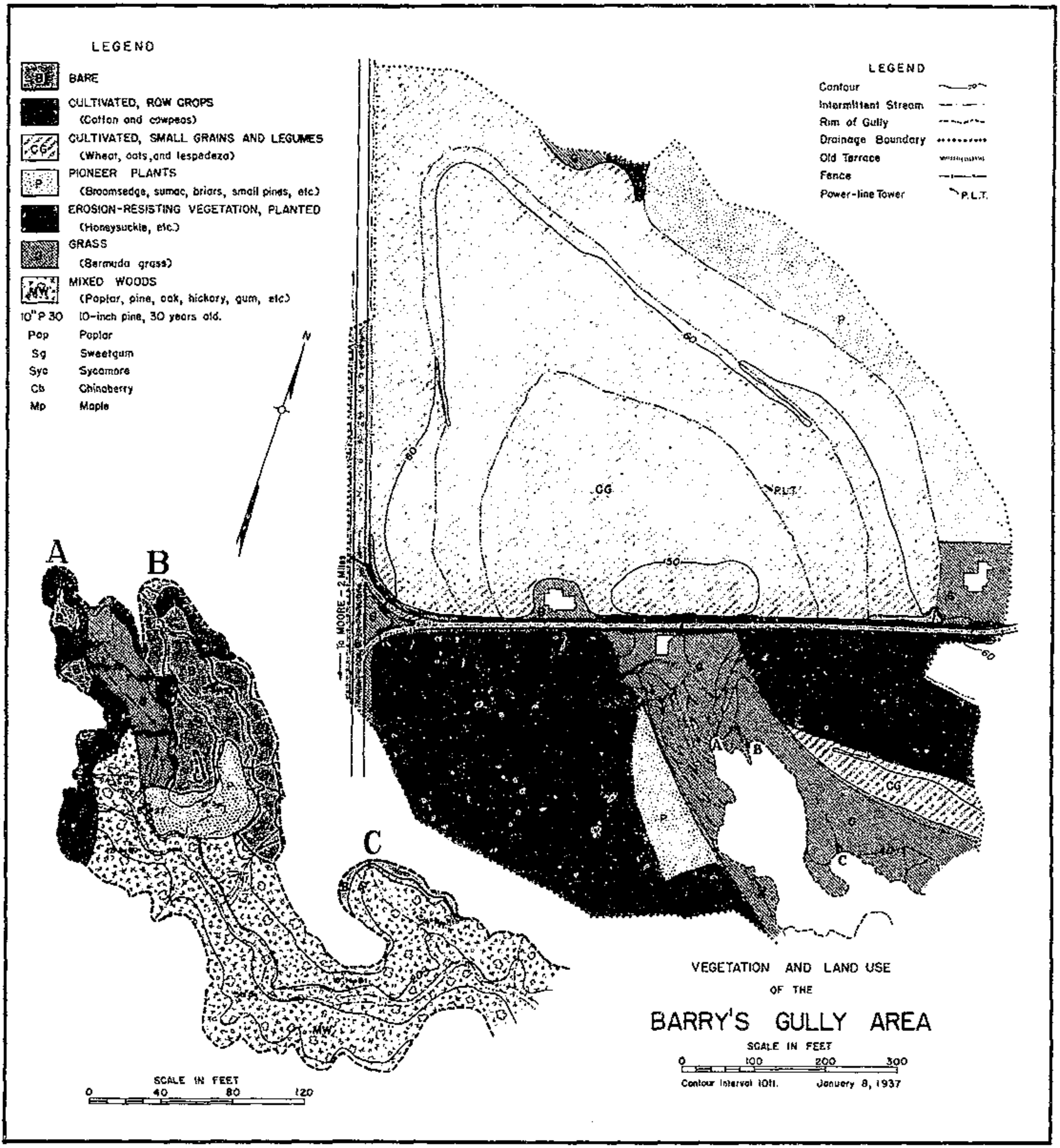


Figure 85.—Vegetation and land use of the Barry's gully area.

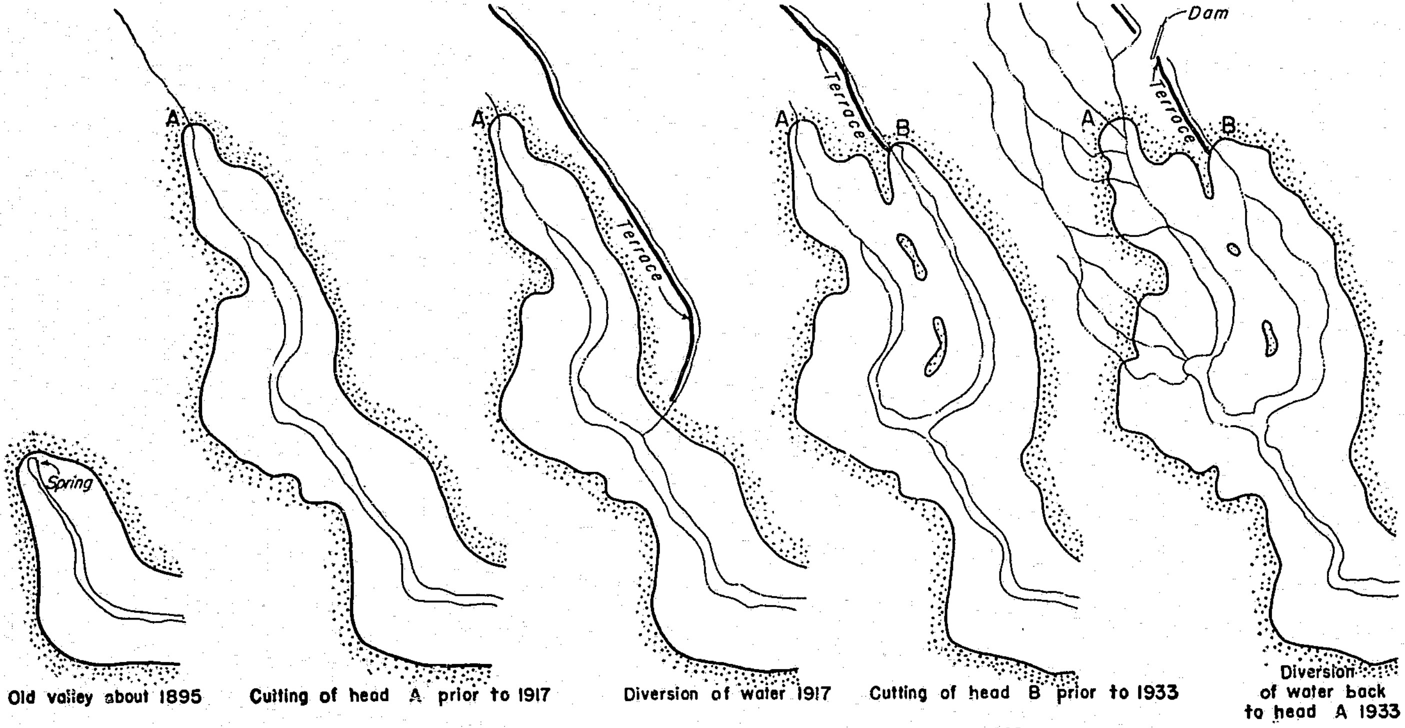
two. To avoid this inconvenient splitting of the pasture and to retard the growth of the gully, the owner, in 1917, constructed a terrace which prevented the flow from reaching head A and carried it some 150 feet farther down the east rim before allowing it to enter the gully (fig. 87). The outlet of the new channel was unprotected, however, and headward cutting developed a new branch of the gully, basin B, which followed the line of the terrace.

The older gully, in the meantime, was planted to briars, climbing rose, honeysuckle, and chinaberry. These, assisted by natural growths of sycamore, cedar, tuliptree, and sweetgum, began to stabilize the head and walls. The Bermuda grass of the pasture, transplanted naturally by the caving of sodded blocks from the gully rim, aided in stabilizing the gully head.

FIGURE 86.—Headward portion of Barry's gully. The Bermuda grass pasture extends to the fence. The field across the road is planted in small grain.

By 1933, basin B had been cut to about the same length as basin A (fig. 87) and threatened to continue headward toward the road. In the interval of 16 years, however, head A had become so well stabilized that the farmer decided he could safely plow out one side of the terrace leading into head B, block the terrace drain by a small dam, and divert the water back into head A. Head B is now beginning to be stabilized by Himalaya-berries and rose cuttings planted there, and by pioneer growths of pine and hardwood saplings. Material caved from the head and walls has begun to accumulate and eventually will form a more gentle slope on which other vegetation can become established.

By 1936 head A had begun to show slight effects from the renewed erosion, but by the time a hazardous stage is reached head B will probably be sufficiently well stabilized to take care of the entire flow.



Old valley about 1895 Cutting of head A prior to 1917 Diversion of water 1917 Cutting of head B prior to 1933 Diversion of water back to head A 1933

FIGURE 87.—Development of Barry's gully from about 1895 to 1933.

The possibility of wide application of this principle of rotation of gully heads as a conservation practice was suggested in a previous article (13). Successful application of the principle depends on many factors, including the soil type, slope, and land use. Although diversion of water from the active heads at the Barry gully did not stop further enlargement, it prevented division of the pasture, protected the road, and retarded the erosive processes. Complete control of the erosion would probably have been too expensive a project, both in labor and money, to be undertaken privately by the landowner. Retirement of the Bermuda grass pasture from grazing and more complete planting of the gully heads and walls would have been valuable though relatively inexpensive additions to the control program that was used.

Head C of the Barry gully developed many years ago where drainage from a terrace entered the lower part of the valley at a break in the surface slope. Erosion of this gully head was arrested by reversing the drainage in the terrace, thereby cutting off the supply of water. Since that time the walls of head C have gradually assumed a more gentle angle. Trees as much as 30 years old are now growing in that basin of the gully (fig. 85).

THE KNICKPOINT

Rotation of the heads has greatly diminished the hazard of this gully to the farm land above. Another source of danger, however, is found farther down the gully. During the cutting of basins A and B, the channel within the gully has gradually grown deeper. This has not taken place uniformly but has been most marked downstream. A knickpoint (p. 74) about 6 feet high has developed and is moving upstream (fig. 88). Its lip is at the level of the floor of

FIGURE 88.—Knickpoint 6 feet high in the lower end of basin A of Barry's gully, at cross section 5-5′ on the topographic map.

basin A and is held up by the root mat of the vegetation which had partially stabilized that gully channel. Close beneath this old channel floor lies the weak rotten rock or saprolite of the disintegrated granite gneiss, and this material is rapidly being cut away by plunge-pool action. Unless this rejuvenation of the erosional process is checked, the whole gully will be cut downward into the weak C horizon, and stabilization will then be a much more difficult problem.

FOSTER'S TAVERN AREA

The Foster's Tavern area, located 3 miles southeast of Spartanburg along United States Highway No. 176, is named for the pretentious old brick house north of the crossroads (fig. 89). The house was built by Anthony Foster about 1815, and was used for many years as a tavern and inn. Its position at the intersection of the old Georgia Road, now a county road, and the Spartanburg-Columbia Road, now a concrete highway, made it an important stopping place for travelers, especially those going between Alabama or Georgia and the Central Atlantic States. Some of the gullying of the lands is believed to have started from the enlargement of pits from which clay was taken to make brick for the house. By the time of the Civil War the fields across the road intersection from the house (figs. 90 and 91) were deeply dissected by gullies, apparently developed in part by the abandonment and neglect of the land during the war. According to local tradition, these gullies were used for meetings of the Ku Klux Klan, and the initials KKK deeply carved in the trunk of an old maple tree in the gully basin

FIGURE 89.—Foster's Tavern, at the intersection of United States Highway No. 176 and the old Georgia Road, near Spartanburg, S. C. This mansion, built about 1815, is now a private residence.

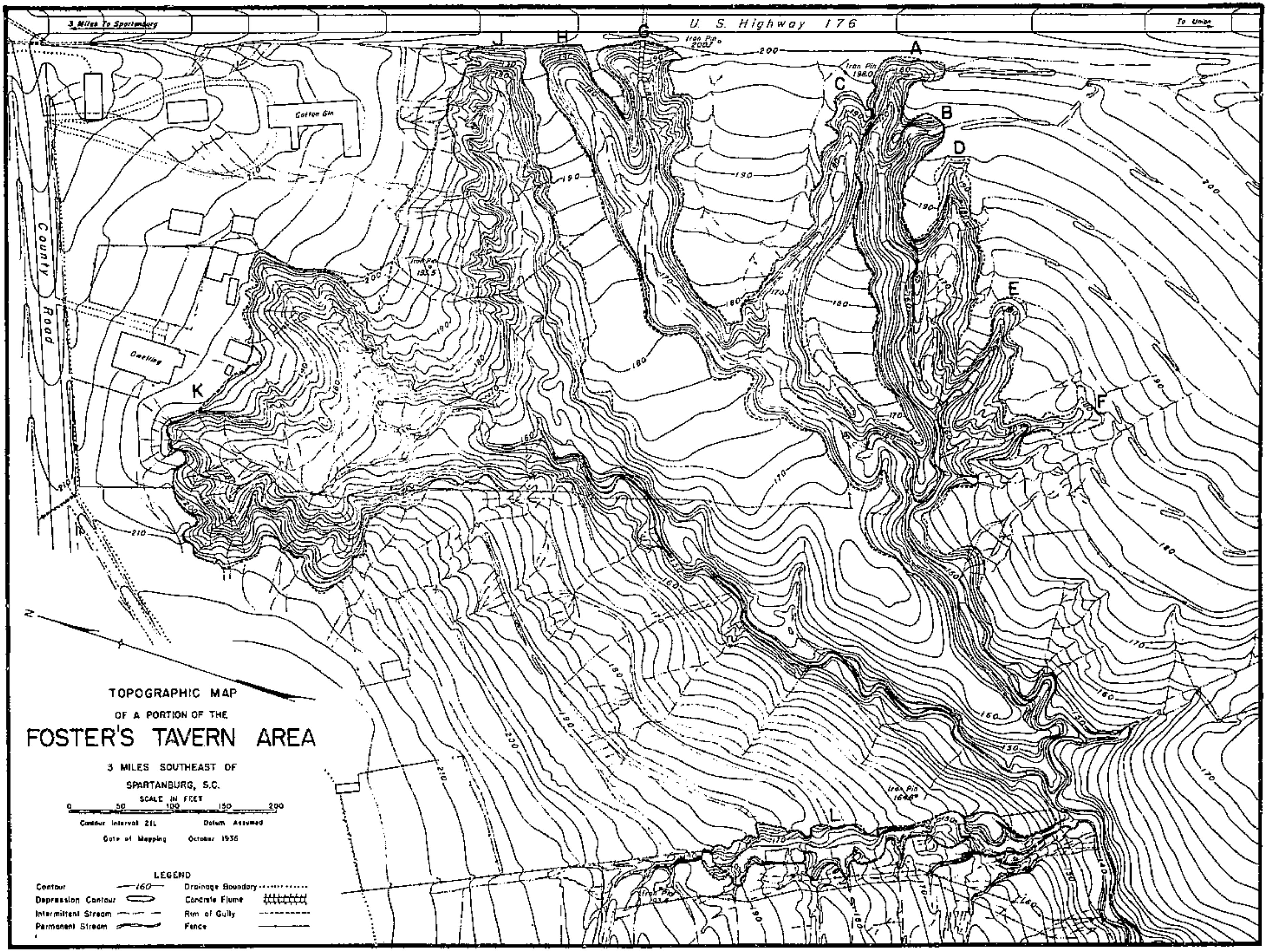


FIGURE 90.—Topographic map of a portion of the Foster's Tavern area.

here designated K, are sometimes taken as substantiation of this story.

Field surveys made in 1936–37 show that much land in the Foster's Tavern area has been abandoned. Most of that still under cultivation is badly sheet washed, and deep gullies have so dissected the area that the fields are small and of irregular shape. A large part of this damage can be attributed to improper design of terraces and terrace outlets. Lack of adequate terrace maintenance is also an important factor; and many of the gullies in abandoned fields have developed from old terraces which have filled with washed soil and have broken over, causing destructive erosion at each break.

Land taken out of cultivation in this area grows up in a pioneer succession including crabgrass, Bermuda grass, broomsedge, sumac, briars, and pines. If left in a natural state the vegetation gradually changes toward a thick growth of shortleaf pine on the uplands and pine with a scattering of hardwoods, such as maple, tuliptree, and beech, in the valley bottoms and in gully channels, where ground water is normally close to the surface.

GEOLOGY AND SOILS

The Foster's Tavern area is underlain by a deeply weathered coarse-textured granite gneiss, containing many large crystals of acid feldspar which now have weathered to kaolin or white clay. These, with the dark minerals present, give a pepper-and-salt appearance to the decayed rock or saprolite. This material, once hard and resistant, is now so friable that large masses can be broken with the bare hands. It disintegrates readily when saturated by water, and blocks of it in a stream crumble and disappear much like lump sugar in hot tea. In several gullies in the area there are more resistant masses of a schistose or slaty rock; dikes or veins of resistant quartz are also present.

In the Foster's Tavern area a definite relation exists between the character of the soil and the slopes. Cecil soil occupies the uplands and extends downward to about the middle of the slopes, where, usually, it grades into a zone of Appling. Colfax soil is present from the Appling zone to the break in slope or shoulder of the hillside and is found also around the streamheads. From the break in slope to the edge of the flood plain the soil is Worsham. The narrow flood plain itself is alluvial. A small area of Lockhart soil, developed on a belt of unusually highly porphyritic gneiss, crosses gully basin L (fig. 90) near its upper end.

The topsoil of the Cecil, wherever present, is sandy and the soil is therefore classed as Cecil sandy loam. In parts of the upland area, however, removal of the topsoil by erosion has revealed the tight, resistant red clay of the B horizon, thus placing the soil in the Cecil sandy loam, mixed phase, classification. The resistant clayey subsoil of the Cecil is 12 to 15 feet deep on the uplands, but is generally less than 10 feet thick on the slopes. Beneath the subsoil lies the rotten rock or saprolite usually exposed in the deep gullies of the area.

The Colfax soil has poor internal drainage and moderately good surface drainage, and is characterized by a topsoil of gray sandy loam and a subsoil of yellow sandy clay. Under this, at a depth of about 24 to 36 inches, is a gray clay containing masses of kaolin produced by the weathering in place of feldspar crystals of the original bedrock. Layers of tight gray clay occur in some places in the basal material of the Colfax soil and greatly retard the cutting of gully channels. The average depth of the resistant parent material underlying the Colfax is about 12 feet, but beneath this is a friable saprolite, the same as that underlying the subsoil of the Cecil and Appling. Gullies cutting into the resistant material, therefore, eventually reach the saprolite, and rapid advancement of the gully by undermining and caving of large blocks of material ensues. In this area, several gullies that have developed up-slope in the Cecil soils have had their progress retarded for some time by the tough material underlying the Colfax and Worsham at the shoulder of the hill. When this material has been cut through, however, another cycle of down-cutting has been able to progress up the gully channel, deepening it considerably.

The Worsham soil is similar in some ways to the Colfax but has a gray loamy sand topsoil and a bluish gray subsoil. The soils of this series generally have poor internal drainage and are found near the zone of permanent ground water, low on the valley sides. The Worsham is not extensively developed in this area.

TOPOGRAPHY AND DRAINAGE

Most of the gullies are grouped radially around the semicircular headwater basin of a small stream (fig. 90), but others enter the stream approximately at right angles farther down its course (fig. 91). Some follow natural drainage lines, but others bear no relation to preexisting stream courses. The slopes of the valley sides are slightly convex in profile and range from 10 or 15 percent close to the streams to less than 5 percent along the divides. The general physiographic setting and the patterns of the gullies suggest that the natural streams formerly headed at springs, one each in basins J and K, and another close to the junction of basins A and G (fig. 90). On the upland above the streamheads the run-off followed gentle sags in the slope. Closer to those heads, however, between the break in slope and the valley bottom, the flowing water descended steeper slopes, of 20 or 30 percent or more. It was in this area that gully cutting probably made its start.

Much the same conditions prevail on the sides of the valley as around the streamheads. Two differences are: (1) The presence of a well-developed bench above the break in slope and 20 or 30 feet above the stream and (2) the entrenchment of the stream to a depth of about 2 feet into its narrow flood plain. This entrenchment is greatest in the southwestern part of the area, shown in figure 91, and farther downstream, where the channel has been cut to a depth of 6 feet below the flood plain. Entrenchment of the stream suggests recent rejuvenation in its activity, and this idea is borne out by other factors. Within very recent times the stream has swung laterally and has undercut the banks, causing portions of the slopes to slide downward. In the large bare spots which have resulted, gullies are beginning to form and work headward, undermining large trees. Remnants of old high-level scars where the stream has undercut its banks show the former elevation of the stream channel. Tribu-

FIGURE 91

FOUND AT END OF BULLETIN.

taries have entrenched their channels in the alluvial plain, keeping pace with the down-cutting of the main stream. and many natural bridges formed of tree roots and surface sod have been left where the tributary streams have deepened their channels. It may thus be seen that the down-cutting and adjustment of the streams of this area are still going on.

DEVELOPMENT OF THE GULLIES

In order to understand fully the present relationships of the various gullies it is necessary to look back into the history of their development. So far as is known, the entire area was in virgin forest until about 1785. Settlements grew up in the region about that time, much of the timber was cut, and major roads including the Georgia Road and the Spartanburg-Newberry-Columbia Road were laid out. Gullying may have begun fairly early after the land was cleared. It was active long before the Civil War, and by 1864 gullies G, H, J, and K (fig. 90) not only had been cut but had already begun to stabilize.

In the latter part of the nineteenth century, chiefly between 1880 and 1900, terraces were constructed on much of the land in this area, and gully basins A to F got their start during the latter part of that period. The Spartanburg-Union Road, now United States Highway No. 176, was improved and macadamized about 1906. The heads of gullies G and H were filled artificially and a culvert was installed that diverted drainage into gully basin A. Between 1920 and 1925 the alinement of the road was modified slightly and the new route was paved with concrete. In that period also the culvert at head A was abandoned and a new one was installed at head G, which now carries most of the drainage from the area east of the highway. A few years later two tracts of land south of the gullied area were united in ownership, and the new owner revised the terracing system of the fields, thereby diverting more of the drainage to gully basin A.

GULLY BASINS A TO H

These eight gully basins are parts of one dendritic gully system (fig. 15), the branches of which come together at the head of the permanent stream 460 feet west of the highway. They were cut into a relatively smooth hillside and do not appear to have followed any older water courses. Any drainage channels which may have existed must have been very small and indistinct, as all traces of them have been removed by the gullying. It is thought that most of the gullies were initiated where surface run-off, concentrated by old terraces and road drains, was released and allowed to flow down the slopes to the streamheads. Gully cutting started at the steepest and weakest parts of the slope and worked headward toward the divide.

The gully heading in basins G and H was the original gully of this southeastern group. It had reached essentially its present form before the Civil War, as some of the trees in basin G now are more than 70 years old (fig. 92). The stabilizing vegetation remained undisturbed from that time until a year or two ago when the channel below basin A started to cut very rapidly. The lower part of the gully below heads G, H, and C is now being deepened and the trees are being undermined by a knickpoint several feet high which is cutting its way up the channel.

Basin G now receives the run-off from about 12 acres east of the highway. The water reaches the gully through a culvert and is lowered to the floor by a concrete flume, which prevents abrasion of the gully head. The large flow of water has caused a slight scouring at the outlet of the flume, but the vegetation has resisted erosion effectively and basin G has remained stable. Head H receives very little water and is entirely stable.

Gully basins A, B, D, E, and F, are related directly to terrace outlets or terrace breaks. The origin of basin C is less distinct. This basin may have been carved by water from the old culvert under the highway at the present head A or by drainage from a terrace which since has been destroyed by the cutting of basins A and B.

Basin C is one of the older branches of the gully and is well stabilized with trees more than 30 years old. It now receives drainage and sediment from the sheet-washed field immediately to the north, and, owing to the thick vegetation, much of the sediment is caught and deposited on the gully floor, which has thus been built up to a comparatively steep grade. This basin will not exist much longer, however. Its headward portion is being undermined on the south side by basin A, and is gradually being eaten away by that branch of the gully (figs. 90 and 93).

FIGURE 92.—Basin C of the Foster's Tavern area was eroded to much its present condition before the Civil War. Some of the trees are now more than 70 years old.

Basin D is similar to basin C in that it is one of the older branches of the gully and has become stable and has accumulated sediment on its floor. Basin D receives water from two terraces, the flows from which enter it over a tough gray clay, the parent material of the Colfax soil. Owing to the resistance of this material, cave heads have not developed at the present terrace outlets. Although basin D is not cutting rapidly around the rim it is being enlarged and attacked from below. Basin A, which flows at a level many feet lower, is cutting away the divide between them, and the channel in basin D is being eroded by a knickpoint moving headward from the lower end of the basin.

Basins E and F each receive water from terraces, but, because of the presence of resistant material similar to that in head D, are not eroding rapidly. These basins were active in the past, at a time when they carried a greater flow of water and before vegetation was able to gain a foothold there.

Basin A is the deepest and most active of the entire group. It now drains about 6½ acres of cultivated land, the concrete highway, an abandoned macadamized road, and a small area of abandoned farm land. For some time prior to October 1, 1936, the flow into head A was relatively small (p. 89). Much of the water draining through the highway ditch escaped through a break in the ditch bank and flowed across the field along a terrace channel to head B.

FIGURE 93.—View westward along the divide between basin A, on the left, which is actively cutting and is now 15 feet below basin C, on the right, which is stabilized. Foster's Tavern area, near Spartanburg, S. C.

On October 1, however, the break was repaired and the entire flow in the roadside ditch was diverted into head A, causing it to advance at a much faster rate. This head is absolutely unprotected and is enlarging so rapidly that it is a very real hazard to the concrete highway. The gully has already cut into the shoulder of the road, and the danger will continue to increase unless preventive measures be taken. Head B is advancing along the course of a terrace channel. Owing to the diversion of water back to head A, the B head now drains less than 2 acres and is cutting much more slowly than it did before October 1, 1936.

The channel draining basins A and B was formerly one of the minor branches of the gully, but, owing to an increase in its drainage area in the past 15 years by reterracing, it has deepened and enlarged to such an extent that it has become the master channel of the whole gully system. This channel is now 26 feet deep near basin B, and its level controls the levels of the other gully channels. The tributary gullies emptying into this main channel are all cutting downward near their mouths to keep pace with the downcutting of the master channel, and a knickpoint is progressing up each tributary. Falls or steep sections in the channel profile are present near the mouths of gully basins D, E, and F, and in the C–G–H branch of the gully. The advance of these knicks is retarded somewhat by the thick growth of vegetation on the floors of the tributary gullies, but the knickpoints are steadily moving upstream, deepening the channels and bringing an end to the period of stability.

The lower portion of the channel draining basin A is now in the healing stage. The walls are weathering and washing down to more gentle slopes, and vegetation is gaining a foothold. Trees up to 30 years in age are growing in the main channel 150 feet above the junction with the C–G–H tributary. Above this point, to the junction of basins A and B, pioneer growths of tuliptree, mimosa, and blackberry are established. In basins A and B, caving and cutting are so active and the walls are so steep that vegetation is unable to make a start. The rapid caving and erosion of the heads in basins A and B has been described on pages 89–90.

GULLY BASINS J AND K

Basins J and K are believed to have developed from the extension and enlargement of two natural stream valleys, each of which headed in a spring in a shallow natural depression in the upland. The eastern depression was enlarged by water flowing in a single channel, and developed into a more or less linear gully, now gully basin J. The other, gully basin K, had a more complex history and is broad and bulbous or fan shaped. Gullying in these two basins is reported to have started from clay pits which were opened about 1815 near the junction of basins J and K to make brick for the construction of Foster's Tavern.

From the evidence available, it appears that gully basin J has advanced about 150 or 200 feet from the head of the natural valley. Downstream from the former head the valley has less steeply sloping sides and a broader bottom than above that point (fig. 94). The gullied portion of the valley is about 20 feet deep. Little water flows over the south rim, and the wall is steep and smooth. The northern rim, however, is irregular, owing to cutting by numerous streamlets.

Trees 60 years old are growing in the bottom of basin J and, except for the northern rim, the gully is essentially stable. Where each streamlet flows over the wall, a raw active head has formed and is slowly cutting away the soil. These heads are only in the initial stage of development, but they constitute danger points, which in a few years may become serious.

Gully basin K also appears to have advanced about 200 feet above the original spring and streamhead. Part of this enlargement very probably was due to removal of clay for brick making. Drainage enters this gully in about four major channels, and, as in basin J, there are bare scars down the gully walls at each of these points. Denuded places of this sort are regarded as danger points where active gullies are apt to begin. At present, however, the drainage is small and the flow not highly concentrated, so erosion is slow. A comparatively deep B horizon of resistant clay at the gully rim is in part the cause of the slowness of cutting. Trees have been able to grow in the gully for the last 70 years or more, and it is near the mouth of basin K that the maple tree, bearing the carving "KKK" stands. The lower portion of this gully basin is in Worsham soil, and is a flat meadow covered with grass and containing a stream which flows most of the year. This part of the valley appears to have been stable for many decades. The small stream, however, has several knickpoints in its channel, below which it is entrenched to a depth of about 2 feet. How long it will take for this renewed cycle of cutting to destroy the meadow and undermine the trees remains to be seen. It is evident, though, that gully stability is relative and easily may be upset, after remaining undisturbed for a long period of years.

FIGURE 94.—View upstream in the old normal valley several hundred feet below the juncture of gully basins J and K of the Foster's Tavern area.

GULLY L

Gully L lies about 500 feet southwest from the broad upper portion of gully K, but its drainage enters the main stream only 30 feet below the outlet of the J–K gullies (fig. 90). Gully L is typical of the erosion where terrace waters are directed into a ditch along a property line. It is distinctly linear, although its rim outline is irregular and tends toward a trellis pattern, owing to the extension of lateral heads up terraces and other drainage channels entering the gully. The gully follows the property line so closely that for several hundred feet only a few posts of the line fence are still in the ground; the others hang over the gully, dangling from the useless fence wire.

Although gully L has a maximum depth of 24 feet, it is much younger than basins A to K. According to the owner of the property, on the west side of the fence the rapid erosion which formed the gully took place in "freshets" in 1928 and 1929. Prior to 1928 there was only a ditch that one could step across at almost any point. In 1928 and 1929, however, torrential rains caused such heavy run-off that the gully was greatly enlarged almost overnight. No record of the actual dates of the excessive gully cutting is available, but it seems safe to assume that the erosion took place largely in the exceptionally severe rains of August 10–12 and 15–17, 1928 (figs. 4 and 5), and September 23–27 and September 30 to October 3, 1929, which have been discussed in the section on climate (p. 8). Under such conditions there is little wonder that the fence-line drainage ditch running directly down the slope should have been eroded to a moderate-sized gully in the rains of 1928 and enlarged to a major gully in the rains of the following year. The gully has continued to grow since that date, and in the intense rain of October 15–16, 1936, the heads on the west side caved so much that several fence posts were undercut and the entire fence had to be reerected farther back.

Gully L formerly received part of the drainage of the field to the east, but that field recently has been abandoned and the terraces have become choked with sediment. Terrace overflows and breaks have occurred, and most of the run-off now flows directly down the slope to the lower end of the channel that drains gullies J and K (fig. 90). The abandoned heads where the old terraces formerly entered the east side of the gully have now caved in and are becoming healed with briars and honeysuckle.

The large field west of the gully is in cultivation except for the small portion around the gully rim where sheet erosion, rilling, and shallow gullying have removed the A horizon and have cut deeply into the subsoil (fig. 91). According to the owner, the field was terraced about 1912, the terraces being laid out by eye, with a drop of 1 foot vertically in 15 feet horizontally. Most of the water carried by gully L comes from this field, and the rapid run-off owing to the steep gradient of the terrace channels has had much to do with the cutting of the gully. That cutting was speeded by the intense storms of 1928 and 1929; but a gully would have formed, in time, even without these unusual rains. Cutting probably started at the break in slope at the outer edge of the shoulder of the hill, where the gentle slope of the hillside gives way to the steeper inclination extending down to the stream. When the gully channel had been well established, cutting of side heads began, and each major tributary to the gully is now cutting back along its own channel.

The shape of the gully heads and their rates of advancement are dependent very largely on the type of material underlying the soil. Head 1 (fig. 53, Gross' gully No. 1, or basin L, Foster's Tavern area) is underlain chiefly by a saprolite derived from a massive granite gneiss, on which Appling soil has developed. It is a modified cave head, rounded in outline, and is not eroding rapidly. Heads 3, 6–7, and 8–9 are in the saprolite of a very friable porphyritic gneiss, from which Lockhart soil with its characteristic thin soil profile has developed. These are cave heads, of rounded or notched outline (figs. 56 and 95), and they are advancing rapidly. On the contrary, head 13, in the resistant parent material of the Colfax soil is pointed in outline, inclined in profile (fig. 28), and is enlarging only slowly.

Control of such a head would, therefore, be relatively simple. Several of the heads are of modified form, owing to the presence of a resistant quartz dike in the C horizon, or parent material. In one head the dike forms the roof of the cave, and back trickle by water flowing along the wall has softened the underlying material and allowed it to collapse. In two other heads the dikes divide the caves into separate portions (fig. 18).

Gully L shows two distinct cycles of cutting. The upper level, at about 166 to 168 feet, is cutting headward into the hillside and represents the first cycle. Where the 160-foot contour crosses the channel, 150 feet up from the gully mouth, however, there is a secondary head or prominent knickpoint some 8 feet high (fig. 57) which is cutting headward and deepening the gully channel. This secondary head may have been caused by rejuvenated cutting at the lower end of the gully, or may have resulted largely from the nature of the soil profile. The lip of the lower head is held up by the resistant clay of the Colfax parent material which underlies this portion of the gully. Beneath the clay, however, is friable decayed rock, similar to that present under the B horizon of the Lockhart soil in the upper end of the gully. A typical cave head has developed at this knickpoint and is advancing rapidly up the gully channel, largely by the intermittent breaking off of the lip or roof of the cave as the material underneath is removed (fig. 57).

FIGURE 95.—Compound cave head 8-9 in Lockhart soil on the west side of gully basin L of the Foster's Tavern area. Water from two channels falls separately into the plunge pool.

The Colfax soil with its heavy clay layer does not extend far up the slope, and when the knick has been eroded past the upstream end of this layer it will move headward much more rapidly, because the gully floor there is the weak rotten saprolite. Unless the drainage is diverted or other protective measures are taken, this gully, within a few decades, may be 35 feet deep and still enlarging.

GULLY M

Gully M is one of the longest and most linear gullies observed in the Spartanburg area. It lies approximately 1,200 feet southwest of gully L, which it resembles in several respects. It was developed from a property-line ditch used as a terrace outlet and, like gully L, was changed from a ditch to a deep gully by the intense rains of August and September 1928, and September and October 1929.

Gully M is 925 feet in length and has a maximum depth of 22 feet. It is straight but is slightly bulbous at the upper end, where drainage from several terraces and shallow gullies enters from the sides. There are several active cave heads in the upper bulbous portion, and minor ones where terrace waters enter the gully farther down along the sides of the channel (fig. 96). The size of the cutting heads depends in part on the amount of water entering the gully at that point and in part on the character of the weathered rock. The shape of some of the heads is modified by the presence of less weathered rock or by resistant quartz veins.

This gully, like gully L, shows evidence of several stages in its development. The channel in the upper, and slightly bulbous, portion is incised some 8 feet below an older level of the gully floor. The present channel is only 1 to 3 feet wide and winds back and forth, in places cutting into the gully wall and producing an overhang of as much as 7 feet. This entrenchment within the gully must have taken place rapidly because there has been little broadening of the channel.

While the upper end of the gully was cutting downward into the Cecil soil of the upland slope, the lower end, crossing an area of Colfax soil, remained a comparatively shallow ditch. The gently sloping bench or shoulder with its resistant sandy clay parent material, on which the Colfax soil has developed, is particularly broad at this gully and ends, on the downhill side, in an abrupt break in slope. Below the break the hillside dips steeply to the valley flat of the main stream some 16 feet below. Beginning at this steep portion below the break in slope, the gully has cut headward and downward into the Colfax material and a knickpoint has developed. Early in December 1936, there were really two knickpoints, each an overfall with a lip formed of a layer of resistant clay. One knick was at that time 10 feet high and 230 feet up from the mouth of the gully; the other, 7 feet high, was 50 feet farther upstream. Later in December the 10-foot fall was cut back until it had become a steep slope. By July 1937 most of the caved material which formed the incline had been removed, and there was again a vertical fall of some 10 feet. The 17-foot drop between the upper and lower segments of the channel, occurs now within a horizontal distance of 15 feet.

A spring, rising in the gully channel about 200 feet below the uppermost head, has flowed continuously during the period this gully has been under observation. The water passing over the knickpoints in the channel has kept the clays saturated. This has allowed blocks of the material to spall off and has caused the advance of knickpoints up the channel even between rainstorms. Toward the latter part

FIGURE 96.—Looking down-channel from the upper end of gully basin M, in the Foster's Tavern area. Note the eroded land on the gully margins and the recording rain gage in the fenced enclosure in the upper right-hand corner.

of the period of observation, the channel immediately below the lower knickpoint enlarged rapidly, giving the lower basin of this gully a bulbous outline similar to that of the basin below the knickpoint in gully L. This was brought about by caving, spalling, and slumping, and by outflowage of material from the base of the walls. Between storms the stream of clear water flowing over the knickpoint disappears into the caved material and emerges in the channel below, milky with sediment. It is obvious, therefore, that material constantly is being removed from the basin below the knickpoint. With continued erosion and upstream migration of the knickpoints, the upper end of the gully may be cut down an additional 20 feet or more, which will make it one of the deepest in the entire area.

SUMMARY AND CONCLUSION

In this physiographic study of the principles of gullying in the southern Piedmont the problem has been approached in two ways: (1) A general study of the regional and local conditions which make the southern Piedmont particularly susceptible to gullying, and (2 an investigation of the causes and mechanics of gully cutting and the rate at which the process operates, as seen in representative gullies in the vicinity of Spartanburg, S. C. These studies differ from most other research on gullying in their physiographic approach, in that they were made largely on untreated gullies, and in that observations were continued over a period of many months.

The humid and warm (mesothermal) climate of the Spartanburg area, with rainfall adequate at all seasons, varies only slightly from year to year, hence droughts are rare and are not an important cause of soil erosion. The major climatic factors in gully erosion in the Spartanburg area are the intense cold-front rains and tropical hurricanes of late summer and early fall.

Deep weathering of the igneous and metamorphic rocks of the Piedmont prepares the way for rapid erosion. Rocks of this type, rich in feldspar and silica, cover large areas and are much more readily eroded than are the dark, ferromagnesian-rich rocks, which are less abundant in this region.

The correlation of rock type to soil series and erosion hazard is particularly close in the Piedmont. The red and yellow soils are characterized by profiles in which the B horizon is more resistant to erosion than the underlying parent material. Soils having this type of profile are the most common in the areas considered in this bulletin, and include the Cecil, Appling, Durham, Lockhart, Louisa, Colfax, and Worsham.

Past and present land use have much to do with the localization of erosion. The length of cultivation, type of crop, method of tillage, erosion-control practices, and the lay-out of roads and other works of man all affect erosion conditions. Periods of land abandonment, in particular, have been marked by the initiation of sheet erosion and gullying.

Investigation of the causes and mechanics of gullying was carried on in detail at 12 representative gullies and was supplemented by less detailed study of a much larger number in the surrounding area. The maps, photographs, and recorded observations furnish the basis from which measurements of gully changes are made. Concentration of the flow of water is the main cause of gullying, and in this area concentration usually has been brought about by roads and ditches, and by terraces that have been improperly constructed or maintained.

The deep caving gully typical of the soils of the southern Piedmont passes through four distinct stages in its life history. In stage 1, the channel-cutting stage, the gully works downward through the A and B horizons. Cutting in this stage is relatively slow, and this is the time at which protective measures can best be undertaken.

Stage 2 begins when the gully penetrates the base of the B horizon and begins cutting in the weak parent material. This stage, characterized by the headward migration of an overfall and plunge pool and by rapid caving of the walls and deepening of the channel, is much the most violent stage of gully growth and is the least favorable for the successful application of control measures. Caving and slumping of the walls and heads alternate with periodic clearing out of the caved material from the gully channel. Additional substages in the gully's growth may occur in the form of periods of headward progression of successive waterfalls or knickpoints, marking renewed channel cutting and deepening of the gully. Stage 2 ends when erosion is retarded because the channel reaches a graded condition under the control of some local base level.

Stage 3 is a period of adjustment to the graded channel. Slopes of the gully walls are reduced by weathering, slope-wash, and mass movement; plants are able to get a foothold on the lowered slopes, and vegetation gradually brings about a healing of the gully.

Stage 4 is a period of stabilization and is characterized by the slow development and accumulation of new topsoil over the old scarred surface. Rejuvenated cutting brought about by lowering of the base level or an increase in the amount or rate of run-off can at any time cause stage 3 or 4 to revert to stage 2.

Studies on the rate and amount of erosion in Piedmont gullies have shown that the gentle, prolonged, widespread rains characteristic of the passage of warm fronts in the winter and spring months bring about caving and crumbling of the gully walls and thus tend to fill the gullies and make them shallower but somewhat wider. The run-off from such rains normally is light and produces little washing or clearing out of the gully channels. Most of the gully clearing and deepening is accomplished by intense local rains, either the summer showers that usually are associated with extratropical cyclones occurring along cold fronts, or the tropical hurricanes of late summer and early fall. Either the gentle or the intense type of rainfall alone would be much less destructive than the alternation of the two, as one prepares the material for removal and the other carries it away. During the season of intense rains special care should be taken to prevent washing of the lands and to repair damages to terraces and other water channels as soon as they occur.

Cutting heads of some of the gullies in the Spartanburg area receded 10 or 15 feet within a few months and then were practically dormant the remainder of the year. A single rain of high intensity caused part of the Layton gully to widen 12 feet. Two gullies known to have been started by intense rains in the late summer of 1928 and 1929 are now 20 to 25 feet deep and are enlarging rapidly.

The life histories of six gully areas have been reconstructed by means of physiographic, ecologic, and human evidence. Layton's gully shows the effect of terrace failure and the rejuvenation of erosion owing to the headward migration of a knickpoint which is destroying the stabilized portion of the gully channel. Walden's gully, developed from terraces and a road drain, is deep and contains many isolated remnants of the former upland surface. Several of the heads show well how diversion of the inflowing water, by man, has resulted in natural healing and stabilization. Littlejohn's gully is an example of the enlargement of a road ditch and drain by gullying from the run-off of an area of abandoned land. Headward extension of the gully may soon necessitate a second relocation of the road. Cox's gully, also formed by the run-off from an old road, is distinctive in that it has a flat aggraded floor and a relatively high level of ground water. Thick growth of vegetation in the lower end of the channel has retained much of the sediment and is gradually increasing the depth of fill. Barry's gully, in Appling soil, shows the result of an active knickpoint. It also demonstrates how a farmer, by a simple control practice, has retarded the growth of a gully and controlled its shape. The Foster's Tavern area shows the individual and group history of seven gullies ranging in age from a decade to more than a century and now in various stages of development. The relations of drainage and soil type to gully cutting are particularly evident in this locality.

From the standpoint of soil conservation it is in general more essential that we preserve the good land than that gullied lands be reclaimed. Although fields dissected by gullies 10 to 50 feet deep cannot be brought back to good tilth by any reasonable expenditure, it may be necessary to check the erosion of those gullies in order to protect adjoining land. An active gully threatens everything within its drainage basin, and unless gully enlargement is stopped, entire fields or farms may be rendered altogether useless for cultivation.

Many of the worst gullies in the southern Piedmont have resulted directly from old terraces, road ditches, and other drains which were constructed originally to control the flow of water and prevent erosion. Successful control of gullies must be based on an adequate knowledge of the existing conditions and of the processes to be combatted.

Gullying can be and should be prevented by wise land use and proper maintenance. But where gullies have made a start it is imperative that they be checked while still in the first stage of development. Because the shallow gullies in the Piedmont soils cut relatively slowly, there is a tendency to think that a similar rate of erosion will continue, and that control measures are not necessary for small gullies but can be applied later if the gully grows to more alarming proportions. This is far from true. In the soils of the Cecil and related series the B horizon, usually some 3 to 6 feet thick, acts as a tough crust that protects the weak underlying material from erosion. When these few feet of crust have been cut through, the gully will enlarge many times faster, downward, headward, and laterally, and the problem of control will be increased enormously.

Control of gullies, especially those which have reached the second stage, can be achieved most economically by following the pattern of natural stabilization and by taking advantage of the most favorable seasons and most opportune stages in the cycle of overfall cutting and of gully development. Unless drainage is to be diverted from the gully, the major aim must be to bring about the characteristics of the stages of healing and stabilizing by (1) establishing an artificially graded condition in the gully, (2) preventing further headward migration of the cutting head or overfall, and (3) preventing the washing out of material which enters the gully and aids in raising the floor and establishing conditions suitable for plant growth.

Artificial establishment of a graded condition in a gully can be carried out by the construction of check dams or baffles, which serve as local base levels and prevent further down-cutting of the channel. In the weak parent materials of the Piedmont soils, however, construction of rigid dams is seldom practicable. Conditions are more favorable for vegetative control. A good cover of close growing vegetation in the lower end of the gully channel, as at Cox's gully, may effectively retard erosion and promote healing.

The part played by seepage in the headward migration of overfalls in this area is much smaller than is sometimes supposed. In the Cecil soils and in other similar series that have a resistant B horizon, back trickle of water down the face of the overfall and under the overhanging lip is a much more effective agent of erosion. Instead of being more or less continuously wet from seepage, the weak material beneath the B horizon is soaked only during rains and for a short time afterward. Deepening of the cave beneath the overhang is, therefore, periodic and associated with rainfall. Caving of the protruding lip usually takes place when heavy rains follow periods of desiccation. Advantage can be taken of this periodic caving to eliminate some of the work of the sloping of walls for gully control. Headward cutting of overfalls can be prevented very effectively by the installation of an adequate drop-inlet culvert. These culverts are particularly advantageous from the physiographic standpoint because they establish a local base level for erosion above the inlet and after lowering the water to the gully floor release it with a minimum of scouring.

The clearing out of gully channels relates directly to the intensity of rainfall and its seasonal distribution. If the heavy downpours could be eliminated from the precipitation regimen of the region, the control of gully erosion would be greatly simplified. Such an artificial change in climate is, of course, out of the question, but the end can be achieved in part by modification of the character of the run-off. The effect of heavy rains on gully erosion can be lessened by maintaining a broad strip of close-growing vegetation around the gully rim and in the drainage area upslope from the gully. The mat of vegetation in this conversion area helps to reduce and retard the run-off and spreads the flowing water so that it enters the gully in numerous trickles instead of in a few large channels.

As long as water passing over the gully rim can reach the weak material of the C horizon, undermining of the resistant B-horizon lip will continue. Accumulation of caved material up to or above the base of the B horizon provides a protection which helps prevent large-scale caving and slumping induced by the action of back trickle. Clearing out of the gully channel removes the protecting material and prepares the way for further caving. If by check dams, vegetative control, or other means the gully can be filled high enough to protect all of the C horizon, further caving can be prevented and lateral expansion of the gully stopped or greatly retarded. Water may be diverted from the gully to prevent clearing out of the channel and to give a better opportunity for healing and stabilization. Unless the new waterway is carefully protected against erosion, however, there is always the danger of developing two gullies where formerly there was only one.

Gully-control work can be performed most efficiently if advantage is taken of the seasonal differences in rainfall and run-off. Work done in the season of prolonged gentle rains will be in little immediate danger of washing away. During the season of intense storms protective works may at any time be subjected to a severe test, and unfinished installations may be destroyed before they can have much effect on the gully system.

Protecting gully heads, walls, and floors is not enough. Protection must also be provided against erosional attack from the downstream end of the channel. This is a factor of utmost importance and one that is all too often overlooked. Where the rate or amount of run-off has been increased by deforestation of hillsides, by brushing out of stream channels, or by changes in tillage practices or cropping systems, increased erosion in the main stream or gully channel may cause deepening which will be propagated up the tributary gullies as small falls or knickpoints. Overdeepening by the headward-migrating knickpoints destroys the adjustment of these channels and causes a rejuvenation or return to an earlier and more active stage in the gully-cutting cycle. The advance of a knickpoint may cut away vegetation and may undermine check dams, baffles, and other channel structures, and destroy their value for erosion control. If this common physiographic process is disregarded, accelerated erosion may, in a very brief time, completely undo the progress of months or years of gully stabilization.

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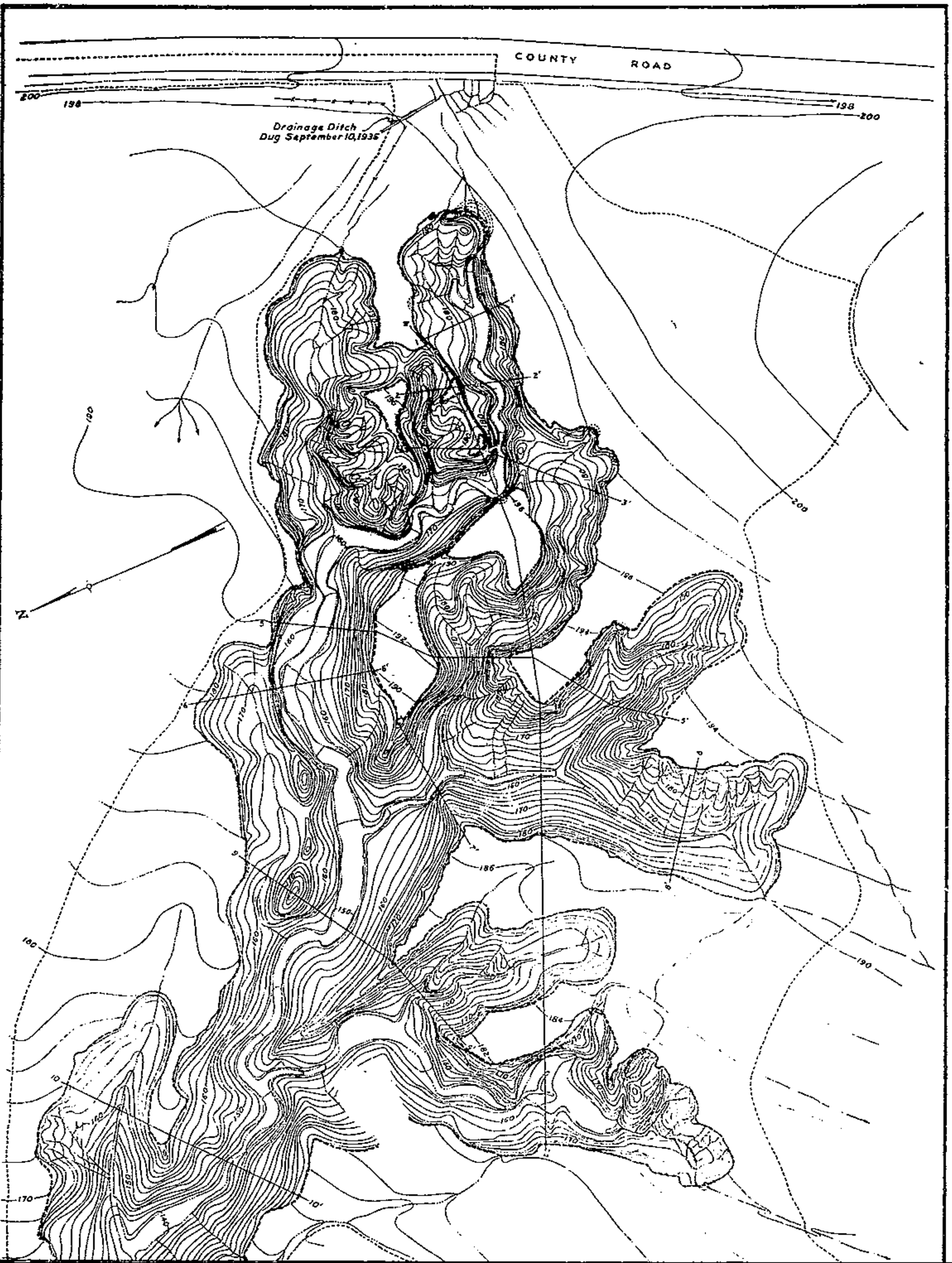
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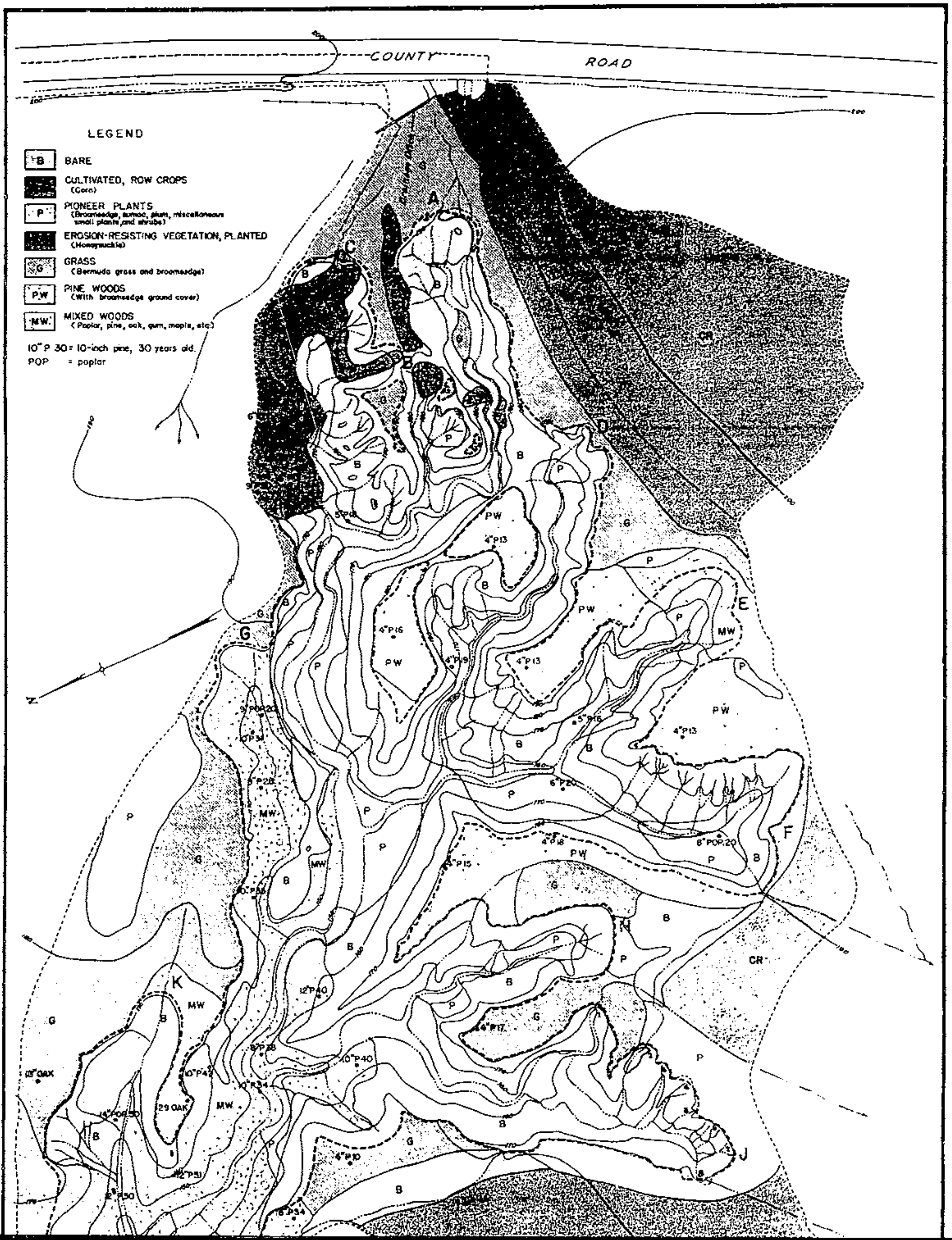
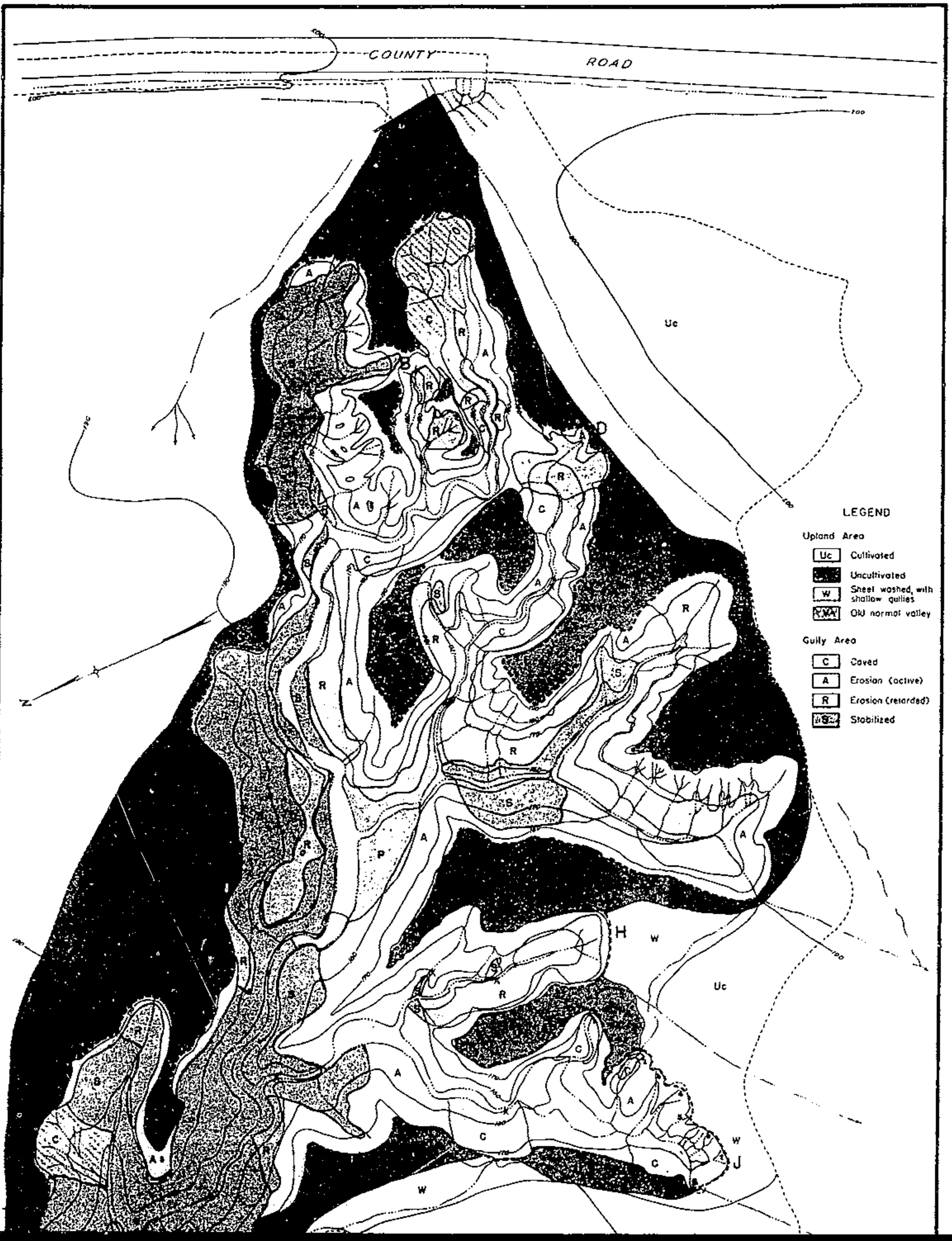
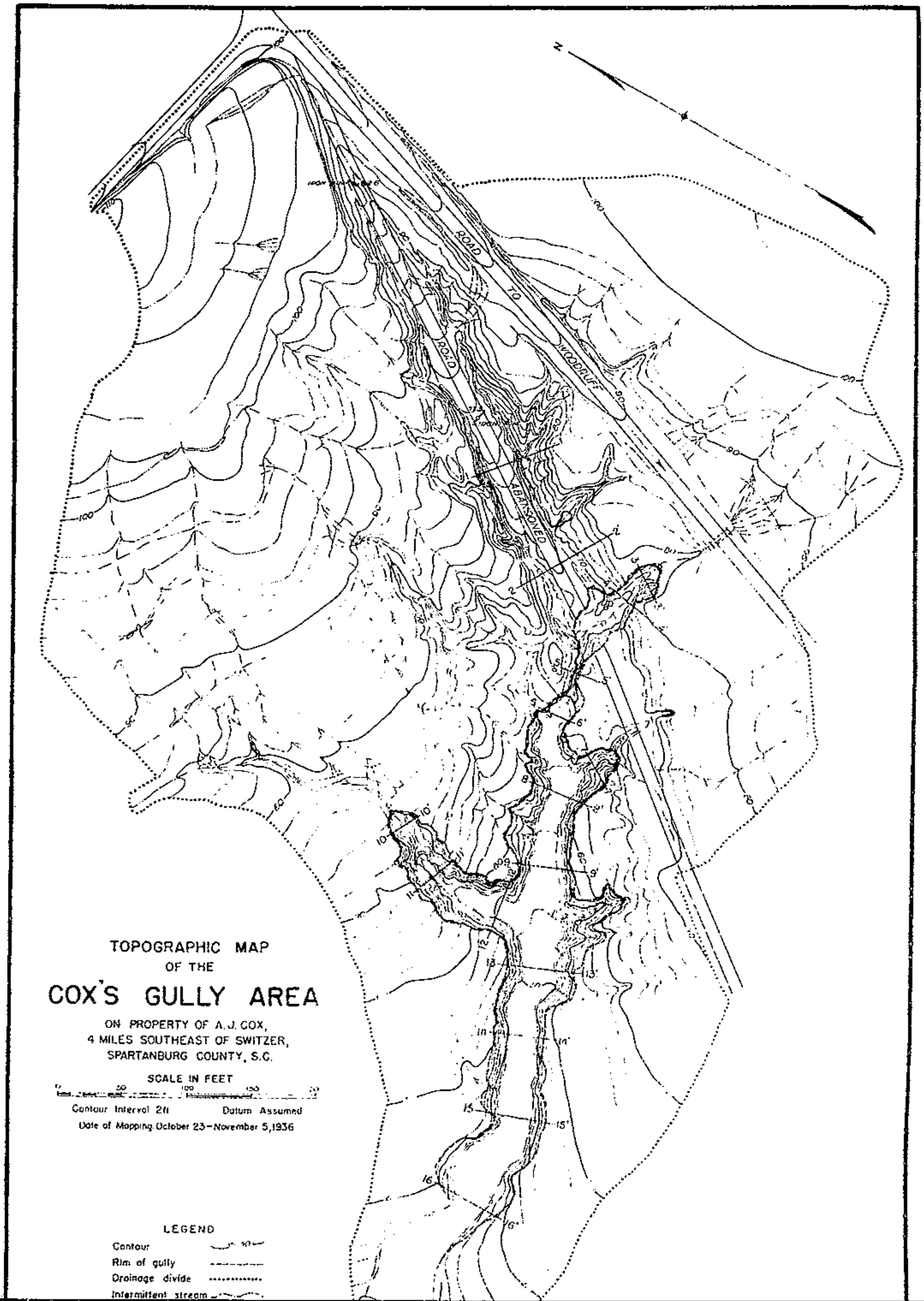

COUNTY ROAD
LEGEND
B BARE
CULTIVATED, ROW CROPS (Corn)
P PIONEER PLANTS (Broomsedge, sumac, plum, miscellaneous small plants, and shrubs)
EROSION-RESISTING VEGETATION, PLANTED (Honeysuckle)
G GRASS (Bermuda grass and broomsedge)
PW PINE WOODS (With broomsedge ground cover)
MW MIXED WOODS (Poplar, pine, oak, gum, maple, etc.)
10" P 30 = 10-inch pine, 30 years old.
POP = poplar
A
B
C
D
E
F
G
H
J
K
N
CR
PW
MW
4"P13
4"P16
4"P19
5"P18
6"P20
4"P18
4"P15
6"POP.20
9"POP.20
10"P34
8"P28
10"P38
12"P40
8"P38
10"P40
10"P42
10"P34
4"P17
4"P10
13"OAK
29 OAK
14"POP.30
12"P51
12"P30
16"P34
100
180
170

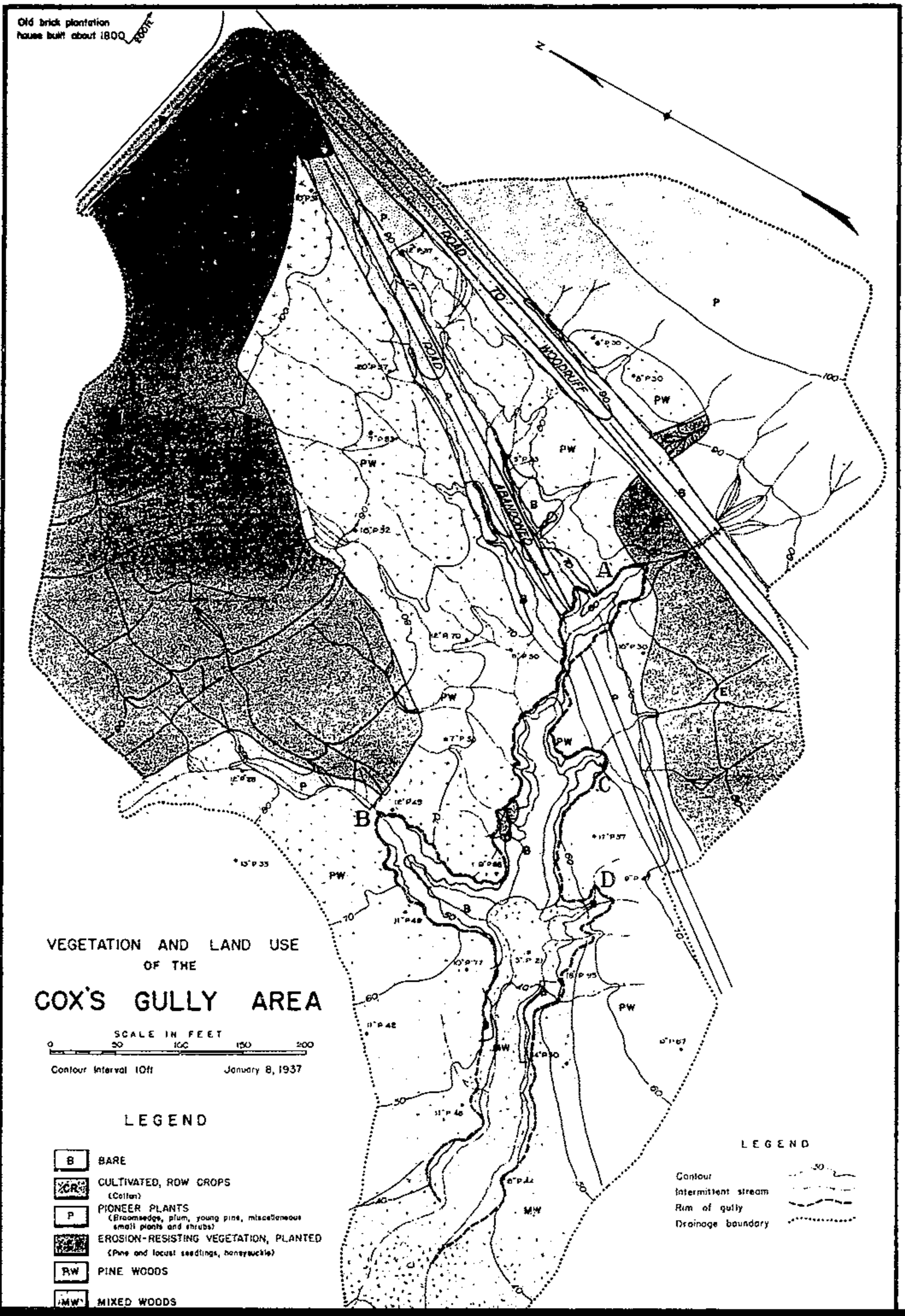

COUNTY
ROAD
Uc
B
D
H
W
Uc
W
J
W
P
S
C
A
R
N
LEGEND
Upland Area
Uc Cultivated
Uncultivated
W Sheet washed, with shallow gullies
ONV Old normal valley
Gully Area
C Caved
A Erosion (active)
R Erosion (retarded)
S Stabilized



TOPOGRAPHIC MAP
OF THE

COX'S GULLY AREA

ON PROPERTY OF A. J. COX,
4 MILES SOUTHEAST OF SWITZER,
SPARTANBURG COUNTY, S.C.



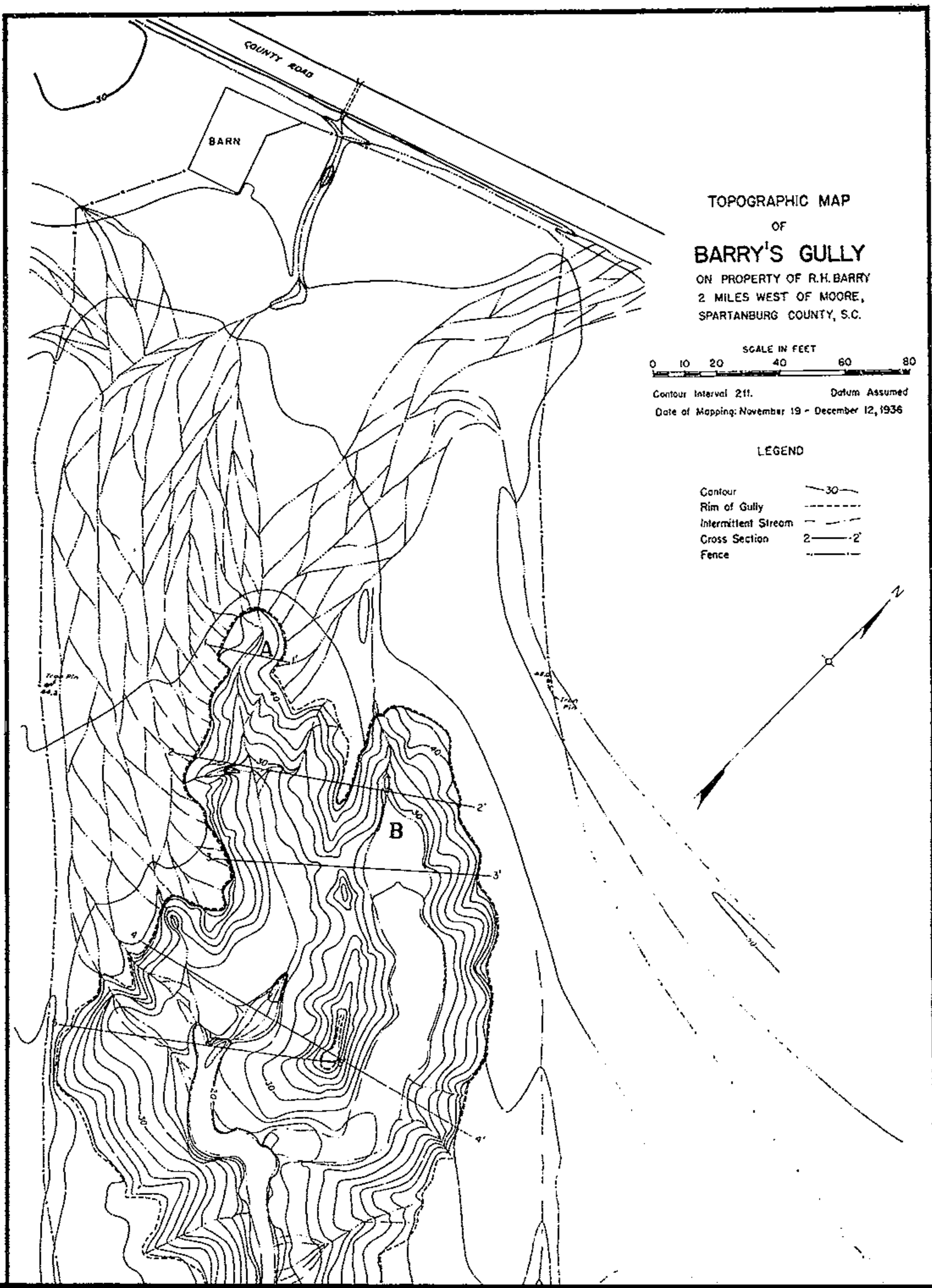
VEGETATION AND LAND USE OF THE

COX'S GULLY AREA

SCALE IN FEET

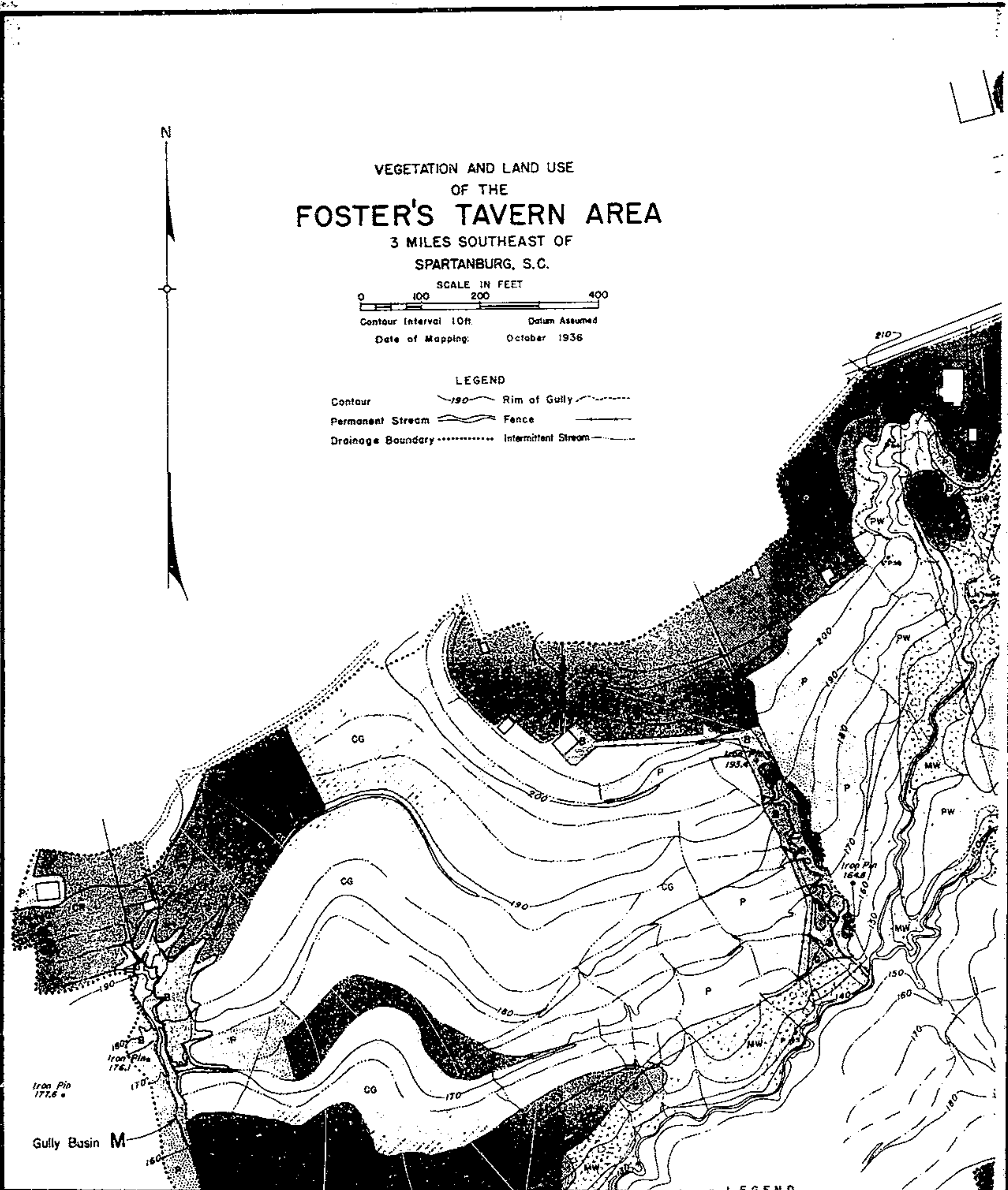
Contour Interval 10ft

January 8, 1937



TOPOGRAPHIC MAP
OF
BARRY'S GULLY
ON PROPERTY OF R.H. BARRY
2 MILES WEST OF MOORE,
SPARTANBURG COUNTY, S.C.

Contour Interval 2ft. Datum Assumed
Date of Mapping: November 19 - December 12, 1936



VEGETATION AND LAND USE
OF THE
FOSTER'S TAVERN AREA
3 MILES SOUTHEAST OF
SPARTANBURG, S.C.

SCALE IN FEET

0 100 200 400

Contour Interval 10ft. Datum Assumed

Date of Mapping: October 1936

LEGEND

Contour ~190~

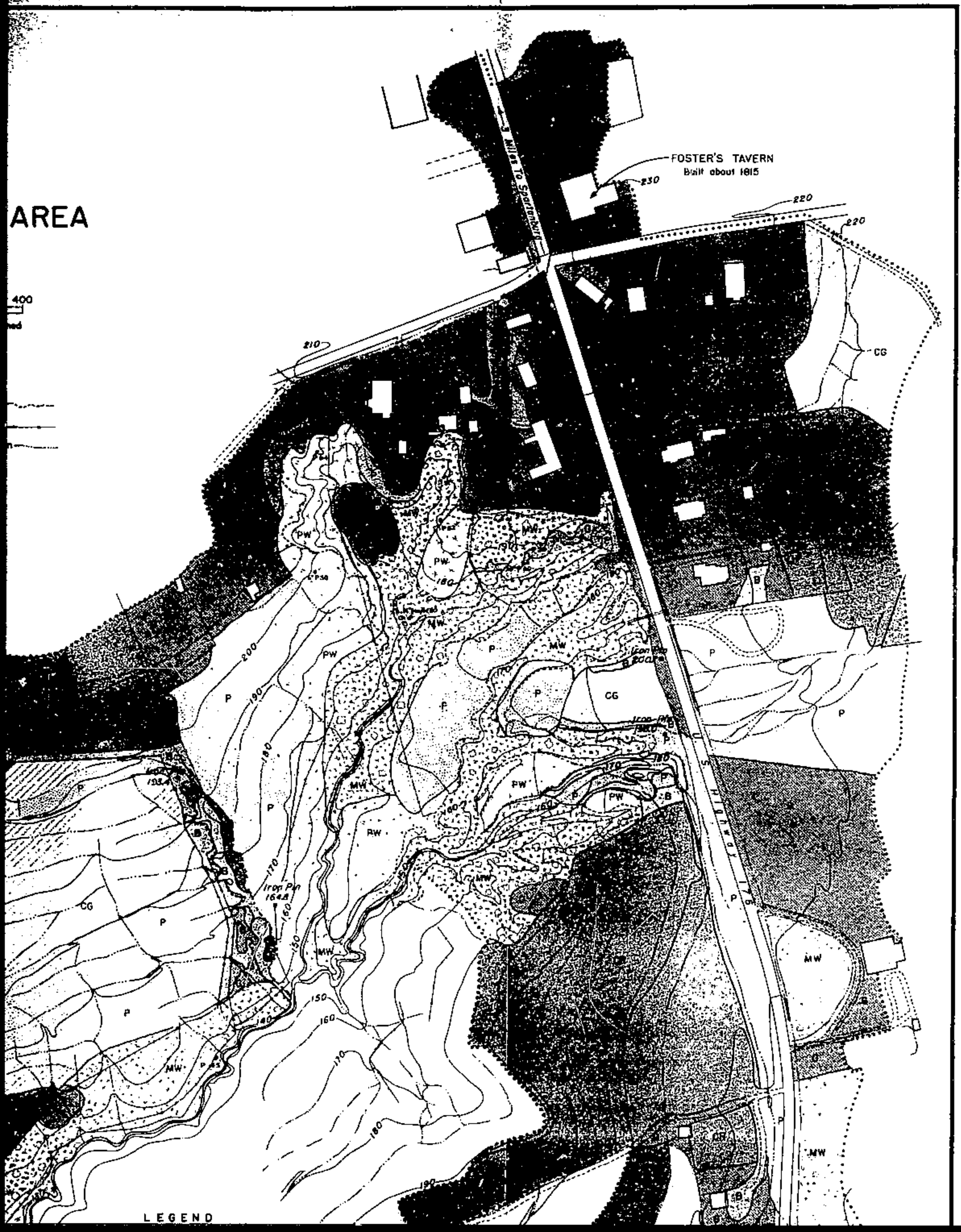
Rim of Gully

Permanent Stream

Fence

Drainage Boundary

Intermittent Stream


AREA
400
FOSTER'S TAVERN
Built about 1815
9 Miles To Spartanburg
230
220
220
210
200
190
180
170
160
150
140
CG
PW
P
MW
RW
B
Iron Pin
164.8
State Highway
LEGEND

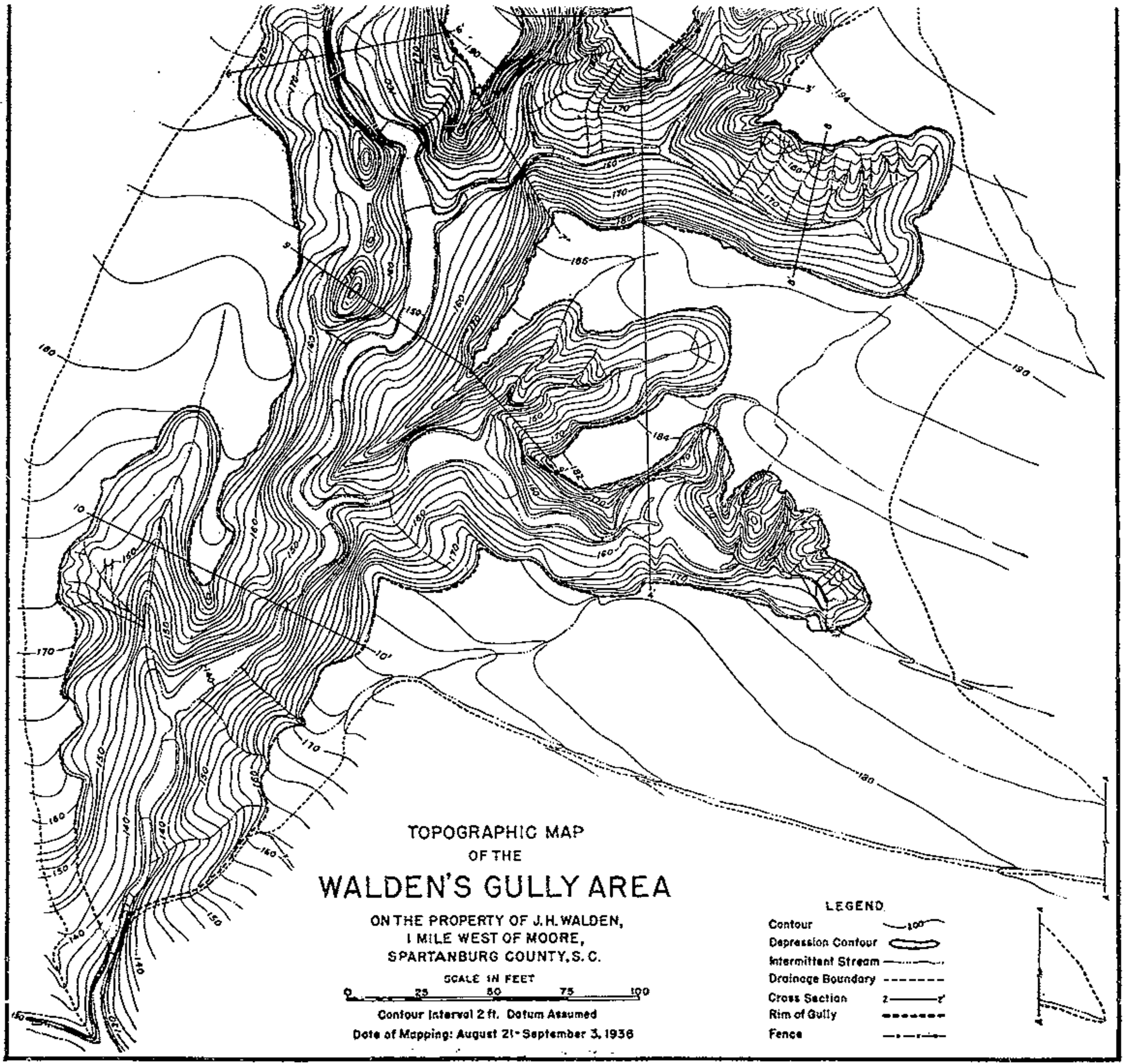


FIGURE 69.—Topographic map of the Walden's gully area.

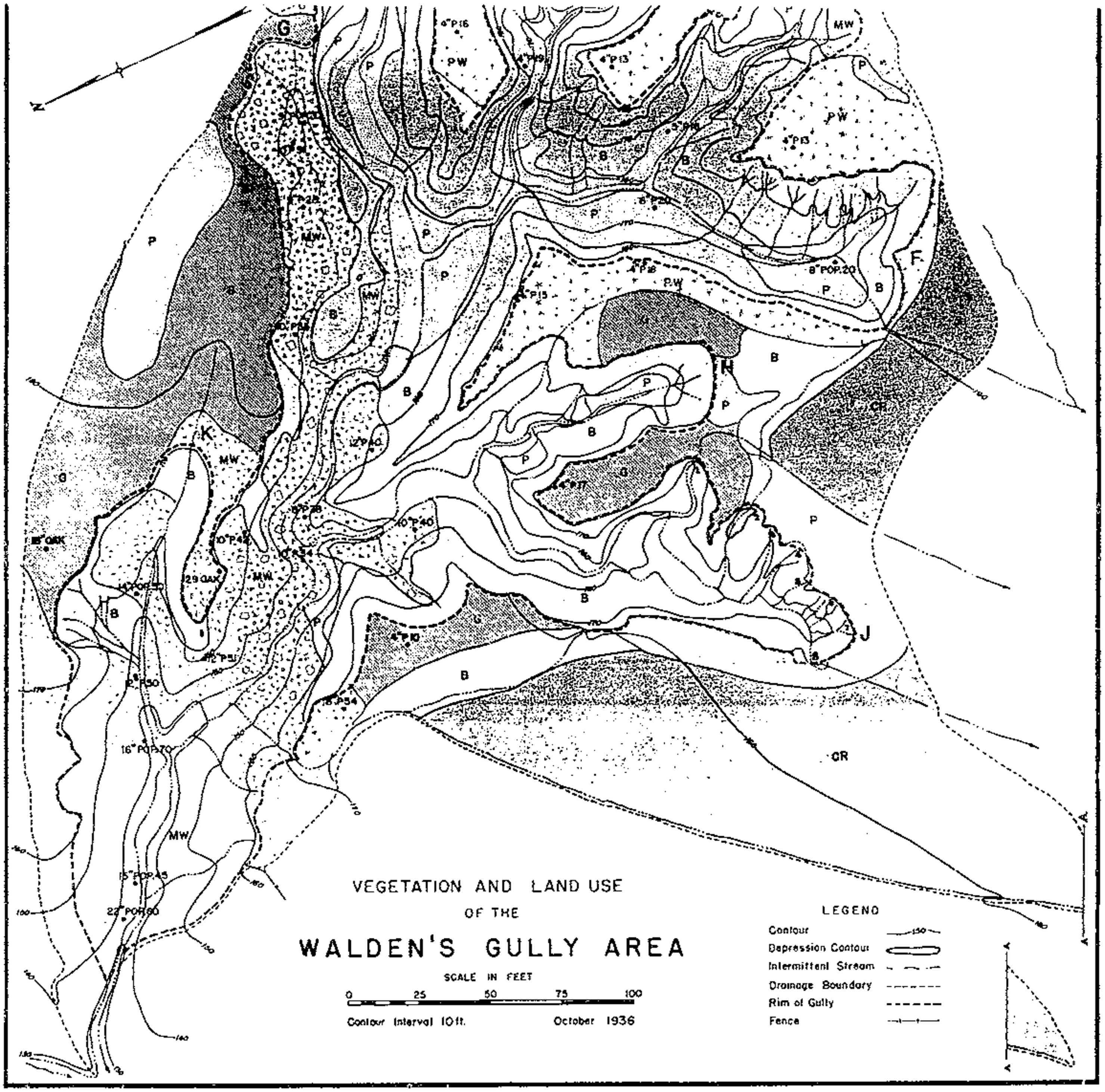


Figure 70.—Vegetation and land use of the Walden's gully area.

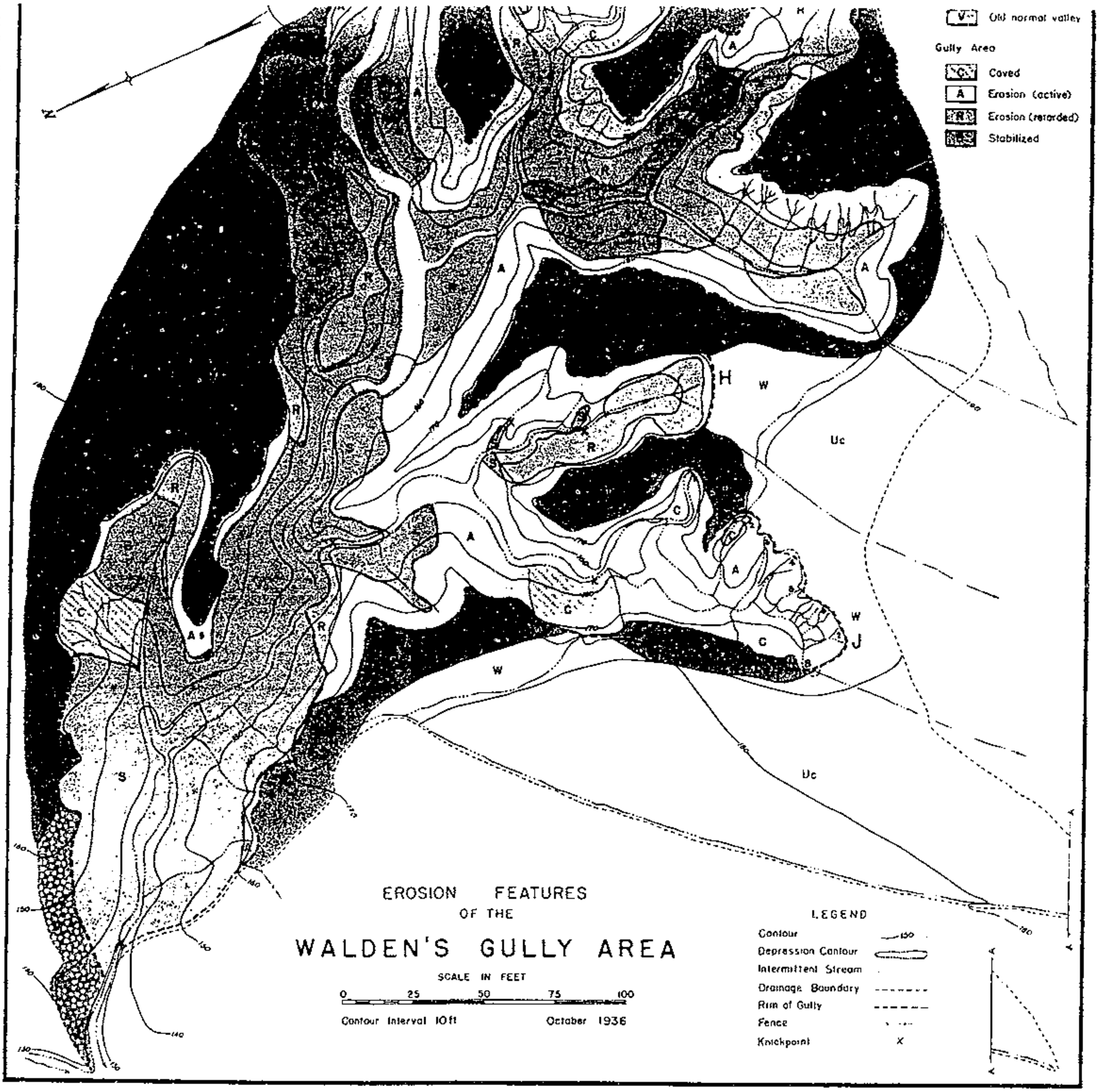


Figure 71.—Erosion features of the Walden's gully area.

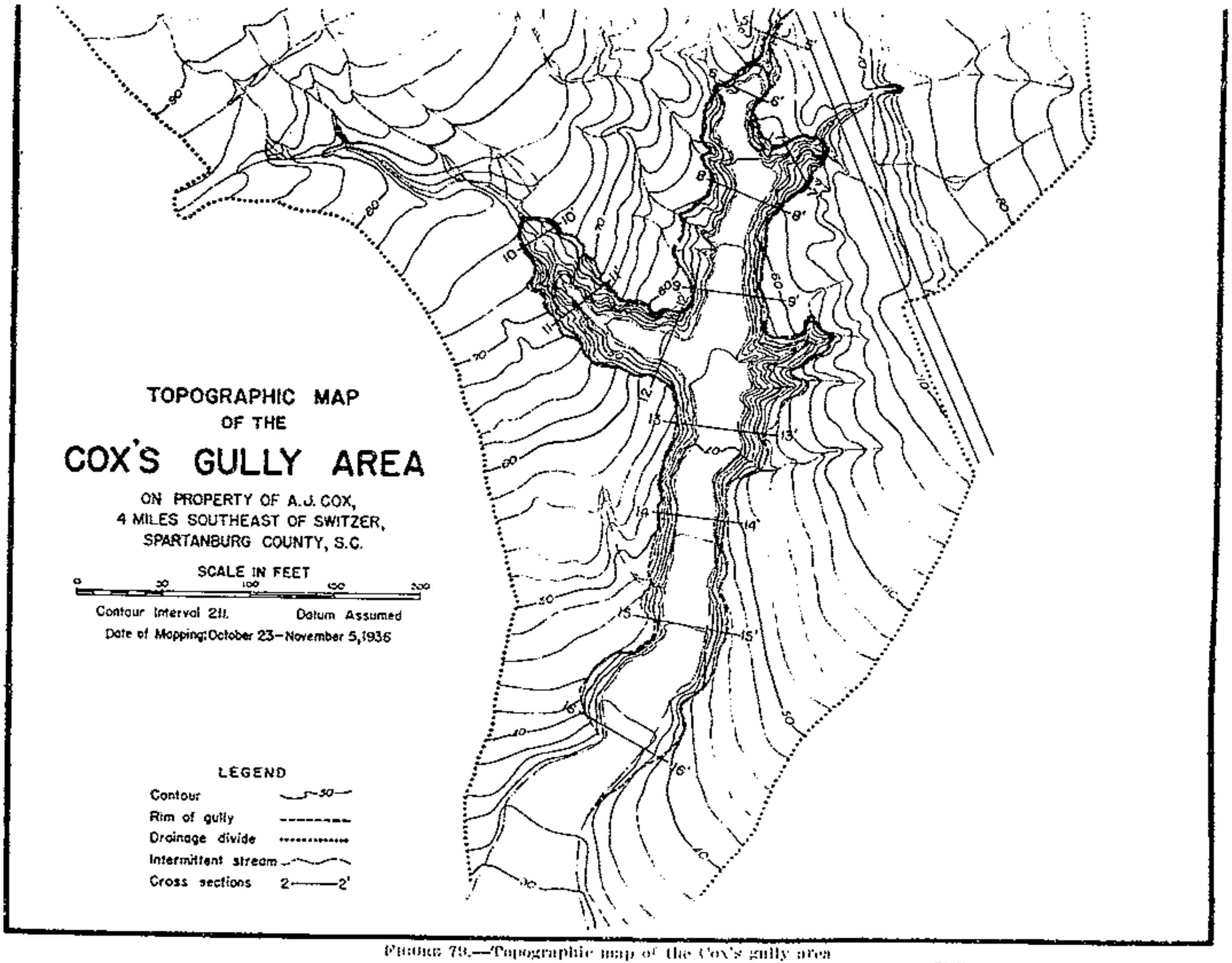


FIGURE 78.—Topographic map of the Cox's gully area

77788—39 (Face p. 116)

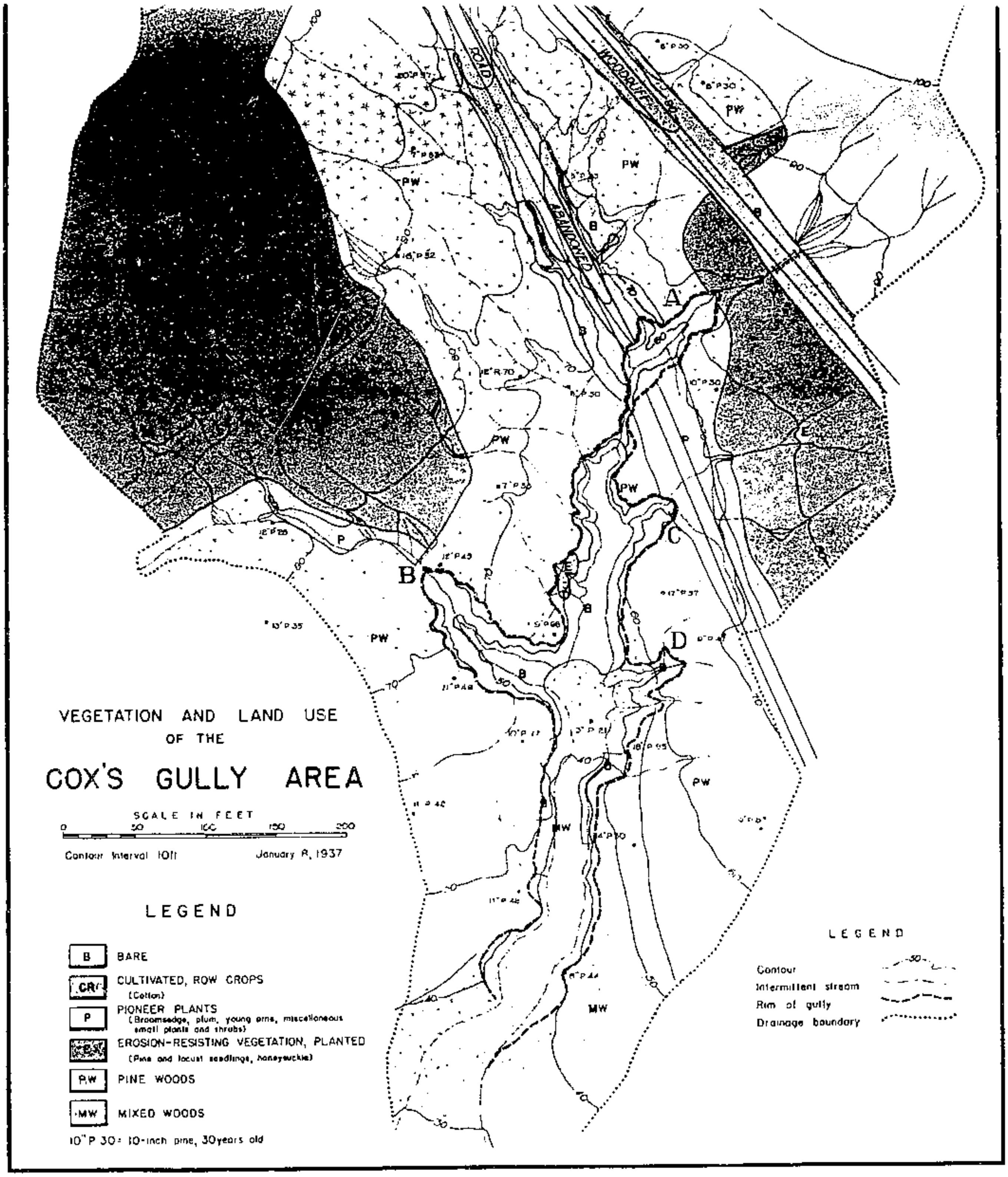


Figure 80.—Vegetation and land use of the Cox's gully area.

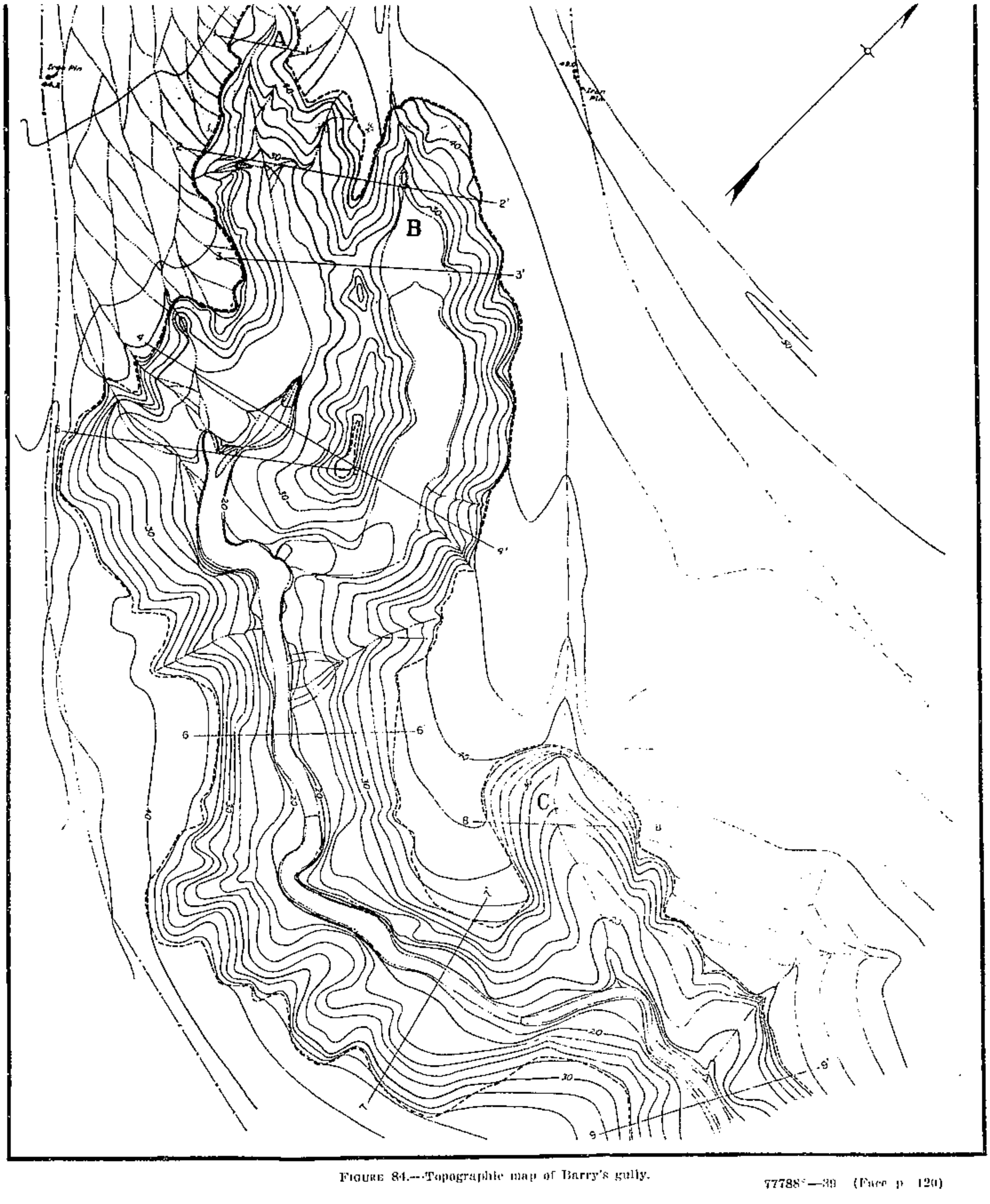


FIGURE 84.—Topographic map of Barry's gully.

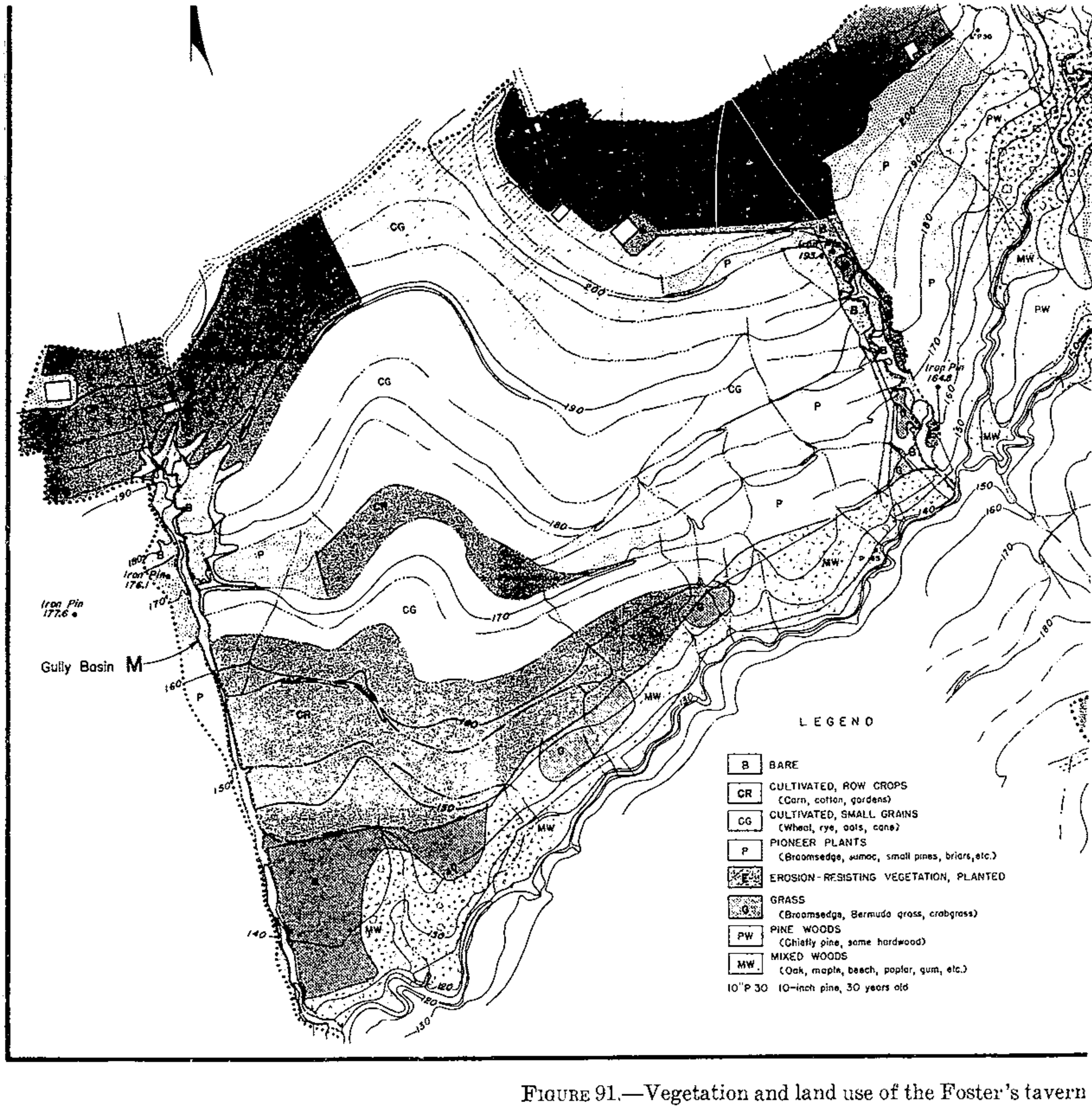
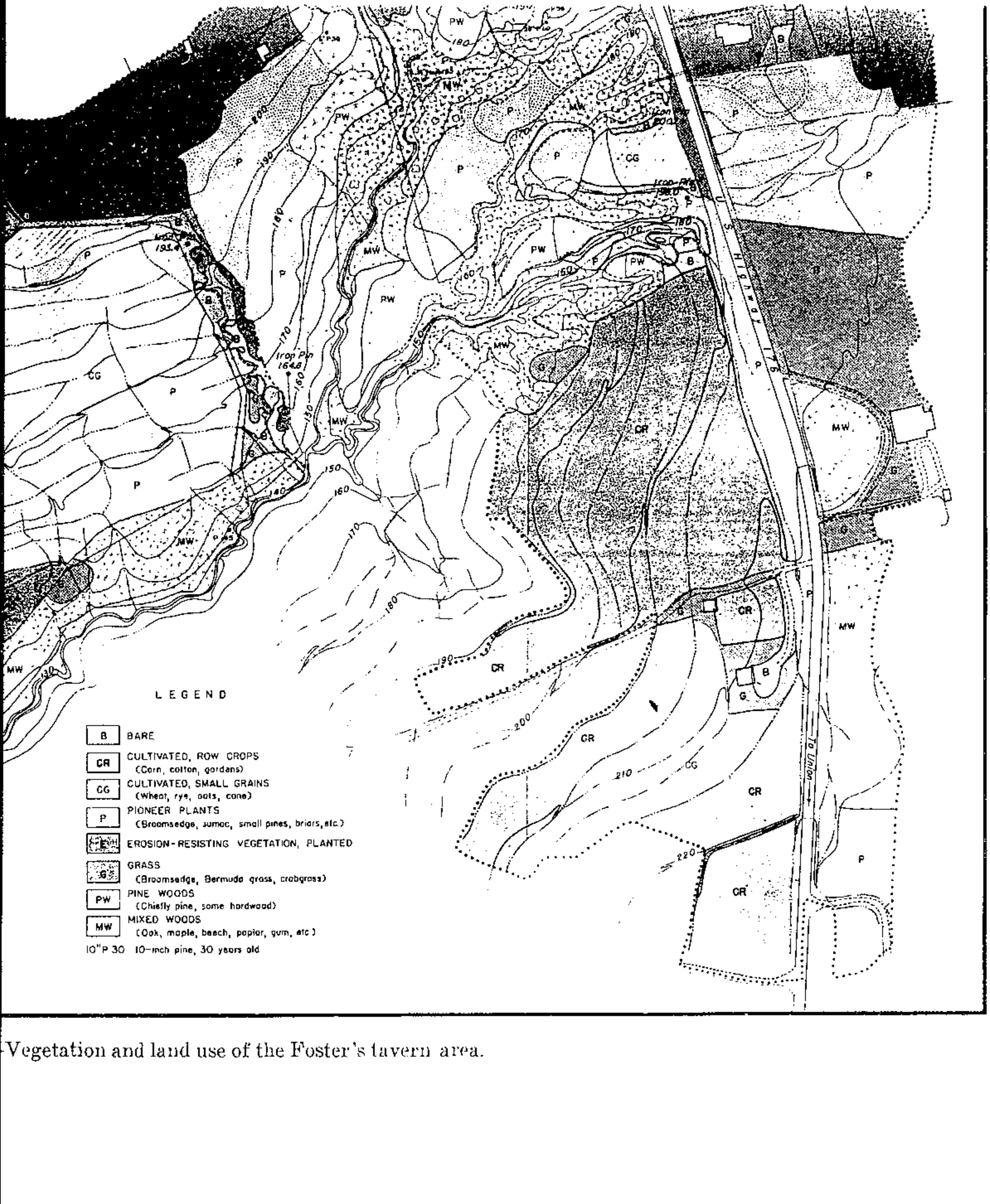


FIGURE 91.—Vegetation and land use of the Foster's tavern



-Vegetation and land use of the Foster's tavern area.

END