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ABSTRACT

Eight professional geography research papers presented at the Geography Section of the 1973 annual meeting of the Ohio Academy of Science are provided. The specific topics of concern range from methodological essays to the quantitative analysis of historical geographic information. The titles of the papers are (1) An Attempt at Reform in Regional Geography; (2) A Climatic Model of the Everglades Drought; (3) A Case Study of Lake Effect Snow Squall Precipitation in Northern Ohio: November 22, 1971; (4) Insolation Climate and Urban Topography; (5) The Structure of Geography: A Revised Version; (6) Policy Implications of the Distribution of Hamilton County, Ohio Park Users; (7) New Towns: Greenbelt, Maryland Thirty-five Years Later; and (8) A Network Analysis of the Roman Roads of Britain. (DE)

OHIO GEOGRAPHERS: RECENT RESEARCH THEMES

Volume Number 1, 1973

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University of Akron

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PREFACE

Once each year, during the annual meeting of the Ohio Academy of Science, geographers are offered an opportunity to share their research findings with colleagues through the presentation of professional papers. In many instances, papers presented during the Geography Section of the Academy are first attempts by graduate and undergraduate students at such an endeavor. Also, faculty members from various Ohio universities usually have research results and methodological points of view to present. Unfortunately, as is often the case with such state-level conferences, little has been accomplished in the past in terms of collectively publishing geographical studies presented to the Academy. As a result, papers presented are often either published in a wide variety of journals or simply set aside because of more pressing professional matters.

The purpose of this volume is to offer for the first time a published collection of research themes of concern to geographers and students of geography from several Ohio universities. While this collection of studies is an out-growth of the Geography Section of the Ohio Academy of Science meeting held at John Carroll University in April, 1973, it cannot be considered a "proceedings" by current definition. This volume is a representative selection of papers from the latter conference. In addition, several of the studies contained herein have been substantially altered from their original form. Still, the Academy meeting served as a point of departure for the initiation of what will hopefully become an annual publication of topics of concern to Ohio geographers.

If there is any one common theme among the eight contributions of this volume it is that the individual authors express their interpretations of how phenomena which vary over geographic space can be understood and explained. The specific topics of concern range from methodological essays to the quantitative analysis of historical geographic information. However, since each contribution is preceeded by an abstract, no editorial summarization is deemed necessary within this introduction. Some attempt has been made to arrange the papers in a logical sequence of related topics, but this sequence is only so meaningful as the papers themselves relate to one another.

All of the mechanical operations of publication preparation were carried out at the University of Akron; however, the 1973 Geography Section of the Academy was organized by Wolf Roder of the University of Cincinnati. Financial assistance for publication was made possible by Allen G. Noble, Chairman of the Department of Geography, University of Akron. We are also indebted to Rebecca Ebie for manuscript preparation, Thomas Kane for editorial assistance, Holly Worcester and Sharon Yerkey for cartography, and Robert Pye for coordination of printing.

Gerald F. Pyle
Akron, Ohio
1973

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AN ATTEMPT AT REFORM IN REGIONAL GEOGRAPHY

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Abstract: Despite the continued importance of regional courses in college curricula and the far-reaching innovation in systematic geography, the format and organizational structure of regional geography has remained obdurately stable. The persistent demand for a regional course on Africa, together with the disturbing anachronistic curricular materials and our difficulty in finding adequate materials for our class, stimulated us to develop a different approach to teaching African geography. The approach is thematic and is intended to modernize African regional geography, bring it into phase with the rest of the discipline, and emphasize the essential unity of the spatial viewpoint. Four themes are used as the framework for providing an integrating overview of the continent and its problems.

Less than two decades ago, a comprehensive survey of American geography placed emphasis on ". . . associations of phenomena that give character to particular places, and . . . the likenesses and differences among places" [35;6]. This definition of geography, frequently referred to as areal differentiation, has a lenthy and continuous legacy both in North America and Europe [27:84-11]. The early importance of this concept of geography led to an era in which descriptive regional studies were the epitome of geographic scholarship. Wrigley [75: 7-11] believes that Vidal de la Blache's work [67;68] early in the present century represents the pinnacle of this tradition. For Vidal and others such as Sauer [59], Whittlesey [74], and James [35], the region was not only the proper unit of study but also the ultimate goal of geographical research and writing. Accordingly, the curriculum of many geography departments here and abroad thrived on courses based upon major and minor regions.

Despite the strength and popularity of the areal differentiation definition of geography between 1920 and 1960, a number of other traditions generated interest. Pattison [49:211], Haggett [65:9-17], and Harvey [28:114-16] identify at least four such traditions which sustained geographic research throughout the regional era of the discipline: landscape, spatial distribution, man-land, and geometric. By the 1950's geographers were becoming increasingly involved in research in these other traditions and a few writers [39;50:185] even contested the ascendency of areal differentiation.

As a total definition of geography, areal differentiation and the broader tradition of search for uniform regions failed in a number of ways. While not inclusive, following are some of the more common criticisms of the regional approach:

1) Regional research was not fundamental in the sense that it provided building blocks for other studies and bridges to other sciences.
2) Regional research often sought the spatially unique and exceptional at the expense of the general and universal.
3) Regions were often conceived as concrete objects rather than as intellectual devices.
4) Regionalization as an exercise in scientific classification was often illogical.
5) The ultimate goal of regional geography to comprehend the integration of a great heterogeneity of phenomena in particular places [27:35] led to the criticism that his holistic goal is virtually impossible for a geographer who is not a genius [50:190].
6) Related to this holistic conception of the region is the criticism leveled initially by Kimble [39] and extended recently by Wrigley [75:7-11] that the region as a concept is inadequate to describe the modern earth.
7) Finally, there is confusion on the question of whether the region as a concept in geography is merely a set of procedural rules for conducting research or whether it has explanatory powers [28:125].

This barrage of criticism has led some observers to toll the death bell for regional geography [29:20]. For example, an assessment of geography as a science, conducted in 1965 [1] makes no mention of regions, region building, or regional analysis as problem areas or clusters of research interest. A survey of the discipline, published in 1970 and providing ". . . a comprehensive review and appraisal of. . . rapidly expanding fields of knowledge . . ." [65:v] does mention the region as one of six illustrative studies.

On the other hand, few, we think, would disagree with Wrigley [75:13] when he asserts that "much geography is still regional, but no longer [is] geography about the region.* Thus, while regional geography no longer comprises the main dish, it still is at least a side portion on the geographer's platter of soul food [42:528]. For example, recent methodological discussions confirm that some geographers still desire to apply regional analysis to the earth's practical problems [3:14-26; 24:241-76; 43: 23; and 61]. And still others argue that regions continue to be important to geographers as conventions [42: 526-27]. We think it is accurate to say that we still do bear many marks of the regional era of the discipline and that we find these useful in our scholarship, teaching, and everyday lives.

Our curricula are even more reflective of the earlier predominance of regional geography. The exceptionalist philosophy which undergirded regional study is still anachronistically present in many geography departments. Theoretical and scientifically organized systematic geography cohabits uneasily with regional geography, possessing as it does many of the distinguishing qualities of the era areal differentiation. Texts for teaching about some of the earth's major regions demonstrate remarkably the gap between the modern research frontier and the regional classroom. The gap exists not only in approach but also in organization and content. Presumably, it extends also to methods of instruction. Good examples may be found among the many texts on major world regions. Almost without exception these are concerned with subdivision of large areas into smaller and smaller areas, fractionalizing the total region, losing sight of its overall spatial character, and producing an illogical system of classification, often an unique set of regions. The basis of organization is the region and all the material is molded into this format.

A survey of forty-three textbooks on major world regions which we recently conducted confirms these viewpoints. These works are so indicated within the reference list of this study. From an examination of these texts, three organizational methods are apparent. The most obvious and widely used one is areal. Here, a series of region, sub-regions, etc. constitute the format by which material is arranged and presented. Over eighty-five percent (thirty-seven) of the books surveyed fall into this category. Assignment to discrete categories is difficult. There are five (de Blij, 1964; Ginsburg, 1958; Hance, 1964; Prothero, 1969; and West and Augelli, 1966) which seem to overlap into the other categories.

A second method of organization is a topical approach to the major region under consideration. Of the books surveyed, five [33; 45; 52; 54; 66] can clearly be assigned to this category with the possible addition of two more [25; 55], also included in the first group.

The third approach is thematic. Only one book [18] can clearly be called thematic, although four others [11; 19; 55; 71], assigned to the first category, could possibly be included since they have elements of the thematic approach.

In assessing the various texts and their approaches to regional geography, the third method [18] seems to have come closest to providing an integrating overview of a large area. Still, he has used only one theme and thereafter has retained the areal format at the lower subdivisions of discussion. West and Augelli (1966) also appear to have a theme--the cultural and historical forces which have had an impact in Middle America, creating complex patterns of cultural diversity. The spatial overview of the dynamic impact of these forces, however, is diminished because the organizational format for discussion (sub-regions and countries) compartmentalizes the material and makes it difficult to grasp the broader perspective.

One final criticism can be leveled at regional geography texts. In most regional books highly descriptive writing and encyclopedic scope continue to substantiate the dull reputation of geographic writing [17]. More serious is that such textual materials focus upon unique and exceptional cases, seek out few generalizations, and fail to note the connectivity of places and the spatial systems present, clearly a legacy of the areal differentiation era. Although they propose to synthesize, their efforts are often unwittingly spatially disintegrative at a larger scale. In addition to all of the above, the characteristic which seems most anachronistic (and which should make cohabitation with modern geography illegal) is that they almost never draw upon theoretical and conceptual developments in systematic geography. Where in any of the regional texts can one find reference to perception, spatial diffusion, network analysis, central place theory, or recent advances in the use of historical sources and quantitative methods? The answer is virtually nowhere.

Curricular materials and courses in regional and systematic geography thus stand in sharp contrast; a crew-cut, narrow-lapeled, poglegged regional geography pretends that his long-haired, doublebreasted, flair-bottomed systematic cousin does not exist. It is little wonder that, when seeing this anachronistic regional figure and his mod counterpart in the same department, some of our students leave the field displaying latent schizoid symptoms.

Is there a need to resolve this apparent dichotomy, to give substance to what leading thinkers argue is unity? For many reasons, if this has not already become apparent, we believe that there is indeed a clear call to modernize regional geography, to bring it into phase with the remainder of the field, and to emphasize the essential unity of the spatial viewpoint [2:4; 20:105]. And if we have correctly interpreted the forces impinging on teaching college geography today, it seems reasonable to conclude that, whether we are ready to admit it or not, regional geography continues to have a role in the curriculum and in research as well. The question is: How can the great gap that seems to separate regional and systematic geography be bridged?

In pondering this question, Berry's [2] attempt to demonstrate the interdependency of systematic and regional geography by using a geographic matrix is helpful. He states that the key to attaining this unitary view in which systematic and regional geography become parts of the same whole is the identification of a common theme or themes throughout an entire set of systematic or topical variables recorded for the places in the region. Such identification leads to an understanding of the character of the region under study and helps to distinguish it from other earth areas. Harvey [28:116] agrees: "A 'theme' acts as a directive by indicating the sort of facts the geographer ought to collect and by suggesting the mode of organization of these facts." We contend therefore that the method of bringing new vigor and life to regional geography so that it reflects the research frontiers of the discipline is to isolate a number of themes--themes which express not only the character and interrelated parts of the particular regional (sub)system under study at a given scale but also reflect the conceptual structure of geography. If themes can be chosen which can give rise to theories, regional geography will at last be striving for the generic rather than the unique [28:116]. The exceptionalist legacy of areal differentiation will no longer be the foundation for regional teaching.

In view of the success of a thematic approach to systematic curricular materials such as that of Kasperson and Minghi [38] writing in political geography, it is surprising that few thematic attempts have been made in regional geography. This vacuum, which to us seemed striking, stimulated our thinking about a thematic approach to Africa. Would a thematic approach communicate the special ambiance of Africa as well as incorporate modern perspectives in the discipline? Would it be possible to bring some order to the hitherto chaotically described spatial systems of Africa and to incorporate some of the revolutionary recent developments in geography? We concluded that given the dismal state of African curricular materials it would be worth conceiving a thematic approach for Africa. The project below had its origins in these questions.

From another survey, this time of periodic literature of Africa and geography, we selected five themes (see Appendix for an outline). These themes are intended to provide a continental view of significant spatial processes and patterns. Additionally, they furnish a geographic perspective to research topics in the other social sciences. Following is a brief description of this thematic structure.

Theme I is called "The Environment: African Views and Adaptations." Although it concerns the environment, it begins with the assumption that an "objectively" described environment is often irrelevant to African human geography. Arguments that descriptions of physical landscapes provide a setting or stage for the unfolding of human spatial patterns are untenable. Such settings are usually not an objective base upon which human behavior unfolds, but rather are themselves interpretations--seen through the eyes of Western observers. The environment is therefore considered a <u>milieu</u> not only surrounding and underpinning African cultures but also interacting with them. It is interpreted not from the viewpoint of outsiders, but is explored through the eyes of local cultures since African views of and adaptations to the environment are a result of cultural conditioning. It is put in a mode that is meaningful to the man who interacts with it. From the conceptual frames of environmental perception, spatial organization, and cultural ecology, African interpretation and adjustments in various parts of the continent are examined.

Cultural origins and dispersals are the focus for Theme II, entitled "Cultural Genesis and Process." The basic premise of this theme is that a great thread of continuity may be found in African cultural evolution. This is of interest in itself, but it is also geographically relevant because tracing this thread sheds light on the processes of modern cultural change, human occupancy, and spatial arrangements in Africa. The thread results in an intricately woven web of spatial and temporal interaction. Diffusion theory, which is examined methodologically as a dynamic process with particular reference to Africa, provides the framework for this discussion.

Theme III, entitled "Population Movement and Change," is concerned with population mobility and demographic change. The movement of African peoples, both now and in the past, is viewed as a ubiquitous process and significant integrating factor in African human geography. While most geographic textbooks fail to give this theme adequate coverage, studies made in disciplines such as history [58; 47] and economics [32; 72], recognize population migration as a critical factor in the exchange of ideas and in Africa's development. Modern movements, especially those semi-permanent, interregional moves between rural areas and developed regions, are the most recent pulsations of population mobility.

The fourth theme, entitled "Response to Modernization," discusses the transition from traditional life to modernity, occurring in varying degrees in every corner of the African continent. The processes which have been most significant are economic change, urbanization, and political modernization. From the building block of agricultural change, the concern is on the modernization process of the rural sector. Set within the rural matrix are urban nodes possessing rural links in varying degrees and growing differentially, internally and externally. Modulating the whole process of change are the political systems of the individual countries, each striving toward a common goal of nation-state and attempting to overcome critical problems.

The fifth theme, called "Man's Impact on Africa," attempts to assess the imprint of man on the continent and provide an overview of the fundamental spatial changes occuring, with a look to future directions. Drawing conclusions from the first four themes, a contemporary baseline is developed as a measuring point for evaluating future spatial trends.

These five themes are the framework for our attempt at curriculum re-evaluation, improvement, and innovation in a field which we feel has been long bound by the shackles of traditional methodology. If regional courses are to be taught in geography departments and make positive contributions to geography's development, they must change. The thematic structure is one form such change might take. We believe it brings to the regional classroom a new sense of relevancy and enables students to envision the geography of Africa as something more than an encyclopedic collection of facts, dutifully and dully repeated for every major region. Themes provide an integrating overview of the continent and its problems. They also offer a set of specific concepts and models which can be applied in small areas and in case studies. They furnish cross-disciplinary links to other social sciences. Finally, and perhaps most importantly, they give students challenging generalizations set in an interpretative framework--generalizations which apply in Lusaka, Abidjan, Dar es Salaam, or Rabat.

APPENDIX

Africa: A Thematic Geography

Themes and Sub-themes

I. African Views and Adaptations to Their Environment
   A. Environmental Perception
      1. The Perceptual Approach
      2. African Perceptions
   B. Spatial and Territorial Organization
      1. General Systems
      2. Land Tenure Systems
      3. Other Forms
   C. Traditional Systems in Ecologic Perspectives
      1. Cultural Ecology
      2. Sedantary Systems
      3. Pastoral Systems
      4. Role of Disease

II. Cultural Genesis and Process: Diffusion of Ideas and Ways
   A. Human Origins and Cultural Beginnings: The Spread of Prehistoric Man and His Culture
      1. Environmental Interrelationships of Evolving Man
      2. Cattle Nomadism: An Example of Cultural Origins
      3. Impact of Food Production on Man-Land Relations
   B. Diffusion: The Process of Spread and Dispersal
      1. Invention vs. Dispersal
      2. Diffusion: The Spatial Process
      3. Dispersal Mechanisms
      4. Scale Networks
   C. Diffusion of Culture Traits
      1. Agriculture
      2. Language Groups
      3. Organized Societies
      4. Markets
      5. Islam

III. Population Movement and Change
   A. Population Movements in Historical Perspective
      1. Slave Trade
      2. Others
   B. Modern Population Movements
      1. Permanent
      2. Temporary
      3. Periodic
   C. Problems of Population Growth
      1. Distribution and Density
      2. Demographic Change
      3. Implications of Growth

IV. Response to Modernization
   A. Economic
      1. Agricultural Change
      2. Market Systems
      3. Infrastructure-Circulation Systems
      4. Industrialization and Resource Development
      5. Regional Development
   B. Urbanization
      1. Growth
      2. Central Place Systems and Rural Linkages
      3. Central Places and Internal Spatial Change
      4. City as a Node of Modernization
   C. Political
      1. Contemporary Territorial Trends
      2. Problems of Territorial Cohesion

V. Man's Impact on Africa

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A CLIMATIC MODEL OF THE
EVERGLADES DROUGHT

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The Florida Everglades function as a natural water reservoir for the population of south Florida. A watershed comprising three Conservation Areas and the Everglades National Park collect surplus moisture for use by urban, industrial, and agricultural activities whose water demands have increased significantly in recent years. The moisture required to maintain the unique character of the Everglades environment is a competing demand for water which is derived from the natural endowment of moisture for this area. The Everglades experienced droughts and damaging fires in 1965 and 1971, but there is some question concerning whether these droughts were natural or were the result of water being allocated to human uses at the expense of the Everglades ecosystem. The nature of the climatic drought during these two years can be assessed by examining the fluxes of energy and moisture which define the environmental demand for water.

Water balance techniques were employed to model the nature of the energy and moisture exchanges occurring in Conservation Area I from 1963 to 1971. The annual precipitation regime, the annual moisture index, and the annual AE/PE ratio were graphically analyzed to assess drought severity in 1965 and 1971. The analysis revealed that the climatic drought of 1965 was more severe even though the 1971 drought was perceived as being the worst drought on record. The 1971 drought was more severe than the drought indicated by the climatic model, and this suggests that the drought may have been influenced by the transfer of water for man's activities which reduced the proportion of the common water supply available to the Everglades. This evidence indicates that water management schemes in southern Florida must consider the potential impact of water allocation decisions on the Everglades if this area is to be preserved.

The relatively flat and low-lying peninsula of southeastern Florida, underlain by porous limestone and capped with a layer of peat, serves as a natural reservoir for surface water. The Everglades have developed as a product of this environment. However, recent urban, industrial, and agricultural demands for water are competing with the Everglades for the natural endowment of moisture. Management of this resource must consider alternative schemes for allocating water among the competing demands. This cannot be accomplished without understanding the importance of water in maintaining the balance of the Everglades ecosystem.

The topography of the Everglades is characterized by a slope of only one-tenth of a foot per mile, and consequently is a difficult watershed to manage. The Everglades consist of 4,000 square-miles of marshes and prairies which are seasonally inundated. Alternating dry and wet conditions are responsible for the formation of saw-grass marshes so important in the life cycle of the Everglades. During the dry season, the Everglades are often swept by saw-grass fires that may even consume the peat soil which lies above the porous rock cap.

Since 1940, southern Florida has experienced extremely rapid growth in urbanization and industrialization. As urban areas expanded to the west along drainageways on lands formerly used for agriculture, they displaced agricultural lands farther inland to the eastern edge of the Everglades [5;15]. In 1965, at the time of one of the worst droughts, agricultural users consumed about six times more water than the other users. Irrigation use for agriculture is projected to increase nearly two-and-a-half times by the year 2000. In addition, increased population growth and tourism place a greater stress on the water supply. By the year 2000, the fresh water demands of Dade, Broward, and Palm Beach counties are also expected to increase one and three-quarters times the amount consumed in 1965.

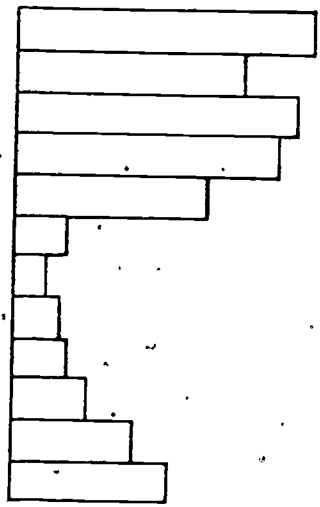
Furthermore these demands are seasonal, and during the dry season, most of this additional water consumption occurs [5;21]. Southern Florida's natural reservoir is dependant upon precipitation as the only means of water recharge. The rainy season, extending from June to October, contributes about 70 per cent or 41 inches of the 59 inch annual total. It is during the wet season that the areas of standing water are replenished. The remaining 18 inches are distributed throughout the other seven months as illustrated by Fig. 1 [2;3].

The purpose of this paper is to identify the extent to which climate may be considered responsible for the 1971 drought. Through the employment of water balance analysis, the climatic environment of the Everglades is assessed in an effort to determine its role in the perceived drought condition.

STUDY AREA

The Everglades are divided into four entities as shown by Fig. 2. These subdivisions are the Everglades National Park and three Water Conservation Areas. Forty-nine percent of the Everglades marsh lies within the three conservation areas. Within the Everglades National Park there are approximately 200 square-miles of the total 2,300 square miles of the Everglades [3;2].

The purpose of the conservation areas in the Everglades is to store excess water, reduce flooding during wet periods, and release water during dry periods



	Rainfall	% of Total
June	9.57	16.0
July	7.76	13.3
Aug.	9.35	16.0
Sept.	8.68	14.8
Oct.	6.03	10.0
Nov.	1.66	2.8
Dec.	0.99	1.7
Jan.	1.53	2.6
Feb.	1.66	2.8
March	2.51	4.2
April	4.04	6.9
May	5.22	8.8
Total	59.00	100.0

Fig. 1

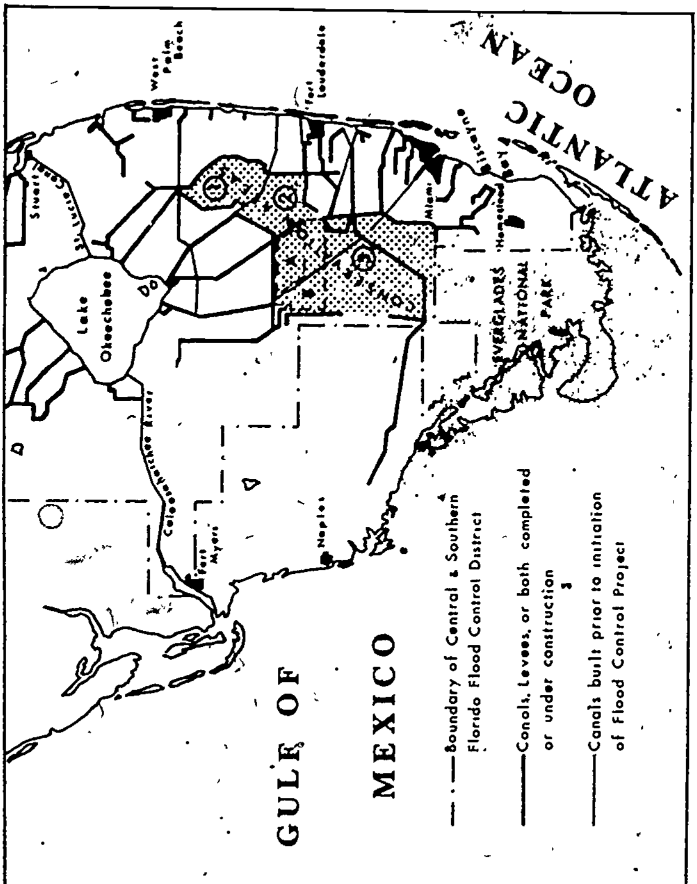


Fig. 2- Everglades National Park and vicinity (6)

to minimize the effects of drought. Thus, runoff is delayed, and floods are reduced in the urban areas by impounding the excess water in the conservation areas. The stored water is later available either as direct releases through canals or as seepage from conservation areas during the dry season.

In order to study the problem on a smaller scale and to examine the conditions more precisely, analysis was limited to Conservation Area I of the Everglades. Fig. 2 shows the location of Conservation Area I with respect to the other divisions of the Everglades.

Data for water budgets were obtained from records of two weather stations located in the vicinity of Conservation Area I. Belle Glade Experimental Station is located northwest of the conservation area, and Loxahatchee is located to the northeast. Due to the absence of a weather station within the conservation area, averages for temperature and percipitation values of the two stations were used to obtain annual water budgets for the area.

METHODOLOGY

Thornthwaite's water balance techniques were employed to examine the coincidence of energy and moisture. The water budget is a balance between the inputs of water from precipitation and the outflow of water by evapotranspiration. Temperature is directly related to energy demands as defined by the PE values, while the values of AE indicate the amount of moisture consumed by evapotranspiration. A four inch soil moisture capacity was used in calculation of the water budgets.

Analysis of the data is shown graphically using precipitation data, the moisture index, and the AE/PE ration. The precipitation graph, Fig. 3, reveals the amount of moisture available. This is the moisture endowment which must be shared between the Everglades and human activities. The annual variation in moisture supply is revealed by the graph.

The moisture index values, as shown within Fig. 4, indicate on a broader scale, the classification of climate based on climatic criteria alone. In essence, the moisture index separates a region into either a moist or dry climate independant of vegetation, soil, or water resource characteristics [1:310].

Fig. 3

Moisture Index Graph

Over 9 year period (1963-1971)

High = ++++

Average = ———

Low = - - -

Year	I(M)
1963	3.
1964	10.
1965	23.
1966	47.
1967	-10.
1968	54.
1969	62.
1970	44.
1971	16.

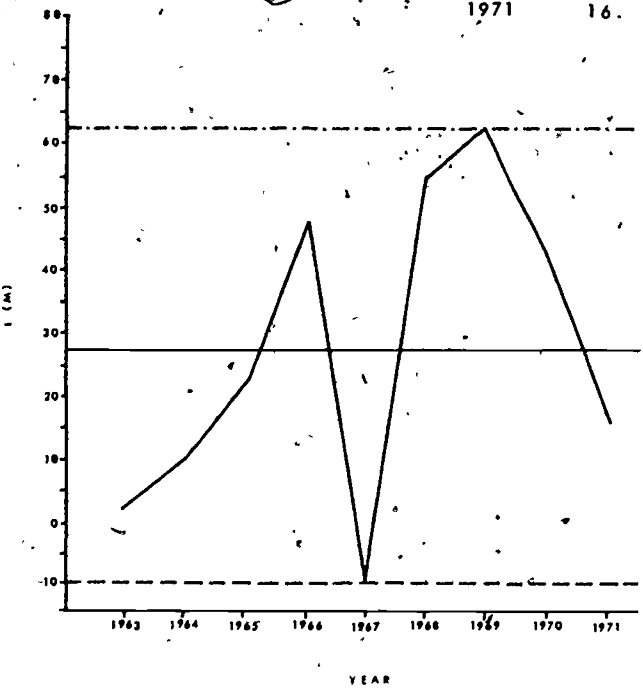


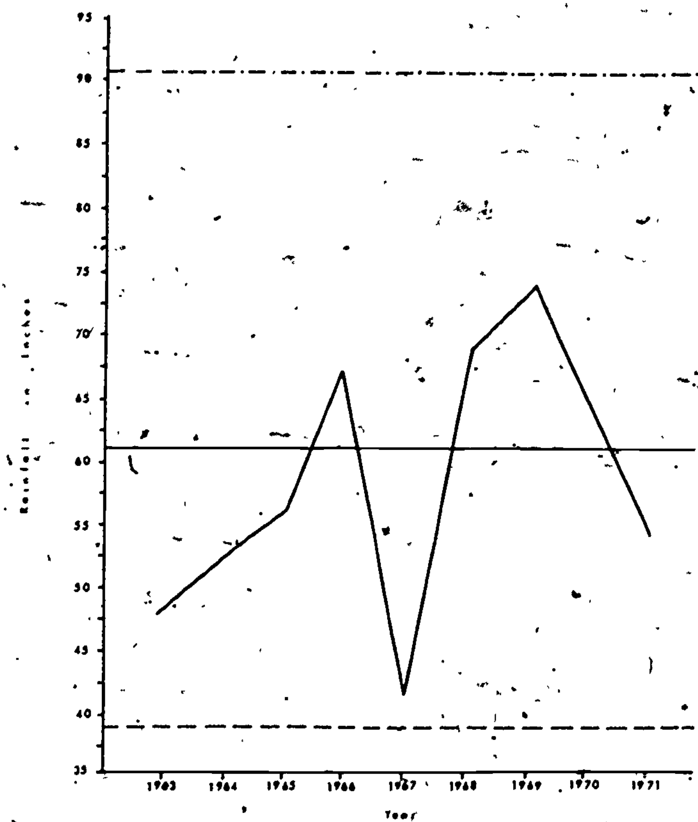
Fig. 4.

Precipitation Graph

Over 20 year period (1940-1965)

High = 90.44
Average = 61.05
Low = 38.09

Year	Precip.
1963	47.5
1964	52.3
1965	56.8
1966	67.0
1967	42.4
1968	69.5
1969	74.4
1970	65.6
1971	54.1



The values given to the AE/PE ratio (Fig. 5) more specifically deal with the significant variations involving temperature and precipitation. PE cannot be satisfied unless the necessary moisture is available. Using PE as the denominator of the ratio, it is only when AE equals PE that a value of unity is obtained. A value less than unity indicates a defecit in moisture. Through the employment of this ratio, the nine years, between 1963 and 1971, are compared with reference to fulfilling the annual moisture demands when consideration of capillary storage is included.

ANALYSIS OF DATA

The specific years involved in this study are the years prior to the 1965 and 1971 droughts. Antecedent conditions are important in determining the severity of drought, and water budgets were therefore computed for the nine years between 1963 and 1971.

The graphs all show a similar trend in the nature of their values. The points of reference used in explaining the graphs are the highest value, the lowest value, and the average of these two, based on data obtained for the nine years.

The graphs of all three parameters for 1963, 1964, and 1965, have a value lower than the average. Although the AE/PE graph of 1964 is above the average, this can be explained by a closer analysis of the water budget for that year. The precipitation values show there were only five months out of the regular seven months when moisture could not fulfill the demands of PE. But, the latter four months of 1964, with the exception of October, show that there was a general deficiency in precipitation. Leading into 1965, with the exception of February, there was a five month period of moisture deficiency. This explains the cumulative effect of moisture deficiency which culminated in the 1965 drought. Although the yearly precipitation value for 1965 was higher than either 1963 or 1964, it is evident from the analysis of the water budget for that year that 48.3 inches of the total 56.8 occurred after June with only 8.5 inches distributed from January to May.

In summary, the 1965 drought was caused by a lack of moisture to fulfill

Fig. 5

AE/PE Graph

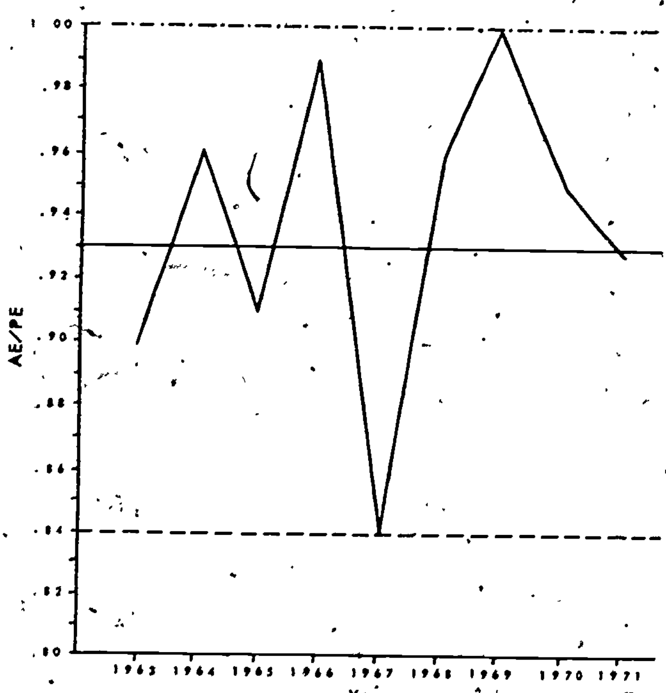
Over 9 year period (1963–1971)

High = 1.00 —·—·—·—

Average = .93 ————

Low = .84 — — — —

Year	AE/PE
1963	.90
1964	.96
1965	.91
1966	.99
1967	.84
1968	.96
1969	1.00
1970	.95
1971	.93



the demands placed on it as based on prior conditions to that drought year.

For the recorded drought of 1971, the preceding years show evidence that the drought occurred for the same reason as in 1965, but the severity of the drought is questionable. Analysis of the annual precipitation values for the years of 1966 through 1971, reveals that the average for the six years was 62.1 which is 1.1 above the average value obtained over a 25 year period from 1940 to 1965. But in following this same procedure for 1963 through 1965, the average precipitation value was 52.3, which is much lower than any of the average overall precipitation values, and also lower than the average values for the years of 1966 through 1971.

The comparison of the AE/PE ratios for the years prior to 1965 and 1971 reveal lower values for 1963, 1964, and 1965 than those of 1966 through 1971. The yearly water budgets for 1966 through 1971 also show that 1971 did not experience a greater moisture defecit than 1965. For example, there were only six consecutive months from November of 1970 to April of 1971 when moisture did not fulfill the PE demands. In fact, the moisture indices of the years 1966 through 1971 had generally higher annual values during preceding years than did 1965. Therefore, based on the assessment of the climatic conditions, the 1971 drought should not have been more severe than the 1965 drought. The fact remains, however, that fires raged for over four months and destroyed over half a million acres in the drought of 1971. Furthermore, authorities of the Florida Flood Control District considered 1971 to be the worst drought year on record [4:2].

CONCLUSION

Analysis of the water budgets suggests that the severity of the 1971 drought was not due to climatic factors. Attention must then be focused on other variables which may have contributed significantly to magnify drought conditions. The combination of increased urbanization, industrialization, and population may provide a possible explanation. Increasing allocations of water to these activities has decreased natural runoff and has thus diminished the supply of surface moisture to the Everglades. Further reductions in runoff to the Everglades may produce recurrences of drought similar to 1971 which are not the direct product of climate. Clearly, more adequate controls are necessary to the preservation of the Everglades ecosystem.

ACKNOWLEDGMENTS

The author wishes to express her thanks to Professor Marlyn Shelton for his assistance and encouragement.

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A CASE STUDY OF LAKE EFFECT SNOW SQUALL PRECIPITATION IN NORTHERN OHIO: NOVEMBER 22, 1971

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Abstract: This paper describes and analyzes the pattern of snowfall that occurred during an early winter snow squall in Northeastern Ohio. Snow accumulation from this snow squall varied from a trace to more than twenty-five inches in Summit and Portage Counties. A chronology of the development and subsequent movement of the snow squall is presented, along with the configuration of moderate and heavy snow as indicated on the PPI scope of the Decca 41 weather radar operated by the National Weather Service Office at the Akron-Canton Regional Airport. Also included is a brief description of the meteorological conditions favorable for the development of snow squalls and the effect topography has on these snow squalls and their intensity.

It is well known to meteorologists that frequent and persistant snow showers and snow squalls occur to the lee side of all five Great Lakes from late autumn until late spring. These lake effect snow showers or snow squalls can, under the correct meteorological conditions, deposit as much as two to three feet of snow on the inland areas in a single meteorological occurrence. The heaviest of these snow squalls occur most frequently to the lee side of Lakes Erie and Ontario. The squalls are usually associated with outbreaks of cold, dry arctic air masses which move southward out of their northern Canadian source region and turn easterly as they move over the northern Great Plains states. Such a condition normally leads to a large air mass-water temperature differential, especially in the late autumn, early winter and in the spring. This air mass-water temperature differential, combined with a long over water fetch is capable of producing locally heavy snow squalls to the lee side of Lakes Erie and Ontario as indicated by both Sheridan [7:393-395] and Wiggin [8:123-126].

The most intense of these lake effect snow squalls usually occur when a secondary surface trough forms to the west and moves through the Great Lakes area and combines with the lake induced vertical fluxes of momentum, heat, and water vapor to produce heavy snowfall amounts [5:191-192].

Several climatological studies of total snowfall from individual storms as well as analysis of the total seasonal snowfall have revealed "peak areas" of snowfall for both Lake Erie and Lake Ontario. On a seasonal basis, Lake Erie's "peak area" averages one hundred and sixty inches, and Lake Ontario's is one hundred and ninety inches (Fig. 1). Most of this snowfall is the result of snow squalls [6;2-3].

In this paper, an example of the variation in snowfall accumulation and intensity from such a lake effect snow squall situation for a six hour period in northeastern Ohio is reviewed and a presentation of the formation and subsequent movement of the snow squalls, as indicated by the three centimeter Decca 41 weather radar located at the Akron-Canton Airport Weather Service Office, is also included. The date of occurrence was November 22, 1971.

CAUSES OF LAKE EFFECT SNOW SQUALLS

It is generally agreed by meteorologists that the large scale synoptic situation which can result in the development of lake effect snow squalls is: (1) an upper air trough over the eastern United States which frequently becomes either stationary or broadens to the west; (2) a strong flow of cold, dry arctic air across the lake following a low pressure center that has moved into eastern Canada; and (3) a southward extension of the primary low in the form of a trough over the Great Lakes [2:3]. The lake effect snow squalls, when they form, either have a linear characteristic or are elongated areas, oriented either parallel to the prevailing wind direction or parallel to a shoreline [3:7-8]. Overlake snow squalls usually form away from the shoreline when the upper level winds are approximately parallel along the major axis of the lake. These overlake squalls usually first form as a single narrow line, and at times, stream inland along the axis of the prevailing winds. The squalls are normally two to twenty miles wide and fifty to one hundred miles long [3:8]. Conversely, the shoreline type of squall generally forms with a more northwesterly wind flow and a shorter overwater fetch than is the case for the overlake type of squall [2:3]. Precipitation accompanying the shoreline type of squall generally begins along the lee shore and may move inland as several short lines, or as a single line, from one to five miles wide and twenty five to fifty miles long. However, the overlake type of squall may change to the shoreline type in response to changes in the upper level wind direction [2:3].

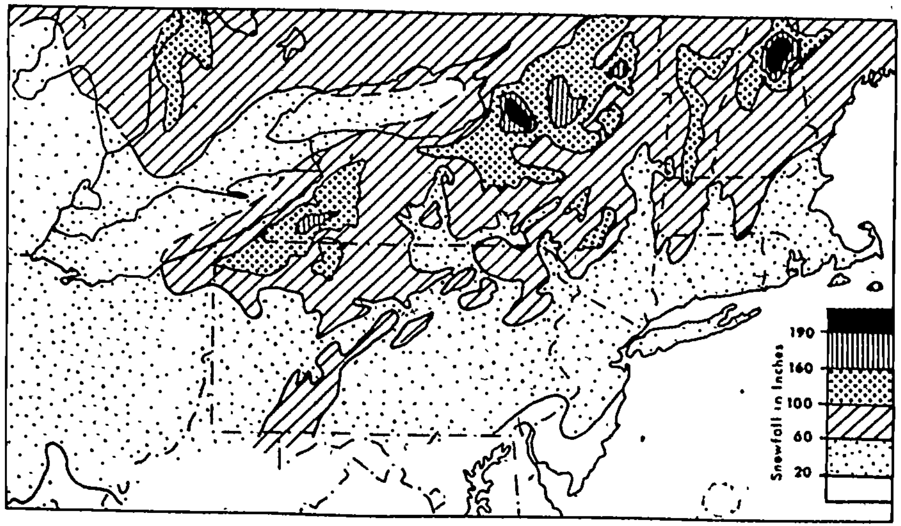

Fig. I MEAN SEASONAL SNOWFALL. U.S DATA ARE FROM 1951 TO 1960.
CANADIAN DATA ARE FROM 1931 TO 1960 (4: 249).

LAKE ERIE'S SNOWBELT

The snowbelt associated with Lake Erie extends from the northern part of Summit County, Ohio northeastward through the remainder of the state and across northwestern Pennsylvania into the area just south of Buffalo, New York. The lake effect snowfall in this area is strengthened by the orientation of the Lake along an east-west axis. The prevailing winds which blow over the Lake in turn cause water vapor to accumulate from the open water. Nearly saturated air of the lower layer of the air mass is further forced up the escarpment of the Appalachain Plateau. This forced ascent causes an acceleration of the adiabatic cooling, condensation and precipitation processes, thus resulting in heavy snowfall close to the lakeshore as well as inland. Studies of this type of orographic lifting indicate that from five to eight inches of snowfall can be added to a mean annual total, on the average, per each one hundred foot increase in elevation [1:9].

THE SNOW SQUALLS OF NOVEMBER 22, 1971

On November 22, 1971 the "0700E" surface analysis map showed a high pressure ridge (1030m.b.) centered over Lake Head, in western Ontario (Fig. 2) The clockwise circulation of air around this high pressure center combined with the counterclockwise circulation of air around a very deep low pressure center (982 m.b.) located in the Gulf of Saint Lawrence between Nova Scotia and Newfoundland. This circulation combined to produce a moderate flow of air over northeastern Ohio.

Shortly after midnight (0015E) on November 22, very light snow showers were observed at the National Weather Service Office. The very light snow showers changed to light snow showers at 0128E and continued until 1138E of the same morning. Total snowfall at the National Weather Service Office by 0645E measured only one half inch. By 0630E, snowfall reports were received at the Weather Service Office indicating accumulation had exceeded four inches in the area to the north and east north-east of the airport. Cuyahoga Falls, Ohio, which is a contigious suburb to the northeast of Akron (Fig. 3) reported six to seven inches of snow on the ground, while the northern part of the city of Akron reported from an inch-and-a-half to a half-inch. Stow, Ohio, located only a few miles to

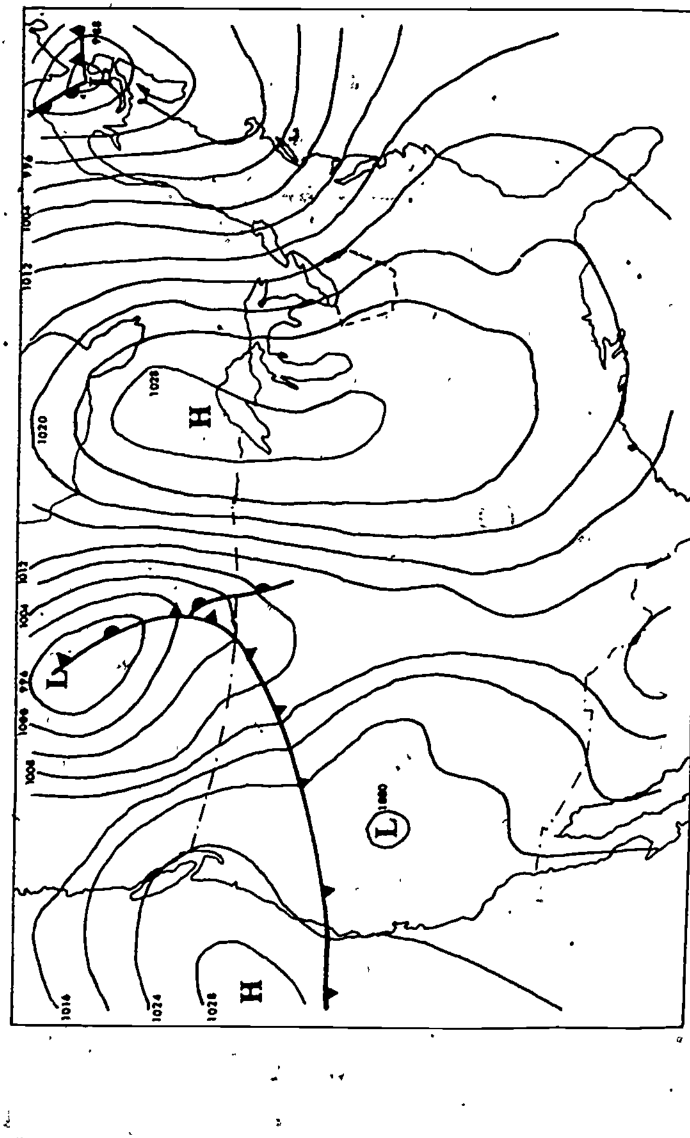

Fig. 2 - SURFACE ANALYSIS DCHART 0700E. NOVEMBER 22. 1971.

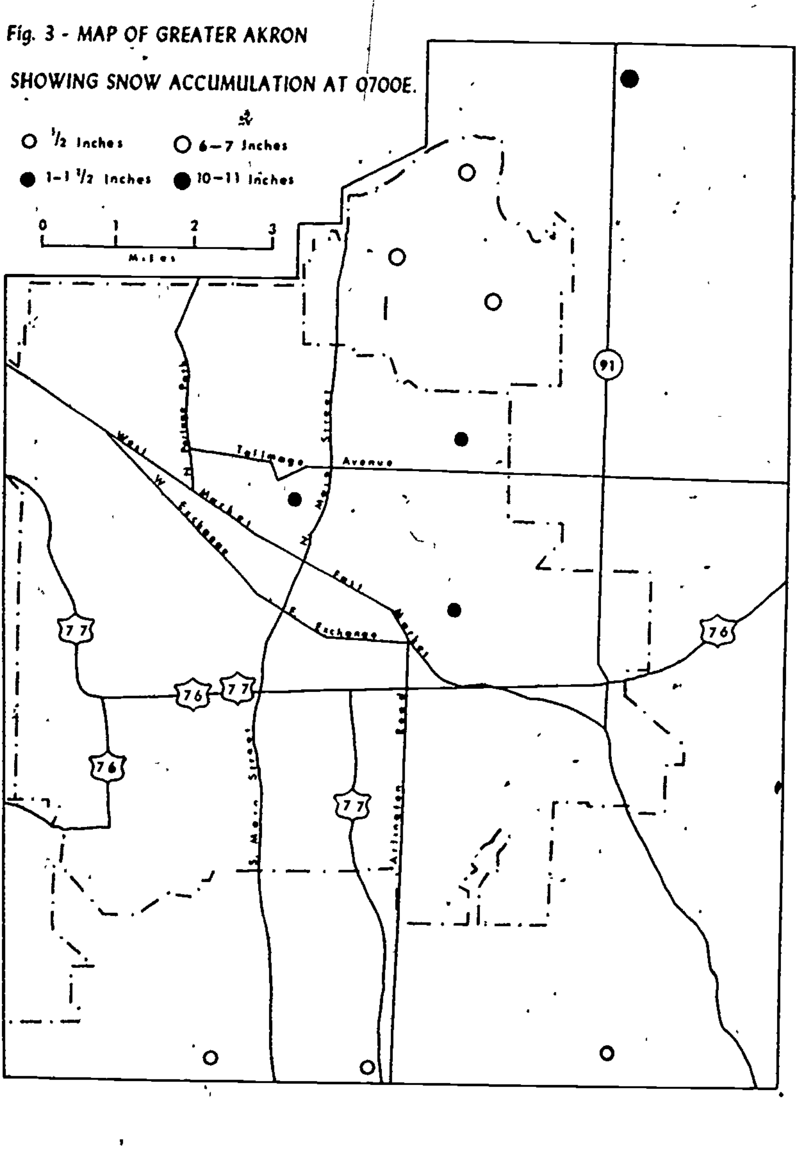
Fig. 3 - MAP OF GREATER AKRON
SHOWING SNOW ACCUMULATION AT 0700E.
½ Inches
6-7 Inches
1-1½ Inches
10-11 Inches
0
1
2
3
Miles
91
77
76
Tallmage Avenue
N. Main Street
Portage Path
West Market
W. Exchange
East Market
E. Exchange
S. Main Street
Arlington Road

the northeast of Cuyahoga Falls (Fig. 3) reported ten to eleven inches on the ground. Kent, Ohio, just to the east of Stow, had accumulated eleven inches by 0630E. The Lake Rockwell pumping station on the northeast side of Kent, reported an accumulation of twelve inches at the same time (Lake Rockwell during the remainder of the day picked up another thirteen inches and reporting twenty five inches on the ground by late evening). Heavy snowfall varying from eight to fifteen inches was reported in the long, narrow line of squalls that extended from southern Lake Erie through Rock Creek, Ohio into Slippery Rock, Penna. (Fig. 4) Reports from the Weather Service Offices located in Cleveland and Youngstown, Ohio indicated one half inch snowfall at both stations at 0700E. The hydrologist from the Weather Service Office at the Akron-Canton Airport, through conversation with road crews and residents, determined that an excess of sixteen inches of snow was on the ground at 0700E at the intersection of State Route 43 and Interstate 80-S a few miles east of the city of Kent, Ohio.

FORMATION AND MOVEMENT OF THE SNOW SQUALLS

The two areas of snow squalls were first observed by the weather radar at the National Weather Service Office at 2330E November 21, 1971. At that time, the snow squalls were located off the south shore of Lake Erie east of Cleveland, Ohio and off shore in the Painesville, Ohio area. They extended approximately thirty miles northwestward into the Lake (see Fig. 5). The two lines of snow squalls began moving inland shortly before midnight. By 0100E they had moved into the area outlined in Fig. 5. Once the snow squalls had reached the outlined area, they became stationary and remained so until 0630E. The two areas intensified as they became stationary, but they changed very little in configuration throughout the period. The location of the snow squalls resulted in an extreme snowfall differential observed in the affected area. The outlined snow squall areas represented in Fig. 5 are those of moderate to strong echo return as determined by radar, and verified by measured accumulations. As can be seen in Fig. 6, the areas which received five inches or more correspond well with the areas of moderate or strong echo return on the PPI scope of the Decca 41 Weather Radar at the Weather Service Office.

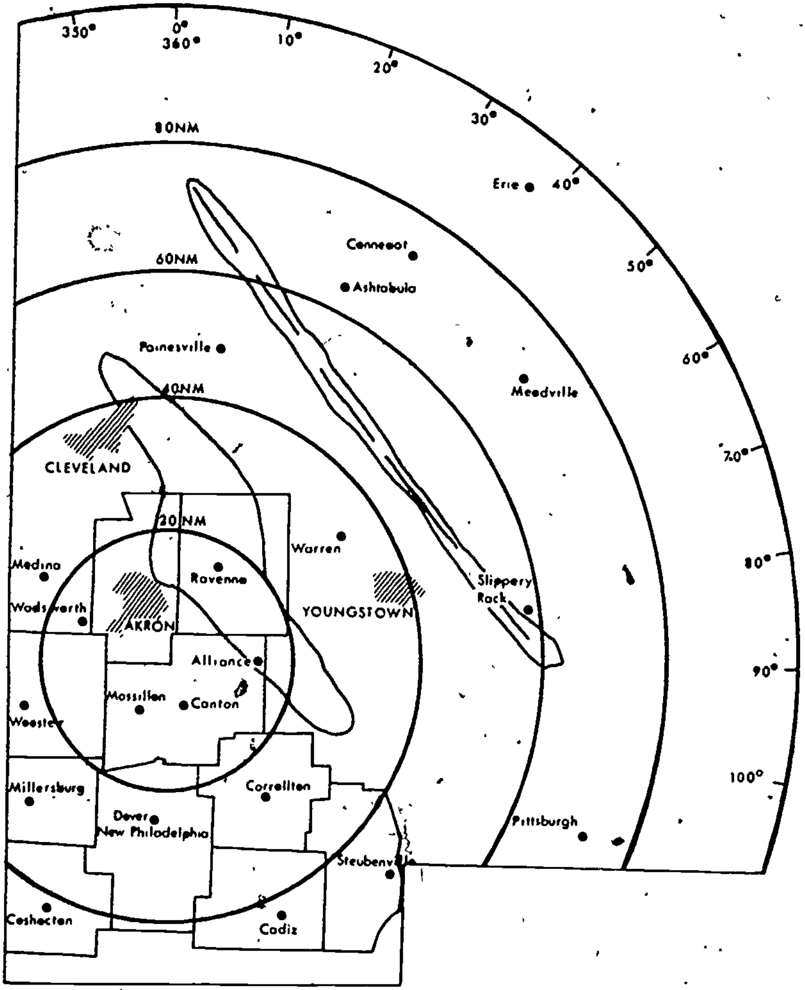

Fig. 4 - LINEAR SNOW SQUALLS AS DISPLAYED IN THE SCOPE OF THE DECCA 41.3CM. RADAR.

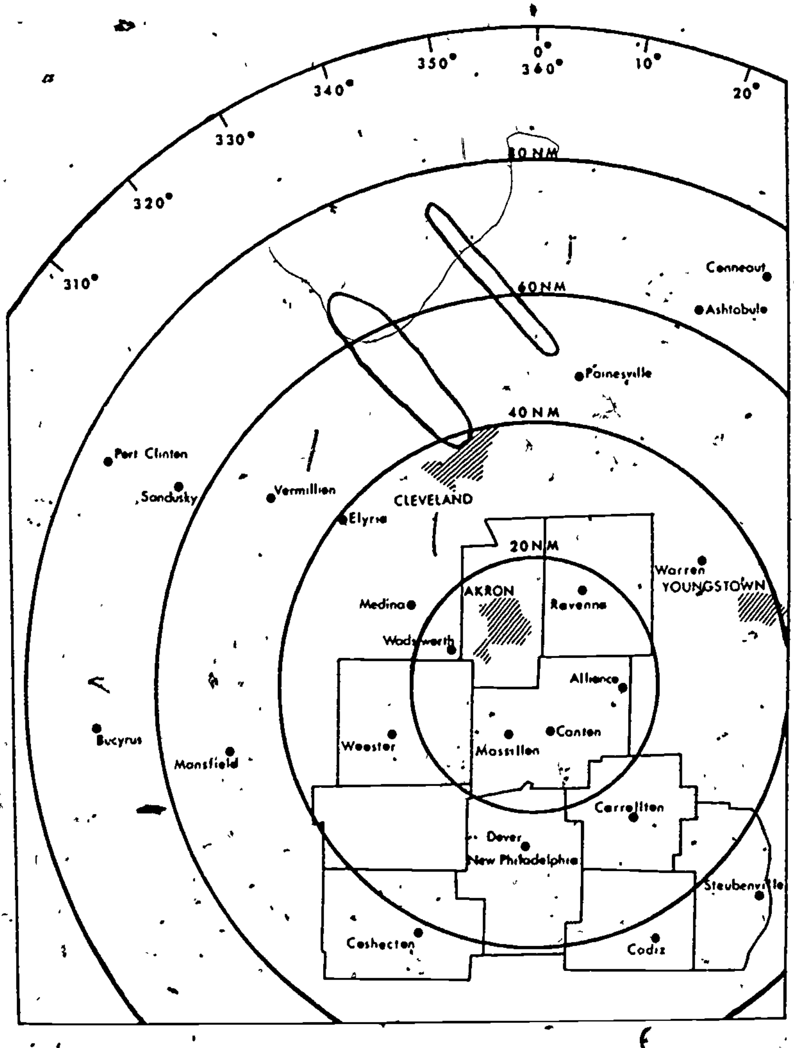

Fig. 5 - LINEAR SNOW SQUALLS AS DISPLAYED ON THE PPI SCOPE OF THE DECCA 41 RADAR AT MIDNIGHT NOVEMBER 22, 1971 (BEFORE THEY MOVED INLAND)

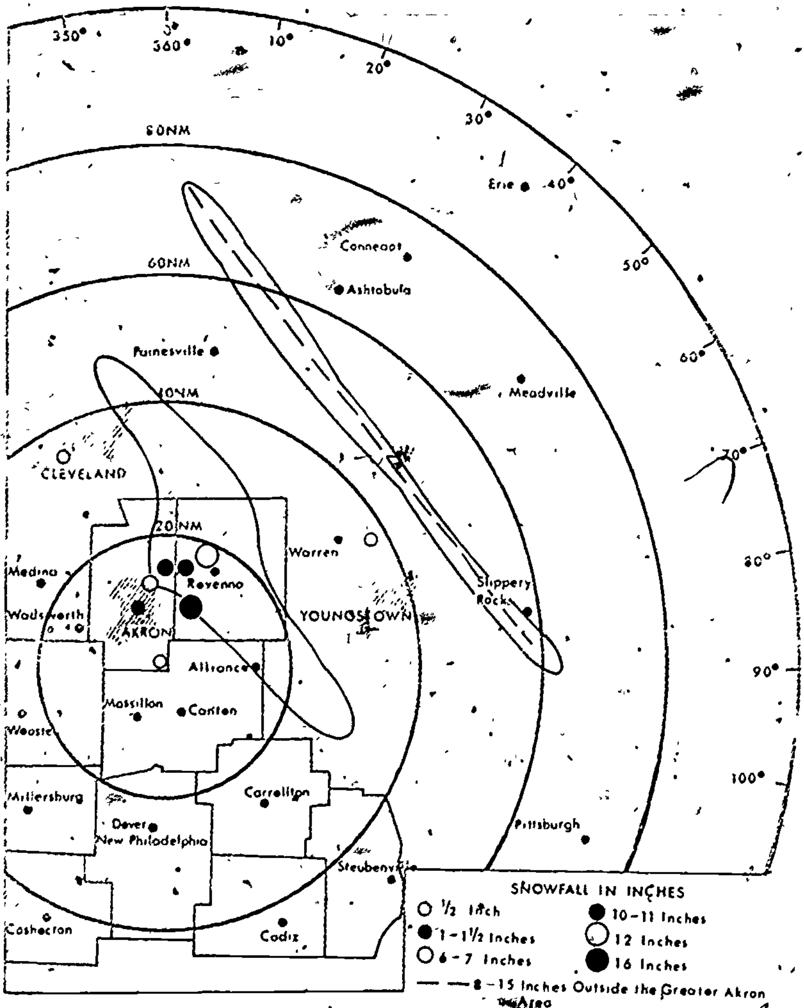

Fig 6 COMPARISON OF SNOWFALL AND MODERATE OR GREATER SNOW INTENSITY AS DETERMINED BY RADAR.

CONCLUSION

It is evident from the preceeding description that the type of snow squalls that covered the study area were the overlake type in origin. Supporting northwesterly winds were only moderately strong, but they were intense enough to push the snow inland. However the winds were not strong enough to overcome the frictional drag the physiography produces, and this condition resulted in a stationary squall for an extended period of time causing in the great variation of snowfall observed in the Akron area. This type of snow squall situation is not unusual in some parts of northeastern Ohio, namely, from the eastern suburbs of Cleveland eastward and northeastward into Pennsylvania. However, snow squalls of this intensity do not normally extend so far to the south nor are they so strong as they were on November 22, 1971.

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INSOLATION CLIMATE AND URBAN TOPOGRAPHY

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Abstract: Energy exchange processes of urban environments are significantly influenced by the physical structures comprising our cities. Modification of natural energy fluxes creates a true urban climate which is a function of the presence of the city. While considerable progress has been achieved toward understanding the macro-scale energy system of urban environments, many questions concerning micro-scale energy fluxes in cities remain unanswered. The quintessential energy input of climate is solar radiation and knowledge of the quantitative and distributional characteristics of insolation is essential for understanding the energy system of the city.

Measurements of global radiation near a west facing vertical wall were employed to examine how insolation receipts are modified by urban structures. The data revealed a direct relationship between insolation and increasing vertical height and increasing perpendicular distance from the base of the wall. Post-zenith global radiation was most intense at the wall, which received 91 percent of its total insolation after 1200 hours, but the influence of the wall disappeared within six feet of the wall. The intensity of the post-zenith insolation did not compensate for earlier shading, however, for a point fifteen feet from the wall received more insolation than any measured point on the wall. The wall at ground level received only 45 percent of the expected insolation for a comparable horizontal surface, and a point six feet high and fifteen feet from the wall received only 78 percent of the expected amount. These data suggest that steep gradients in horizontal and perpendicular micro-insolation climates of cities may be confined to the immediate vicinity of urban structures.

Urban landscapes are a composite of insolation climates. "Latitude, tilt of the earth, and the slope and aspect of the surface exert the major geometrical controls over the amount of insolation received by a particular site" [8:14]. The influence of these controls is complicated by the buildings and multiple-level surfaces of urban areas which present a complex, three-dimensional geometry to incoming solar radiation. Energy exchange processes of urban environments consequently are more complex than energy exchanges characteristic of surface configurations in the natural landscape.

The magnitude of potential surface exposures associated with urban topography contrasts markedly with conditions found in the natural landscape. Urban landscapes are composed of structures with a variety of shapes and orientations. The walls and roofs of buildings function as a maze of reflectors which absorb some of the insolation they receive and direct much of the remainder to other absorbing surfaces [7:15]. Almost the entire surface of a city is available for receiving insolation, and this is a significant factor when considering energy fluxes associated with structural features of urban topography.

The conversion of the natural landscape to the artificial city-scape creates modifications in energy and moisture fluxes and produces a true urban climate which is a function of the presence of the city. Considerable effort in urban climatology has been devoted to defining the nature of changes produced by urbanization, and examination of differences between urban areas and rural areas has been the principal focus of these endeavors. Many studies have relied on traditional parameters, such as air temperature, precipitation, and humidity, and are illustrated by the work of Landsberg, Geiger, and Peterson [5;4;8].

Recent studies by Bach and Patterson and by Terjung [1;11] have demonstrated a concern for the energy balance of urban areas. Such studies reflect an increasing awareness of the necessity to understand the input/storage/output components of the urban energy system and its influence on energy fluxes at the earth-atmosphere interface. Solar radiation is the quintessential energy input, and knowledge of the quantitative and distributional characteristics of insolation is necessary for eluciadation of the energy system of the city. Measurements of global radiation on and near a west facing wall were employed in the present study to examine the pattern of insolation inputs associated with a common feature of urban topography.

GLOBAL RADIATION

The components of global radiation received at the earth's surface are direct solar radiation and diffuse sky radiation; their summation is known as global radiation. The percentage of each component in the total radiation received by an area varies primarily with astronomical, geographical, and meteorological variables and with varying atmospheric contamination [3]. The incident angle at which this radiation reaches the surface of the earth is governed by: geographic latitude, solar declination or time of the year, altitude of the sun or time of day, angle of the slope, and surface orientation of the slope.

A horizontal surface has been taken as the reference plane for the description of insolation in general, and it is therefore a simple geometrical problem to translate from the horizontal reference to a sloping surface. The amount of direct solar radiation received on a slope is equal to the product of the radiation received on a horizontal surface and the cosine of the angle between the solar beam and a line perpendicular to the sloping surface [10].

Determination of the diffuse sky radiation reaching a sloping surface is extremely complicated and is dependent upon cloudiness, atmospheric turbidity and the albedo of the surface material. On a horizontal surface, diffuse radiation for an average clear sky is about sixteen per cent of the total radiation when the sun is high in the sky; and about thirty-seven per cent of the total when the solar elevation is about ten degrees [2].

Calculation of insolation on urban structures is complicated by the slope and orientation of building surfaces. Both direct and diffuse insolation receipts are influenced by the ninety degree slope of walls, the multitude of surface orientations, and the varying height of buildings. Measurements of insolation are needed to assess the full impact of these variables on insolation.

Global radiation may be measured by use of a pyranometer which senses solar radiation received from the whole hemisphere on a horizontally exposed surface. The measurement of global radiation requires only a horizontal-surface receiver sensitive to short-wave radiation and a suitable registering apparatus, except when the radiation components are to be measured independently.

STUDY RESULTS

The west facing wall of a solitary concrete building in Carbondale, Illinois, was selected as the site for measuring the insolation microclimate of an urban structure. The wall was fifteen feet high, contained no windows, and had no noteworthy surface irregularities. A center section of the wall approximately eight feet wide was unobstructed to the west, and it was not affected by shading after the sun passed the zenith. The terrain immediately to the west of the wall was a relatively level grass surface clipped to lawn height.

Measurements of global radiation were taken on May 25, 1969, at thirty minute intervals between 0545 and 1945 hours Central Standard Time. A Dirmhirn-Sauberer star pyranometer was employed to detect the intensity of insolation. This instrument is a thirty-two junction thermopile device employing eight white and eight black copper plates alternately mounted in the form of a star.

Radiation intensity is measured by the electromotive force difference between the warming of the black or radiant heat plates and the white or ambient temperature plates as indicated by a potentiometer.

Measurements with the star pyranometer were made at the wall and at points perpendicular to the wall every three feet to a distance of fifteen feet from the wall. The perpendicular measurements were made at ground level, at a height of three feet, and at a height of six feet. Fig. 1 is a graphical representation of these data for the measurements made at the three foot level.

Irregularities in the curves are due largely to cloud affects at the time of the reading. The sky was generally clear on this date, but occasional clouds influenced some readings. During the early morning, an overcast or haze condition prevailed but it dissipated between 0815 and 0845 hours.

The wall shaded the study area during the morning and the influence of the obstruction is clearly revealed by the graphs. At any particular time before noon, global radiation increased with increasing distance from the wall and also increased, for a specific perpendicular distance, as vertical height increased.

The changing role of diffuse radiation as a component of global radiation can be observed, especially for those locations near the wall, prior to 0845 hours. While the haze condition prevailed, much solar radiation was scattered and consequently more of the insolation was represented by diffuse radiation which arrived equally from all directions, was less influenced by obstructions, and reached all surface orientations. When the haze dissipated, locations shaded from direct solar radiation showed a brief loss in insolation intensity in response to the reduced contribution of the diffuse component of global radiation.

Soon after noon, but varying with the vertical height, the global radiation at the wall exceeded those values measured at perpendicular distances from the wall. This condition prevailed until 1815 hours when direct sun rays were no longer reaching any of the measurement points and diffuse radiation was again dominant.

The influence of the wall in reflecting solar radiation is further observed by the character of the insolation measurements away from the wall. At all

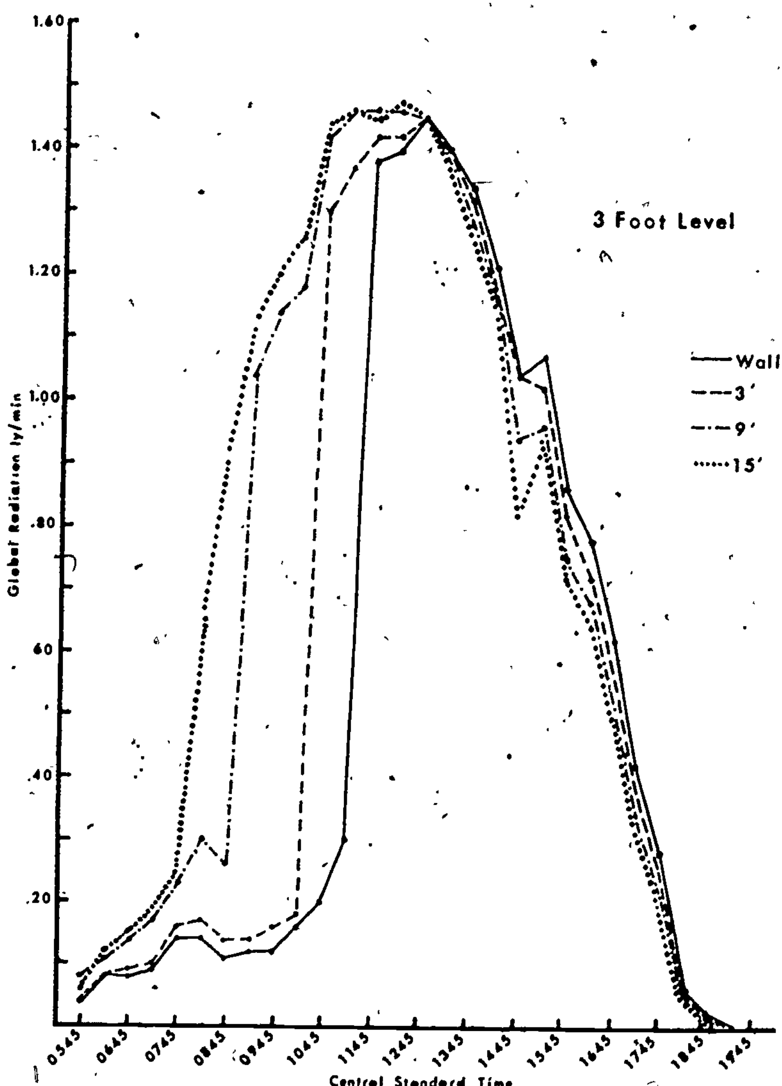

Fig. 1 — Regime of Global radiation, langleys per minute, near a west facing wall on May 25, 1969.

vertical heights there were basically three insolation levels after noon: a maximum at the wall, a slight decrease at three feet away, and a consistent reading for distances between six feet and fifteen feet away from the wall. The data suggest that the influence of the wall in increasing global radiation did not extend beyond a perpendicular distance between three and six feet.

Global radiation at 1200 hours was estimated by averaging the readings for 1145 and 1215 hours, and the results are shown in Fig. 2. These values reveal the decreasing influence of the wall as an obstruction to the receipt of direct radiation as vertical height and perpendicular distance increase. The values for 1315 hours, which are also shown in Fig. 2, disclose the reflective influence of the wall in increasing the insolation intensity near the wall in the afternoon.

Table 1 shows the langleys per hour calculated by averaging the 30 minute readings and multiplying by 60. The total langleys received at the wall and at fifteen feet from the wall for the three vertical heights also appear in this table. The wall at ground level received significantly less global radiation than any other location, and 91 per cent of its total was received after 1200 hours.

Following procedures suggested by List [6], calculated global radiation on a horizontal surface at this latitude would be 855 langleys on May 25. The percentage figures in Table 1 show the relationship between measured values and expected insolation on a horizontal surface. The wall at ground level received only 45 per cent of the amount expected for a fully exposed horizontal surface. The maximum receipt measured, the point six feet high and fifteen feet out, was only 78 per cent of the expected amount.

Prediction of global radiation received on a sloping surface is difficult due to the variable influence of diffuse radiation. Direct solar radiation on a sloping surface can be estimated, however, with the equation:

$$I_p = I_o \cos B$$

where I_p is the radiation intensity on a given slope, I_o is the solar constant, and B is the angle between the solar beam and the normal to the plane under consideration [10;39].

	Wall	3'	6'	9	12'	15'
6 Feet	1.43	1.47	1.48	1.49	1.48	1.49
3 Feet	1.39	1.42	1.44	1.46	1.46	1.46
Ground	0.77	1.37	1.4	1.4	1.44	1.44

	Wall	3'	6'	9'	12'	15'
6 Feet	1.38	1.37	1.36	1.36	1.36	1.35
3 Feet	1.40	1.40	1.39	1.38	1.38	1.38
Ground	1.42	1.40	1.36	1.36	1.36	1.38

Fig.2 — Global Radiation, langleys per minute, near a west facing wall on May 25, 1969. Top 12noon and bottom 1315 CST.

Table 1

Average Hourly and Total Daily Global Radiation for a West Facing Vertical Wall on May 25 (ly/hr).

CST	Ground Level Wall	Ground Level 15 ft.	3 Feet High Wall	3 Feet High 15 ft.	6 Feet High Wall	6 Feet High 15 ft.
0600	3.0	4.8	3.6	5.4	3.6	6.6
0700	3.3	8.4	5.1	10.2	5.4	11.7
0800	5.4	14.7	8.4	27.3	9.0	46.2
0900	4.8	30.3	6.9	60.9	6.9	65.1
1000	6.0	70.8	8.4	73.8	12.6	81.3
1100	10.2	82.8	15.0	87.0	17.4	84.9
1200	46.2	86.4	83.4	87.6	86.1	89.4
1300	84.6	84.9	85.5	84.9	86.1	84.6
1400	75.6	75.0	76.5	72.0	77.1	71.4
1500	69.3	62.7	63.3	56.4	66.6	57.3
1600	52.5	47.1	49.2	41.1	48.6	42.0
1700	22.5	19.2	31.2	24.6	29.7	21.4
1800	2.4	2.7	2.4	2.4	9.6	7.2
1900	0.9	0.9	0.6	0.6	0.6	0.6
Total	386.7	590.7	439.5	634.2	459.3	670.7
% of Expected	45%	69%	51%	74%	54%	78%

Solving this equation for the west facing vertical wall at 1200 hours yielded a value of 0.7 langleys per minute. The value derived by averaging the measured insolation was 0.77 langleys per minute for the ground level measurement at the wall. This is a difference of 10 per cent and it could be accounted for by diffuse radiation and reflected radiation from the wall. Values measured higher on the wall increased and indicate that the obstructing effect of the vertical surface decreased with height at this latitude and at this time of year.

EVALUATION OF RESULTS

These data suggest that steep gradients in insolation microclimate may be confined to the immediate vicinity of urban structures. Perpendicular gradients observed at the wall were not identifiable at a distance of fifteen feet from the wall. These conditions may be a function of the height of the wall, however, and additional testing with different structures is needed to identify the precise nature of energy fluxes in the vicinity of perpendicular surfaces.

Measurements of insolation at different times of the year are also needed before generalizations can be formulated concerning energy fluxes associated with vertical structures. Conditions near adjacent urban structures should also be studied to determine whether buildings have overlapping zones of influence. Diffuse radiation reflected from adjacent buildings might increase insolation inputs significantly and thereby diminish the insolation differences observed in this study when buildings are juxtaposed.

The urban energy system is driven by insolation. The present study only suggests the type of research needed to understand the role of this component in urban energy flux processes. Extended periods of observation and study of conditions between buildings are needed. The insolation microclimate of urban topography represents a crucial component in the urban energy balance, and in our understanding of the causality of urban climate.

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THE STRUCTURE OF GEOGRAPHY:
A REVISED VERSION

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Abstract: The initial attempt to order the spatial organizational approach to geography, under the label "the structure of geography," is felt to be so highly simplified as to be of limited value. Thus, a new, revised version of the structure of geography is proposed. This revised version is thought to more closely approximate the approach of geographers. Of particular value in the new version is the specification of the difference between spatial pattern and structure. The general structure of geography presented is comprised of four conceptual domains: 1) spatial data, 2) spatial pattern, 3) spatial structure, and 4) spatial synthesis.

A definition of geography sufficiently general to be acceptable to a majority of geographers might be: Geography is concerned with the spatial organization of phenomena on the earth's surface. This definition, it can be noted, is not focused upon a particular data set but rather on an approach involving the examination of spatial distributions. Edwin Thomas, in work associated with the High School Geography Project, has attempted to order this spatial organizational approach by explicitly stating what he labels a "structure of geography." [7]. This structure (Fig. 1) notes the intellectual paths from the basic building blocks of geographic facts through spatial distributions to regions areal associations, and spatial interaction. Scale is utilized as a variable entity, capable of being changed at any step in the methodological progress by the process of aggregation or subdivision of areal units.

It is believed that Thomas' structure of geography, while useful to a degree, is too highly simplified. The revised structure of geography presented here (Fig. 2) was inspired by Thomas' earlier structure, and is felt to more closely approximate the spatial organizational approach of geography. The following discussion, based on Figure 2, attempts to provide a framework within which much of the geographer's activities can be profitably viewed.

SPATIAL DATA

Initially, it is assumed that there exists a reality which is external to the geographic observer, and that it is the spatial organization of this reality which is of particular interest to geographers. There are two fundamental ways of ordering portions of this reality so that geographic information can be

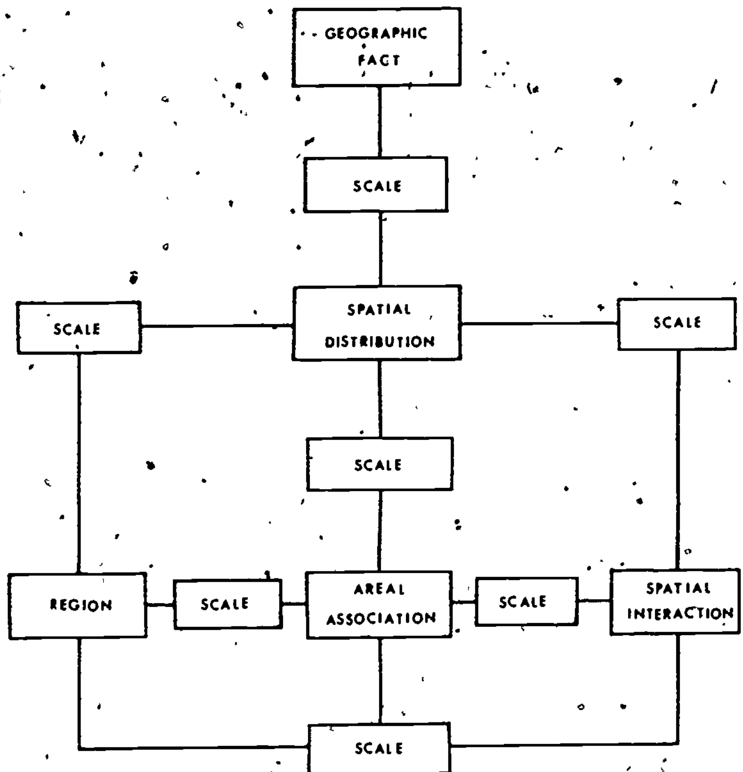

Fig. 1 — A Structure of Geography (from Thomas, 1964).

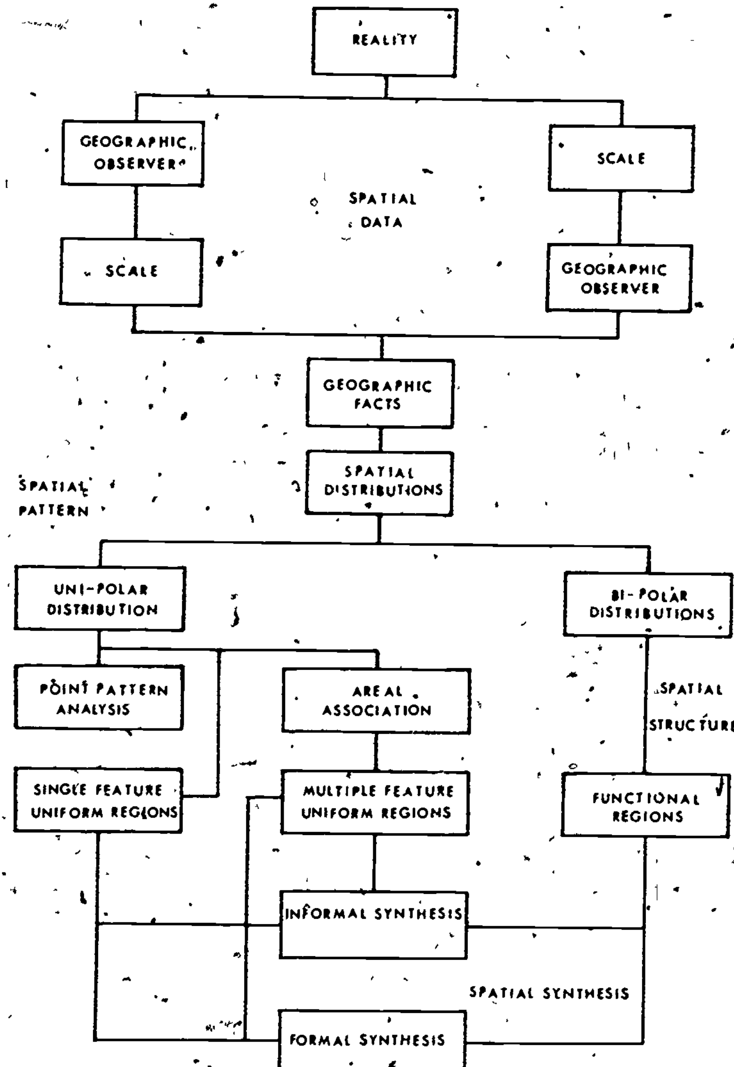

Fig. 2 A Structure of Geography, Revised Version.

assembled. [5:240] In one, the geographic observer scans the reality, focusing on those topical items in which he is interested. In this way, the geographic observer acts as a filter which selects certain abstracts from reality and allows these to pass through while preventing others from passing. For example, an urban geographer interested in the condition of housing in an urban area would allow information about levels of physical deterioration, plumbing facilities, rental levels, etc., to pass through his filter while rejecting information about the condition of retail structures or the average number of automobiles. The geographer is thus selective about the topical items which he wishes to examine, with this selection based on hypotheses suggested by theory. After the topical items of supposed importance are filtered through the observer, they are further passed through a scale filter which assigns items to standaridized areal units. The screen of this scale filter is of course variable from study to study; however, for any single study it is ideally of the same gauge.

The second manner of ordering geographic information is perhaps the more traditional one. It involves the use of the scale filter as the initial filtering device. This is accomplished by setting the scale filter at the desired level, and allowing information about that desired level to pass through. The geographic observer then acts as a secondary filter, selecting those topical items at that particular scale which he feels are worthy of further consideration. This is the general filtering procedure used in regional descriptions. As an example of the results of such a filtering process, consider the recent description of the Colorado Plateau rendered by Durrenberger. [4]. His scale filter was set at "the Colorado Plateau;" and he originally considered a variety of available information about this area. For formal consideration (publication), however, he selected only certain topical items, namely those reflected in his article's subheadings.

These two ways of ordering geographic information are admittedly idealistic when considered separately. In actual empirical research geographers oscillate back and forth between the two. In the above example about urban housing conditions the researcher initially decided upon an urban or metropolitan scale, while for his Colorado Plateau study Durrenberger most likely held certain notions about the type of information in which he was most interested. [6:98-99].

The overall result of the above described filtering procedures is the accumulation of selected topical-areal bits of information which can be called geographic facts. These geographic facts can be defined, following Thomas [7:134] as those "facts which refer to the character of a place or the quality or quantity of some phenomenon which occupies a place at a given time." Once obtained, these geographic facts can be further ordered utilizing the concept of spatial distribution, which is defined as "a set of geographic facts representing the behavior of a particular phenomenon or characteristic of many places. [7:137]."

The spatial distributions or sets of geographic facts that geographers are most concerned with are of two distinctive types, which are here labeled uni-polar and bi-polar. Uni-polar spatial distributions can be thought of as vector descriptors of a set of places. For example, an economic geographer might be interested in the percent of manufacturing employment by county for a particular state, a spatial distribution which could be considered vectorially. (A vector can also describe the location of a set of places, such as for point-pattern analyses.)

Bi-polar spatial distributions represent dyadic flows between a set of areas or nodes, and can be conceived as n by m matrices, where n is the number of origins and m is the number of destination areas. It can thus be seen that these dyadic flows in matrix format represent a type of spatial distribution since they represent the "behavior of a particular phenomenon..." over space [7:137]. A social geographer, for example, might be interested in the origins and destinations of migrants between counties in a state, a set of flows which could be considered in a matrix context. It is also possible to view flows as uni-polar spatial distributions, but only if the total outflow from or in-flow to an area is considered. A vector could be constructed, for example, depicting the total outflow of migrants from each county in a state. However, such a vector would not describe the destination areas of these migrant outflows; for this task a matrix representing the bi-polar spatial distributions of migrants between counties is needed.

SPATIAL PATTERN AND SPATIAL STRUCTURE

A major distinction between uni-polar and bi-polar spatial distributions is that uni-polar distributions serve as input to studies of spatial pattern, while bi-polar distributions serve as input to studies of spatial structure. That is, each of the two types of spatial distributions leads to a different type of regionalization. Uniform regions, contiguous areas homogeneous with respect to selected variables, are based upon uni-polar distributions. Functional regions, comprised of areas having more interaction with one another than with any other areas, are based upon bi-polar distributions. Thus, each of the two general types of regions recognized by geographers is associated with one of two major geographical concepts, spatial pattern or spatial structure.

The framework presented here represents a contribution to geographic methodology for it notes the conceptual difference between spatial pattern and spatial structure, two terms which heretofore have been used somewhat interchangeably. The need for a distinction between the geographical concepts of spatial pattern and spatial structure is evident when it is noted that analyses of uni-polar distributions are focused on the areal units themselves while analyses of bi-polar distributions are concerned with the explicit spatial interaction between areal units. Analytic studies of spatial pattern usually concentrate on hypotheses dealing with distances separating individual areal units, densities, and arrangements such as dispersion or concentration, while similar investigations of spatial structure test hypothetical notions dealing with friction of distance, volume and frequency of flows, and primary linkages between and among the areal units. At least part of the difference between spatial pattern and spatial structure is, then, in the nature of the questions asked and hypotheses tested.

SPATIAL SYNTHESIS

Though considered as separate and distinct concepts, spatial pattern and spatial structure can be linked through the notion of spatial synthesis (see Fig. 2). Harvey [6:129] has recently noted that "The interaction between ...' flows and movement' on the one hand and spatial pattern on the other may well emerge as a focal point for a new kind of geographic synthesis." It is argued here that this spatial synthesis is not new, only a particular operationalization of it is. Two general types of spatial synthesis can be identified: 1) Informal synthesis; and 2) Formal synthesis. The first of these is one which geographers have traditionally used, and involves utilizing spatial structural findings to aid in understanding and explaining spatial pattern, and vice versa. For example, the uni-polar distribution of gasoline service stations in an urban area might be better understood through a consideration of urban traffic flows. The term informal spatial synthesis is used here to indicate reliance upon logical, verbal statements and the imagination of the researcher in the synthesizing procedure.

The second type of spatial synthesis is relatively new to geography, and is labeled formal spatial synthesis due to its reliance on formal statistical and mathematical techniques. (It may have been this type of synthesis to which Harvey alluded.) To date, application of formal spatial synthesis has been limited. Berry's [1; 2:3; 8] general field theory of spatial behavior is perhaps the most publicized, although there are also other examples dealing with this problem. Berry's approach basically involves canonical correlation of an attribute matrix (a set of uni-polar vectors) with a behavior matrix (one of bi-polar flows). As shown by Berry, this canonical correlation approach provides quantitative statements of the relationships between spatial pattern and spatial structure, thus allowing conclusions to be drawn concerning their interdependence.

CONCLUSION

The revised structure of geography discussed here is comprised of four major conceptual domains: 1) spatial data, 2) spatial pattern, 3) spatial structure, and 4) spatial synthesis. The first deals with the collection and ordering of spatial information to obtain geographic facts, a procedure which provides input into one or the other of the second and third domains, spatial pattern and spatial structure. Explanation, if defined broadly as "any satisfactory or reasonable answer to a 'Why' or 'How' question [6; 11]." is explicitly considered in this revised structure and is represented by the fourth and last domain, spatial synthesis. No attempt is made here to incorporate all notions of geographic explanation but rather the purpose is to show the explanatory value of either spatial pattern or spatial structure, given the other. Thus this framework considers a sequence of geographic methodology from observation to explanation.

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POLICY IMPLICATIONS OF THE DISTRIBUTION OF HAMILTON COUNTY, OHIO PARKS USERS

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Abstract: An Analysis of Areal Distribution of Hamilton County Park Users.
The study is concerned with the areal distribution of users of three Hamilton County parks; Sharon Woods, Winton Woods, and Miami-Whitewater Forest.
Three hypotheses were proposed initially. The first hypothesis states that the three parks cater to all of Hamilton County, that the population of the states that park users originate chiefly from the high density areas of the city and towns. The third hypothesis suggests that the parks attract users mainly from the nearby neighborhoods.
During one October Sunday afternoon a sample of automobile license plate numbers were collected from various points of each park, excluding the golf courses. Sample sizes were about N=100 each. Residential location of Hamilton County plate numbers were identified by checking against the listing appearing in the Hamilton County license plate directory. Addresses were noted and thereafter plotted on a county map. Distance was measured from the park to the place of residence of the respective user.
Histograms of user distances showed that distance is a factor determining use. It should be noted that due to residential density differences Sharon Woods and Winton Woods were able to draw more than 50 per-ent of the users from within a five mile radius whereas Miami-Whitewater Forest required a nine mile radius to meet the same percent age.
Numbers of park users were compared to the various township or county subunit populations from whence they originated.
The total number of automobiles (one automobile = one user) per park was divided by the Hamilton County population of 924,018. The resulting figure became a guide point by which the means of the subunits were placed. The subunits consisting of means above the county mean were divided into two groups. The same was done for the group falling below that mean.
The greater numbers of users originate from the subunits with means above that of the county. The remainder of the users originate from subunits below the county mean.
The resulting user pattern are by no means clear, but these conclusions can be drawn with some certainty from the study: (1) the parks being used by all is at best a weak pattern; (2) the parks being used by those from high density areas, especially by inner city residents must be rejected; (3) the parks are mainly used by the neighboring suburban population, thus functioning as large neighborhood parks. This hypothesis is strengthened by the pattern of out of county users.

The study is concerned with the areal distribution of origins of users of three Hamilton County Parks, and the implications this distribution has for the financing of this public service. As a service to the inhabitants of Hamilton County, the Park District receives a three per mile share of the real estate and property tax of the county. In addition, it raises revenue through a \$2.00 annual car sticker or a \$.50 daily user's fee. Several years ago an attempt to raise the tax share of the Park District was defeated by the county voters. At the time many concerned individuals felt that this defeat was caused by lack of publicity for the park issue and poor voter turnout. As a result, the question was put to the ballot only a year later with considerable effort to influence the voting public, only to go down in defeat a second time. This paper is an attempt to identify the users of the parks on the assumption that this may allow some assessment of who ought to bear the costs.

Three hypotheses can be proposed initially. The first states that the parks serve all of Hamilton County equally and that all residents are potential users of one park or another. If true, this hypothesis would justify equal distribution of the costs through taxes. The second hypothesis expects that users originate heavily from the inner city of Cincinnati and other high density areas otherwise poorly served by park facilities. This model could be used to justify park taxes as a welfare measure for the poor and those not served by other readily accessible parks. The third hypothesis considers that the City of Cincinnati is well provided with park space, and expects that park users originate predominantly from suburban towns, many of which are otherwise poorly served by public open spaces. The location of the county parks (Fig. 1) indicates that the third hypothesis would be in accord with user distribution on a gravity model as well.

THE PARKS

The three parks considered are reasonably evenly spaced across the northern half of the county (Fig. 1). In addition, the District operates a small nature preserve and an as yet not developed park in the southwestern part of the county. Each of the three parks contains a golf course and a man-made lake and offers picnicking, fishing, boating and overnight camping facilities.

Clawson [2] has suggested a three-fold classification of recreational parks based on accessibility-distance and attractiveness-size criteria. He sees the smallest parks as neighborhood parks (essentially city parks) with only local drawing power; a second level park as larger with regional drawing power comparable to State Parks; with the largest parks having a national attractiveness for users from a wide region (National and large State Parks.)

The county parks in this classification fall between the first and second size class. In Cincinnati they compete with an unusually large city park (Mt. Airy

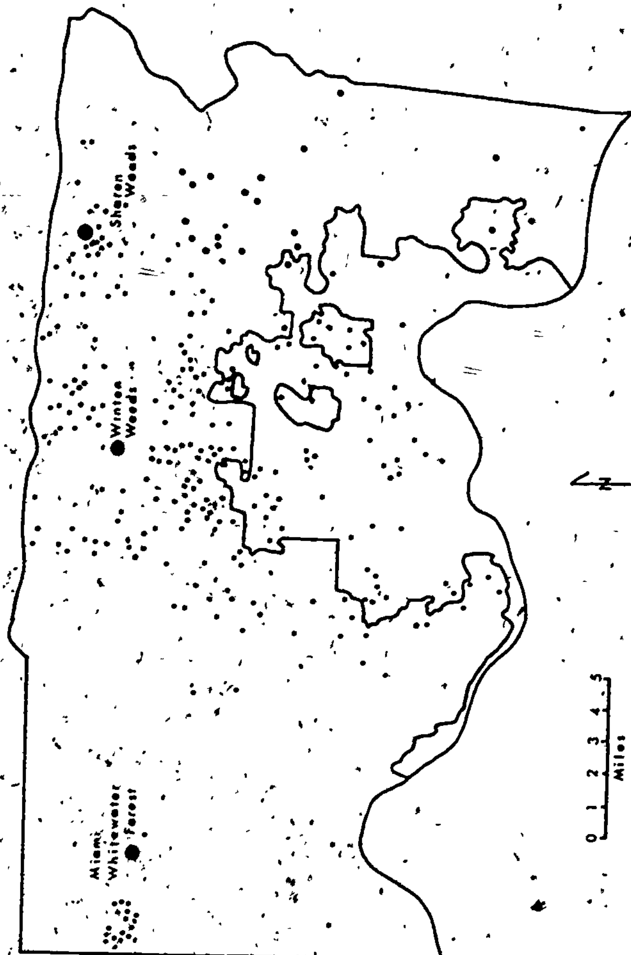


Fig. 1
TOTAL USER DISTRIBUTION

Forest) which is on the same order of acreage, but lacks a lake. Man-made lakes, as Harper [3] has shown, are necessary for recreational areas of regional attractiveness because accesss to water and a shore are perhaps the single most versatile recreational units [4]. It is therefore not unexpected that the nearby competing Ohio State Parks each have a man-made lake as the centers of their attraction. For most Hamilton County users the state parks are 30 to 50 miles distant.

Provision of facilities underlines the intermediate nature of county parks. Golf courses and ball playing fields aim at the day and part-day user, while provision of overnight camp grounds indicate the expectation of visitors from further afield. While lakes and boating are more typical of the state park, heavy user pressure dictates restriction to rental boat facilities in the case of these County Parks, a policy more typical of city park facilities.

THE DATA

The user origin data are represented by three samples of license plate numbers recorded from cars parked in various areas of each park. Golf course parking areas were systematically excluded on the assumption that these represent a special, most likely local and habitual sample of users. The data on two parks, Winton Woods and Miami-Whitewater were acquired simultaneously on a warm Sunday afternoon in early October 1972. The Sharon Woods sample was gathered the following weekend.

The residential location corresponding to the license plate number was identified from a directory [4] for Hamilton County users. These locations are displayed in Figure 1.

EXAMINATION OF THE DATA

Table 1 displays the proportion of users originating in Hamilton County for each park. It is a tribute to the regional drawing power of the parks that thirty to forty per cent of user vehicles in each park originate outside of the county, although some of these may represent recent in-migrants not yet listed in the directory.

TABLE 1
USER ORIGINS

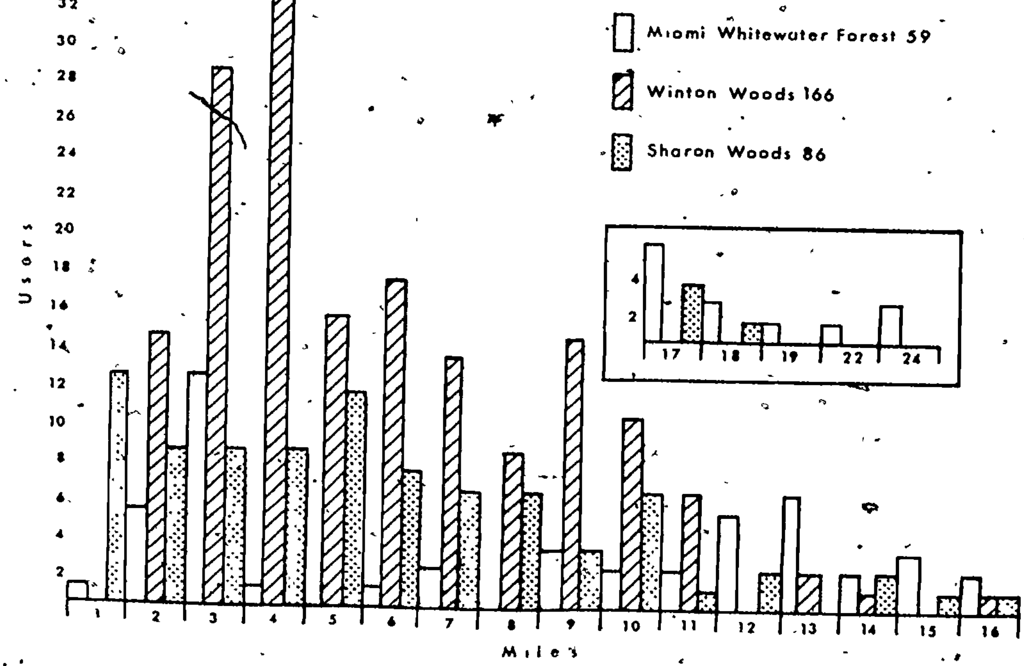
Park	Area in Acres	Hamilton County No.	Hamilton County Percent	Other Ohio No.	Other Ohio Percent	Indiana and Other States No.	Indiana and Other States Percent	Total No.
Miami-Whitewater	1,955	59	52	44	39	10	9	113
Winton Woods	2,045	166	69	74	31	-	-	240
Sharon Woods	740	86	60	49	34	8	6	143

A composite graph for all three parks of motor vehicle frequency by distance to residence in Hamilton County is presented in Figure 2. This frequency histogram shows the distance effect clearly and is in conformity with a gravity model distribution of users. Most users come from near the parks with user frequency decaying rapidly with distance. For the individual parks this relationship differs. While Winton and Sharon Woods draw more than fifty per cent of their users from within a five mile radius, Miami-Whitewater requires a radius of nine miles to meet this percentage. The contrast is instructive because Winton Woods lies in the center of the northern and northeastern expansion of the Cincinnati suburban belt, and Sharon Woods lies on its edge. Miami-Whitewater draws users heavily from the nearby small town of Harrison and its Indiana twin, but is separated from the main urban complex of the county by sparsely occupied topography.

Considerable effort was expended to calculate park users as proportions of the total populations of minor areas of the county (municipalities and townships) and to compare these figures to average users per capita of Hamilton County. The results left the authors dissatisfied because of the small size of the sample, giving a single user from a small municipality a disproportionate effect. Suffice it to indicate that the City of Cincinnati, including the most densely populated area, was underrepresented among park users, while nearby suburban towns provided the heaviest share of users. A careful examination of Figure 1

Fig. 2

USER DISTRIBUTION OF:



combined with a knowledge of the population distribution of Hamilton County will confirm this insight.

CONCLUSIONS AND IMPLICATIONS

Hamilton County parks are not equally accessible to all users in the county, nor do they serve predominantly the inner city or the underprivileged. The distance effect of the gravity model is reaffirmed in that the parks serve mainly the users originating in the surrounding suburban towns and nearby areas outside of the county. In addition the parks exhibit some regional drawing power in competition with nearby state parks.

To the extent that the suburban towns represent middle income families, the levy on all tax payers represents a subsidy to these middle class users, and especially to those suburban towns which have failed to provide park facilities of their own. For those able to pay, the user's fee appears to be a more equitable way of sharing the costs of the parks. In this regard then, the voters appear to have had a clear understanding of their own financial interest in voting down additional taxes for the parks.

A case can be made for requiring higher user's fees from out of county residents. Charging them the same user's fees must be justified on grounds of hospitality and reciprocity rather than equity.

ACKNOWLEDGMENT

The help of David Headley, Michael Hengehold, and Richard Mospens for gathering data and independent evaluations is gratefully acknowledged.

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NEW TOWNS: GREENBELT, MARYLAND THIRTY-FIVE YEARS LATER

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Abstract: Greenbelt is one of three federally planned, developed and financed new towns created by the New Deal. Major features of the Greenbelt Plan are: (1) a girdle of green space encircling the community; (2) residential clustering withing superblocks; (3) traffic separation of autos and pedestrains; and (4) the development of a commercial-institutional-recreational core.

Viability of the plan was evaluated on three bases: (1) unity whereby specialized activities are integrated into a unit; (2) flexibility which accommodates change; and (3) simplicity which promotes flexibility.

The greenbelt is an effective buffer between adjacent areas, but does not separate it from other towns. The economy of the original plan remains; however, personal social interaction has declined. Traffic separation continues, but needs modification. The size and function of the core have increased, although structural deterioration and commercial competition have undermined the viability of some functions. Greenbelt has remained a viable community because the planning process has attempted to maximize the potential of the original plan.

Throughout history man has sought to better his living conditions. This search appears to arise from discontent with the present and anticipation of providing for a better future. A manifestation of this desire is the planned urban community in which man rearranges the landscape to satisfy his needs and aspirations. America has witnessed a number of such communities, including New Harmony, Pullman, Radburn, and Greenbelt. This paper assesses the viability of Greenbelt, Maryland, as a planned community by focusing attention on land use, commercial development, and spatial interaction within the community.

EVALUATION AND METHODS

As man has become more urbanized, he has sought to develop cities with spatial order. Today's plans treat the city as an entity composed of many subsystems. An important measure of a plan's effectiveness is its viability. This aspect of the Greenbelt Plan is evaluated on three bases: (1) unity or comprehensiveness whereby numerous specialized activities are integrated into a unit which is part of an urban system; (2) flexibility which accommodates social, economic and technological changes within an existing or planned framework; and (3) simplicity which promotes flexibility within the original plan and fosters perceptual clarity of the community.

Data were gathered by means of a questionnaire, personal interviews, archival sources, municipal records and housing records. A stratified random sample without replacement based on dwelling construction was used to obtain a target sample of ten percent of the 1668 households. Those not responding after two visits were eliminated from the study. Data were analyzed to find trends and provide qualitative interpretations.

HISTORICAL OVERVIEW

Greenbelt is one of three federally planned, developed and financed new towns created by the New Deal. These towns owe their existence to Rexford Tugwell, a member of President Roosevelt's Brain Trust, who first proposed the new town concept in 1935 [1]. In the same year, Congress passed the Emergency Relief Appropriations Act and the National Industrial Recovery Act [6] which enabled the government to purchase rural land seven miles northeast of Washington, D.C. for the development of Greenbelt [2]. The Green Towns program was then transferred to the Resettlement Administration in the Department of Agriculture. After development, the community was operated as a federal housing cooperative until 1953, when it was sold to the community. It has since operated as a private cooperative. The original community represents a small and declining proportion of the larger city of Greenbelt.

Green Towns evolved from three planning concepts: (1) the garden city as designed by Ebenezer Howard [3] attempting to delineate a comprehensively planned, self-contained balanced new town surrounded by green space; (2) the neighborhood unit plan developed by Clarence A. Perry [5] consisting of a centrally located elementary school, scattered neighborhood parks and playgrounds, shops located on the periphery, and the development of an harmonious residential environment fostered by careful architectural, traffic and service planning; and (3) the Radburn Plan developed by Clarence S. Stein [6] and Henry Wright which focused attention on the superblock intended to decrease the amount of land devoted to streets, separate various types of traffic, provide additional space for neighborhood parks, and promote social interaction.

LAND USE

Greenbelt is situated astride a low, gently sloping crescent-shaped ridge.

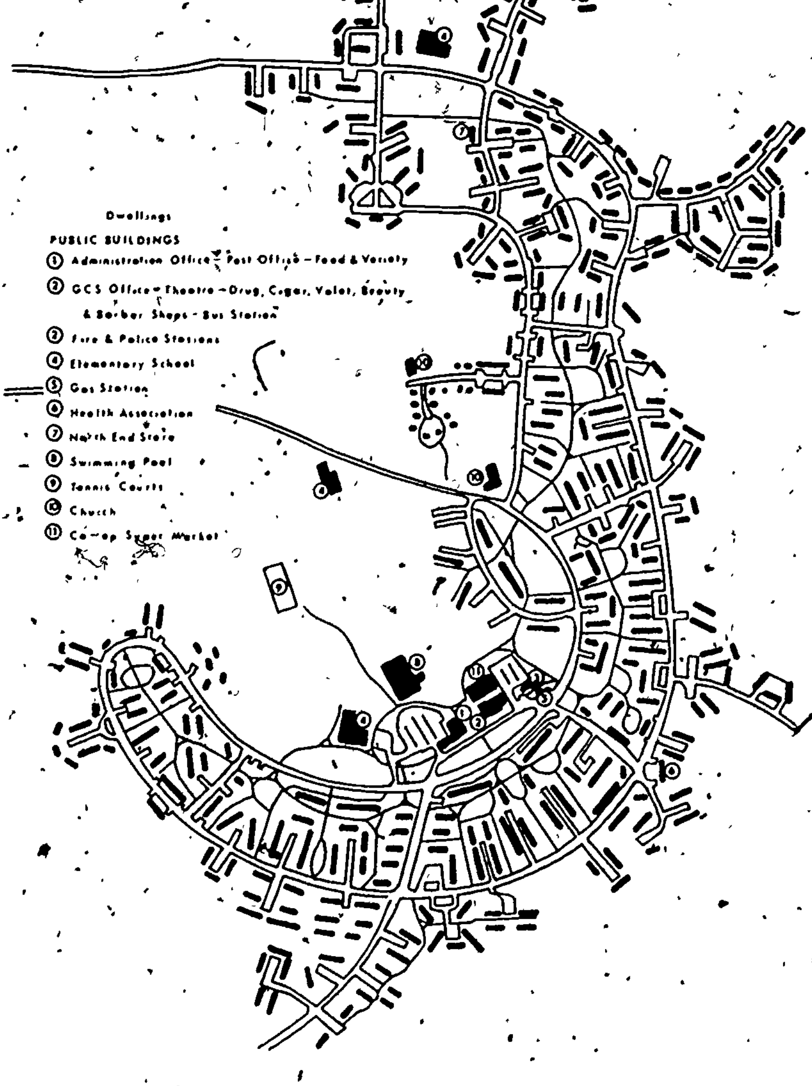
encircled by green space (Fig. 1). The intent of this open space is to establish a non-urban buffer to separate towns, prevent crowding and eliminate urban sprawl. Similarly, it improves the community's identity by setting it off from surrounding areas. It also functions as a watershed to decrease surface run-off and prevent erosion. This in turn increases ground water storage and decreases the potential flood hazard. Because of its proximity to residential areas, this natural greenery provides an opportunity for nature study, walking, cycling and playing. In recent years, the greenbelt has been encroached upon by housing and apartment developments along the southern perimeter. Greenbelt residents have banded together to prevent higher density development, but they have met with little success since the zoning and planning functions were transferred from the municipality to the county. Moreover, the original planned community represents only about twenty percent of the city's 35,000 people [7].

Careful design and layout of drainageways, streets, parks and pathways promotes advantageous residential siting, particularly in the south-central area. Thus, the plan attempts to minimize environmental problems and maximize the potential of the natural landscape. Two separate phases of construction are clearly discernable. Occupancy of the masonry structures located in the well-planned south-central portion of the community took place in 1937, while the wood frame dwellings in the poorly conceived northern and peripheral areas were occupied during 1941 [4].

Along the ridge are superblocks, each five to six times the size of a typical block which contain approximately 120 dwellings. Cluster development of row and town houses was used in combination with courts to concentrate residential development and provide additional open space for parks. Parks with neighborhood playground equipment have been strategically located within interior areas to maximize their use and minimize the traffic hazards. Several playgrounds in the northern areas are situated on corners and represent a safety problem. Economies of scale are gained through residential concentration of utilities, parking, garbage collection, mail delivery, and other services. This scheme also reduces the space needed for streets and utility

Fig. 1

GREENBELT
MARYLAND



rights-of-way.

The southern and central residential areas form a semi-circle around the commercial-institutional-recreational core (Fig. 1). Immediately adjacent to the community's nucleus is a high density apartment area. Zoning has restricted non-residential development to this nuclear core. An open mall, elementary school, library, municipal building, indoor recreational center and major outdoor recreational facilities are located here. A second elementary school has been built on the north side to accommodate the population expansion in that area. The offices of the housing cooperative and an additional service station are situated on the southern periphery, whereas churches are dispersed throughout the community. This core area, although simple in design and function, unifies the community. Moreover, the streets and pathways reflect and reinforce this dominant function of the core area (Fig. 1).

Vehicular separation is accomplished by means of a system of interior pathways connecting residential areas with open spaces and the core area. Several arterial streets provide direct access to the core and distribute local traffic to and from residential-feeder streets.

COMMERCIAL DEVELOPMENT

When Greenbelt was originally developed, it was isolated from other shopping areas by some distance. At this time, the commercial center included a supermarket, theater, dry cleaner, gas station, pharmacy, variety store, shoe repair, barber shop and hair dresser [2]. These functions were designed to meet the needs of the local population and not to secure a more extensive market. With time, additional functions were added, including a cafe, financial institution, recreation center, and smoke shop among others. Today, the center offers fewer goods and more services, especially those housed in a new professional building. Because the shops are few in number and small in size, they offer few specialized goods and compete against one another by employing extensive mixed merchandising techniques. The theater offers the highest order function and appears to be declining. In recent years, the center has lost some of its initial advantage of being isolated by virtue of expanding urbanization, improved access and increased competition. Although the core is simple, its flexibility is limited because of its small self-contained market area, inadequate expansion room and limited access. Moreover, many people expressed negative attitudes toward major commercial expansion.

A service road provides easy one-way access to the front of the mall for persons running errands and early morning truck deliveries. Additionally, there is free parking available to the rear of the mall which also serves the other institutional and recreational functions located nearby (Fig. 1). The mall is arranged to minimize unnecessary traffic and make it convenient for shoppers. The open mall was innovative for its time and continues to foster a small town atmosphere by serving as an informal meeting place for many of the residents.

Originally a low income area, today most Greenbelt families exceed an average annual income of $10,000 [7]. This would seem to provide greater commercial opportunities; however, the automobile with the help of controlled access highways has detracted from most of the increased potential. Accessibility to the core area for Greenbelt residents is generally quite good, except for persons living on the north side, most of whom shop elsewhere. Persons living outside the original development find their access to the center inhibited by the greenbelt, non-residential land uses and limited access highways. These factors perpetuate commercial isolation, increase perceptual clarity and maintain community unity, but severly limit commercial flexibility and growth.

The mall is in need of maintenance, especially the sidewalks which are uneven and the building exteriors which are out-of-date and deteriorating. Litter is a problem. Although not serious, it does give the center a poor image. Although cycling is prohibited, many youngsters continue to ride through the mall or leave their bikes in potentially hazardous places. Thus, viability of the mall is reflected in part by its declining physical appearance.

SPATIAL INTERACTION

The Greenbelt Plan was designed to develop community cohesion by providing efficient internal transportation and promoting personal social interaction. The annular street and pathway networks focus on the community center, while the court arrangement and superblocks promote the physical and social bases for developing neighborhoods.

The street pattern consists of two arterial roads paralleling the ridge and seven connecting cross streets at 600 to 800 foot intervals. (Fig. 1). This system provides flexibility and ease of movement to the commercial-institution-recreational core for residents located in the south-central part of the community. On the north side, distance and more limited access inhibit movement to the nuclear core. Moreover, a number of attenuated cul-de-sacs with multiple inner courts increase parking and traffic congestion. There appears to be unity and flexibility in original south-central development; however, the "newer" northside and peripheral areas are mere appendages to the community. Thus, the initially simple design has been pre-empted by other social and economic considerations.

Initially there was no on-street parking; however, additional parking has been provided by extending the street right-of-ways and trimming lots. This apparent flexibility has had several effects on the community: (1) traffic flow is slower, encumbered and hazardous; (2) street maintenance is more difficult and expensive; (3) sidewalks are needed but additional space is lacking; (4) the principle of traffic separation has been partly discarded; and (5) the once pristene appearance of the community has faded into the past. Flexibility has been maintained at the expense of unity and simplicity.

An extensive system of interior pathways with a number of street underpasses separate pedestrians from automobile traffic (Fig. 1). In the well planned south and central areas, pathways are better designed, more numerous and solidly constructed, while the northern and peripheral areas consist of a few, poorly laid out dirt paths. Today the system is rapidly becoming obsolete for a number of reasons: (1) increased automobile usage; (2) reduced commercial pedestrian traffic; (3) poor sidewalk and hedge maintenance; (4) route circuity; and (5) a decline in interior park use. As a result, the pathways are deteriorating structurally, becoming functionally obsolete and overrun by vegetation. The community is now considering the possibility of improving the pathway system and including it in a more extensive bikeway system. Thus, the original system may be considered flexible without depreciating its simple, unifying function.

In Greenbelt, the houses face the greenspace. The interior arrangement orients persons away from the street by placing the living rooms and patios on the interior side, with bathrooms and kitchens on the street side. This, combined with the physical and social proximity afforded by the dwelling arrangement and courts system, creates a potential bases for social interaction.

The original residents of Greenbelt were screened according to income, religion, and cooperative attitudes. This brought together people who were financially and attitudinally similar, but religiously mixed. Moreover, screening provided a broad base of support for the many neighborhood and community participation programs initiated by the federal government.

The physical design and social programs in the original Greenbelt community provided numerous opportunities for persons to develop a variety of social contacts. With time, many of these programs have been dropped. Similarly, socio-economic changes have discouraged social interaction. The small town atmosphere which once prevailed in the community continues to decline as it is swept up in the growing pace of metropolitanism.

CONCLUSIONS

Greenbelt may be considered viable on the basis of exhibiting varying degrees of unity, simplicity and flexibility. The land use patterns, particularly in the south-central portion of the community, form a well integrated unit. The original plan allowed for considerable flexibility; however, some of the original simplicity has been lost. The greenbelt has proven to be an effective non-urban buffer between towns, and although it does not completely separate it from other towns, it does give the community a sense of perceptual clarity and unity.

The size and function of the core area have increased with time, meeting the minimal needs of the community, although exterior deterioration and commercial competition have undermined the viability of some functions. The commercial core remains simple and unified, reflecting its small "captive" trading area. Flexibility is limited by size and nature of the community and the core area.

Flexibility of the movement systems have been made at the expense of traffic separation and increased safety hazards. Similarly socio-economic changes have reduced social interaction. Thus, the once physically and socially cohesive community has become more complex and less unified. It is readily apparent that the northern and peripheral areas have suffered from poor planning, while the southern and central areas have remained viable. Greenbelt has remained a viable community, although planning has shifted to the county. In the end, it is not whether the plan itself is viable, but rather whether the planning process can maximize the viability of the plan.

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A NETWORK ANALYSIS OF THE ROMAN ROADS OF BRITAIN

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Abstract: The road network built by the Romans in their British province was constructed for strategic, administrative and economic purposes. The purpose varied with the stage of domination reached: as an area became pacified the legions were replaced by the civil administration, which extended and added to the roads to imporve communications and trade.

This paper uses contemporary methods of analysis to describe and compare elements of the Roman road network in Britain. Much of Britain remained under direct military rule, being too barren to support the urban populations of the lowlands. The tribes of these areas were also less sympathetic to Roman rule and were kept under control by a system of forts. Those settlements which did develop in the highlands grew up around the forts.

The difference in development and settlement is reflected in the structure of the road network. The roads in the southeast and those in Wales are compared. The structures of the networks and the connectivity of the individual nodes are contrasted using graph theoretical measures and methods.

The officially approved roads of the Roman Empire were described on the Antonine Itinerary, which detailed the routes across the provinces, with the stages for changes of horse, or lodging, clearly indicated. There are 16 such routes in Britain, forming a highly efficient set of connections that link all the major towns and tribal capitals. This route system is analyzed to show both its importance as a major component of the whole road network and its functionally sound makeup.

This paper is an approach to a better understanding of contemporary road networks by means of a comparison with former systems and also indicates how historical geography may be furthered by the use of such theoretical methods as network analysis.

This paper is a study of the network of Roman roads constructed in the province of Britain from the time of its conquest by Aulus Plautius in A.D. 43 until the middle of the third century. The frequent collapse of central authority and increasing danger of Saxon raids after about A.D. 250 make it unlikely that much road construction was undertaken after this date.

The use of quantitative techniques in historical studies is relatively new: Pitts [19] used network analysis in a study of the real accessibility of Moscow on the Russian river routes, and Hodder [10] has examined the spacing of Roman settlements in Britain using central place theory. The use of such quantitative methods is important for two reasons. Firstly, the methods themselves can be tested under conditions differing from those of the present or the recent past. Such testing will reveal the effects of exogenous variables on the methods and models used, enabling the removal of bias. Secondly, the use of more rigorous methods will permit more information to be extracted from the data examined. This will permit the testing of assumptions and relationships which at present go unquestioned.

For example, Pitts' study shows that several other towns in Russia were more accessible than Moscow, and yet, did not achieve the same importance, indicating that accessibility was not the only or the major factor at work.

STUDY PURPOSE

The present study examines the Roman roads of Britain with a view to showing that within the network, which contains six thousand or more miles of road [13], components can be distinguished whose properties reflect the different purposes for which they were built. Garrison and Marble [8] suggest that seven groups of factors influence the final form of a road network:

1. General economic development.
2. The natural environment.
3. The location of economic activities.
4. Available technology and its cost structure.
5. The interests and preferences of the decision makers.
6. Military and political influences.
7. The historical pattern of development.

These factors are all of importance in the development of roads in Britain, but it must be noted that the Romans entered a land in which the level of economic development was very low, economic activities were mostly ubiquitous rather than sporadic, and the roads were for the most part unengineered trackways. The road builders had a <u>tabula rasa</u> on which to develop their roads, with no previous system to follow and incorporate, a feat possible to no subsequent road builders in Britain.

As the various factors influencing the form of the network changed, the settlement pattern changed also. The settlements were also part of the administrative structure, and their relative importance in the system may be indicated by their accessibility on the road network.

The extent to which the network components differ from each other in terms of connectivity, redundancy and the relationships of the settlements they link will be examined, as will be the indicated relative importance of the towns in terms of their accessibility.

THE ROMAN ROAD SYSTEM

The Purpose of Roman Roads

The Roman roads in Britain are described as having been "laid out as a carefully planned system linking the centres of occupation, both military and civil, to every neighbouring centre, so as to ensure the most rapid communication possible" [14:11]. It is significant that the major builder of roads was the army; the military importance of good communications was fully realized by the Romans.

The first roads constructed in Britain and northwest Europe were those built in response to the military requirements of various campaigns of conquest. After the native populations had been pacified to some extent the legions could move on, leaving the roads to the civil authorities. The road network was then altered to suit changing needs, with some roads falling into disuse and others being built or extended.

The Development of the Roads in Britain

When Plautius landed at Rutupiae in A.D. 43 with four legions (see Fig. 1), the apparent objective was the conquest of the southeast lowlands of Britain. This area was the richest, most productive and most civilized part of the island. The dominant inhabitants were of the same tribal group, as those of the new Roman province of Gaul, and had annoyed Rome by aiding their relations in their resistance. The legions needed to put a stop to this interference were to be based in Britain, both to get them out of mainland Europe, where they would disturb the balance of power, and to make sure that the extra troops would be paid for out of the revenues of a new province.

The invasion was carried out by a tripartite advance [4:89-127], after the preliminary securing of a beach-head. The II Augusta, led by Vespasian, took in the south and Southwest as far as Isca Dumnoniorum. The northwest was secured by the XIV Gemina: starting from the Thames, near the site of Londinium, the line of advance passed through the site of Verulamium into the territory of the Catuvellauni and on to the area around Venonae. The IX Hispania advanced from Camulodunum, which had been captured by that legion, and the XX Valeria

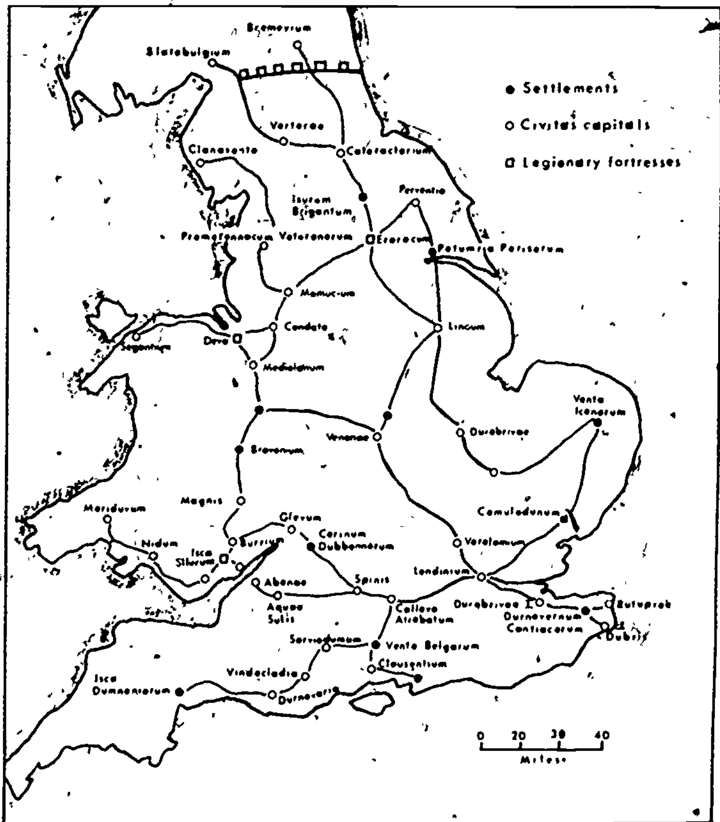

Fig.1 — Routes of the Antonine Itinerary

Victrix, which remained in camp there to control the main Belgic settlement. The IX Hispania moved north to Lindum, where a legionary fortress (castrum) was built in the territory of the Coritani, controlling a future line of advance.

These initial advances of the legions gave vital structure to the road system of Roman Britain. It is likely that construction of the major trunk routes proceeded as the legions advanced [1:37; 13:382]. Four routes radiated from the vicinity of Londinium, leading to the later pre-eminence of the city in the affairs of the province [20:61]. These four routes may well represent the lines of advance of the four legions, with the route from Londinium to Glevum representing the later advance of the XX to build a castrum for the consolidation of the southwest and the containment of the Silures and Ordovices.

The conquest of lowland Britain was rapid and resulted in the acquisition of a new province for Rome. A deep frontier zone was established along a line from the Humber to the Severn. It is widely accepted that the well marked route running from Isca Dumnoniorum to Lindum was the lateral communication line behind this frontier (Figs. 1 and 2). The fact that this route was not of very great importance in the later affairs of the province would seem to support its having been built for a specific and transitory purpose [1:41; 4:118; 20:38].

The conquered area developed rapidly; by A.D. 49 the lead mines of Mendip were exporting [20:56], and in general trade was proceeding well. The towns too were growing fast; in A.D. 61 when the Iceni revolted they found and burned the flourishing towns at Londinium, Verulamium and Camulodunum.

The development of the lowlands led to the rapid development of the road network to serve the new trade and the flow of taxes. However, the very prosperity of the area led to the need for a further advance.

The Romans, as with subsequent occupiers of lowland Britain, found that in order to control their possessions they had first to control the highland Britons. Aided by the rugged terrain, the highland tribes, especially the Ordovices, Silures and Brigantes, gave the Romans a far more difficult task than those of the lowlands. The Romans decided to build a system of roads through the hills with garrisons at strategic points to split up the tribal areas and provide a

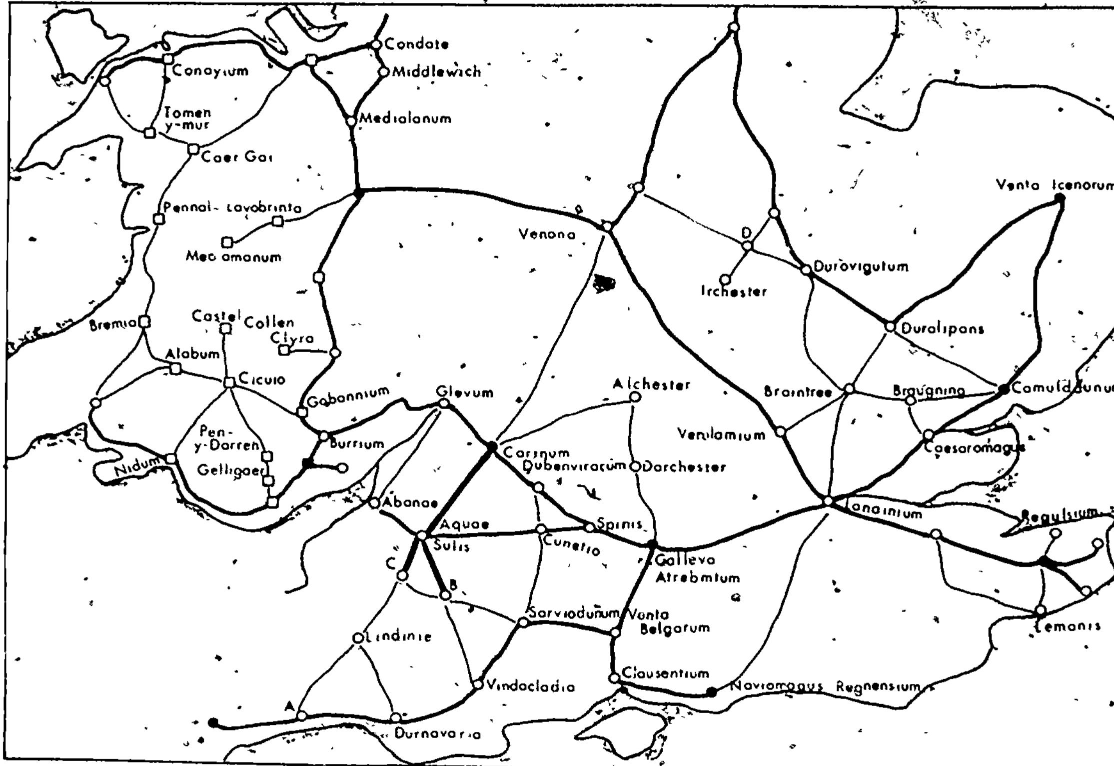

Fig. 2 — Routes of Wales and Lowland Britain

series of bases in case punitive action should become necessary.

Under the second govenor, Ostorius Scapula, and the third, Suetonius Paulinus, a series of attacks were made on the Welsh tribes. Legionary fortresses were established at Deva and Isca Silurum, which remained occupied until the final withdrawal of the legions.

The Brigantes, the largest and most troublesome tribe, were the subject of many expeditionary forces and many roads were built through their territory in attempts to subdue them. The garrisons in these areas were a drain on the resources of the province, although minerals extracted from the Pennines helped restore the balance. The other economic importance of the area was its supply of sheep and cattle. Despite the small degree to which the legionary diet depended on meat, leather was used in large amounts, as was wool.

A new castrum was built at Eboracum by the IX legion. The advance from this base brought the Scottish Highlands into the empire. The Antonine wall, in the lowlands, marks the real northern limit of Rome's power; but throughout most of the occupation the practical limit of the empire was Hadrian's wall, beyond which there is little evidence of permanent settlement.

The Towns and Administration

The towns of Roman Britain were largely the result of the Roman administration, sited along the roads representing the advances of the legions. The tribal territories were made into civitas or administrative cantons, and the most important settlement within the civitas was designated the caput. These settlements were the major towns of most of the province and were in many cases the market centres for the tribes [10].

There were four other types of settlement in Roman Britain. The municipium was the most important and the rarest; only Verulamium is believed to have had this status. The municipium was self-governing and had many privileges. Slightly lower in status was the colonia, a form of settlement set up for retired legionaries, who were supposed to set an example of loyalty and industry to the local population and provide a nucleus of trained men in an emergency.

The castrum, although it was not really a settlement in the same way as the civil towns, was usually a permanent thing, and over time, quite large civilian settlements grew up around the fortresses. The legionary forts were more temporary, but around these too settlements grew up. The legionary forts usually emptied when the troops moved on, but sometimes a settlement would remain and grow. Such towns, together with others too small to obtain any other status, were the vici, the lowest level of the Romano-British urban hierarchy.

Londinium, despite its uncertain official status, was clearly the provincial capital in fact, if not in name. As early as A.D. 60, it was the administrative centre, and later became the headquarters of the imperial revenue service for Britain and legionary general headquarters. Londinium was also the major commercial centre and the site of Britain's chief mint.

The Components of the Road Network

As has been indicated in previous sections, the Romans were faced with a different problem in the highland areas of Britain, north and west of the Plautian limes, than in the lowlands. The population was pastoral rather than agricultural, was less organized, more warlike and had had little or no interest in civilization before the Roman conquest. The valley bottoms were forested and the hilltops either rocky or peat-covered, making the construction of a road network more difficult than in the more open areas to the south.

The highland areas were subject to military rule for most of the Roman period, and almost all of the roads were built for the conquest or policing of the highland tribes. As time progressed and the tribes became less belligerent, trade increased but seems never to have become as well developed as in the south-east.

The roads of Wales have been chosen as an example of a 'military' network; Wales was occupied by the Romans rather than conquered, and the fortresses and forts remained garrisoned almost continously. This is in contrast to the military areas of northern Britain where, as a result of changing policy, the forts were abandoned and reoccupied several times, making it difficult to decide which roads and centres were in use at any given time.

The lowland area dealt with here, is that area bounded to the north and west by the supposed line of the Plautian frontier. The roads are only a selection of those that existed; the major settlements are included and the main links between them. Duplicate routes between centres have been excluded [6]. Cross-roads with no identifiable settlements have been given identifying letters [6].

ANTONINE ITINERARY

As already mentioned Fig. 1 shows the routes of the Antonine Itinerary in Britain. The itinerary is a road-book for the entire empire, giving names of towns and the distances between them, compiled for travelling officials. The administration of the empire depended on the rapid interchange of dispatches, and to make this possible, the cursus publius was invented by the Emperor Augustus. Relays of horses were stationed every 6-16 miles along the main roads, at mutationes, while every 20-30 miles a mansio was provided for over-night rest. The roads provided with such services include all those listed on the Antonine Itinerary, although other roads are known to have had them. The 15 routes listed in the itinerary for Britain pass through all the major settlements of the province, although the most direct routes are often not chosen. "The explanation probably lies in the fact that these routes take in important towns where officials of the third century would be more likely to have business. The direct routes cross less thickly inhabited country." [13;390-391].

The roads of the Antonine itinerary may be thought of as analogous to modern interstates or motorways; they are the major routes on which time or trouble can be minimised at the price of increasing the distance travelled.

This network is composed of routes of the Antonine itinerary and other, more direct, local links. The routes are shown in Fig. 2, and in the form of a linkage graph in Fig. 3. The graph seems to be fairly well connected; the center of the highest order is Londinium, with six routes radiating from it. There are four fifth order centres:

1) Durnovaria Cantiacorum, the caput of the Cantii and a centre for routes to the four main channel ports.

2) Braughing, a fairly small settlement whose centrality is possibly due to a small fort built during the early advance of the legions.

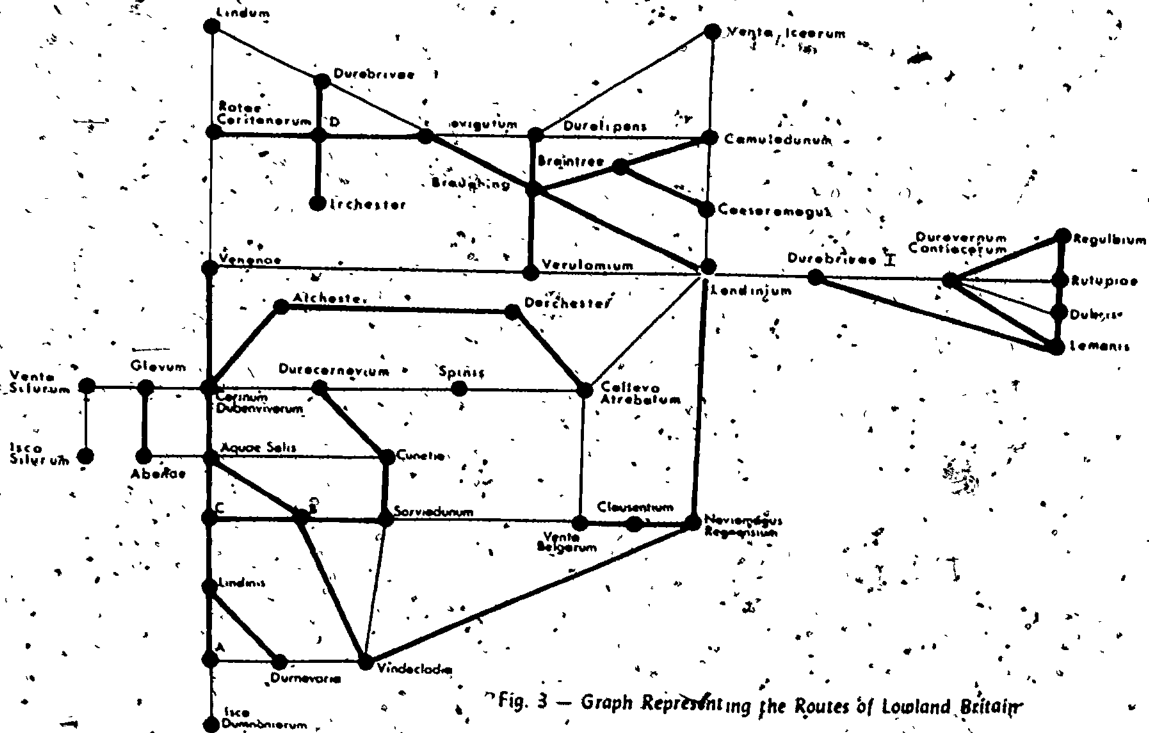

Fig. 3 — Graph Representing the Routes of Lowland Britain

3) Corinum Dobbunnorum, the caput of the Dobunni at the junction of the major southwest-northeast route and the Antonine route to Wales.

4) Aquae Sulis, the major British spa town, lying just to the north of the mendip mining area.

Most of the settlements away from the Antonine roads are military in origin, and even the civilian settlements are fortified, a rare thing in Roman Britain before the third century. Segontium was a mining centre and Moridunum seems to have been a pre-Roman hill fortress. Both places may well have been the equivalent of civitas capitals for the local tribes, who may not have been as civilized as the Silures.

Cicuio and Deva are fourth order settlements, and there are thirteen third order, nine second and five first order settlements. In general, the network in Wales is more uniform than that of lowland Britain, with third order centres predominating. There are several roads whose presence is only suspected; if these are included in the graph then the number of first and second order centres drops, a barrier network is ineffect created [9]. Such a network is ideally suited to the purpose of splitting and controlling an area.

The Antonine roads are not a subset of the whole road network, however, they were important as the framework of the whole system and as an indicator of the routes, which the Roman administration thought most important. The Antonine itinerary may be considered as the practical second or third century solution to a routing problem, in which the main settlements of Britain were to be efficiently connected with each other and to the rest of the empire.

Fifty of the more than 150 centres named in the itinera have been included in this analysis. These have been identified as having been settlements of some importance, rather than stages on the cursus publius.

Londinium, Eboracum and Lindum are fourth order nodes, Londinium because of its situation at the meeting of routes to the channel. Eboracum was one of the three castra, near which was a flourishing colonia. Lindum was also a colonia, and was for a short time a castrum and a frontier settlement.

Thirteen settlements are third order, four of them civitas capitals. Mamucium and Cataractonium are large fort-vicus settlements, while Venonae is one of the smallest settlements, but occupies a vital location at the junction of two important routes.

THE NETWORK ANALYSIS

Using graphs abstracted from the maps (Figs. 3 and 4), connectivity matrices were prepared for each network. These matrices (see [12] and [15]) were submitted to a network analysis program. The program calculates the diameter of the network and raises the connectivity matrix to this power. During this operation, the shortest path distances between the center (nodes) are calculated. The rows of the powered connectivity matrix and the shortest path matrix are summed to give what Pitts [19] calls the gross and nett connectivities of the centres. These values, together with the sum of the shortest paths and the average shortest path lengths, are also printed. The final output from the programme consists of the S and I ratios for the network [11], calculated from the shortest path matrix.

Before the connectivity values for the individual centres are considered a few simpler measures for the networks are worthy of mention. First, the gamma values for the networks were calculated and expressed as a percentage of the connectivity of a completely connected network:

1)	Lowland Britain	6.87%
2)	Wales	8.62%
3)	The Antonine roads	4.24%

Next, the alpha values were calculated; this value expresses the amount of redundancy in the network as a percentage of that of a completely connected network:

1)	Lowland Britain	2.436%
2)	Wales	1.851%
3)	The Antonine roads	0.443%

From these two values, it may be seen that the Welsh network is better connected and more efficient than that of lowland Britain. The extent to which this is due to the different numbers of nodes is uncertain, however, the diameters, (or longest shortest path), are the same, nine. That of the Antonine road network is fifteen.

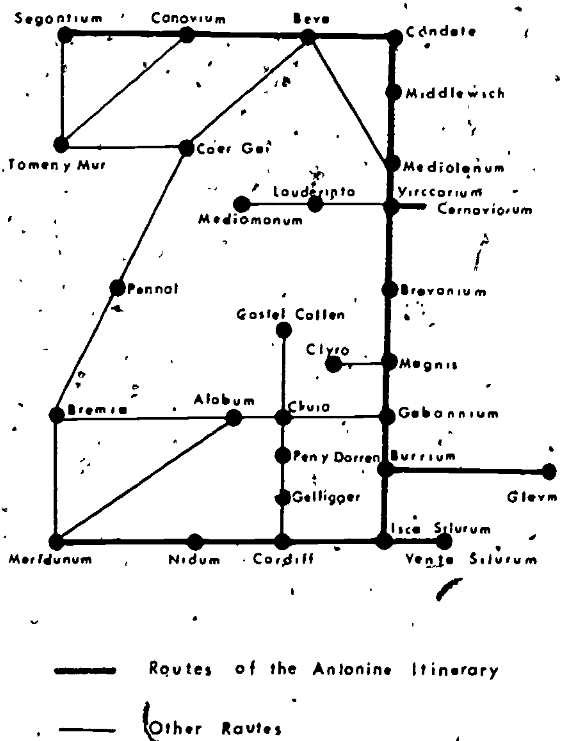

Fig. 4 — Graph Representing the Routes of Wales

The relative sizes of the redundancy ratios are repeated in the mu values (Also known as the first cyclomatic, or Betti number), which are the numbers of links in excess of those needed to connect all the nodes of the network. There are twenty-two such links in lowland Britain, five in the Antonine network and seven in the Welsh.

These ratios and index numbers are of some use in comparing the networks, but other measures, which involve the linkage of the entire network, are more useful. These measures describe the size and the connectedness of a network, enabling comparisons to be made. Two such measures, the dispersion (the summed shortest path lengths) and the mean path lengths, are given below for the three networks:

1)	Lowland Britain	7,918	4.1
2)	Wales	3,557	4.2
3)	The Antonine roads	15,341	6.1

The dispersion indicates the connectedness and the size of the network, increasing with the number of nodes and decreasing with the number of links. The dispersion of the southeast network is greater than that of the Welsh network because of the greater number of nodes, despite the greater number of links.

The gross and nett connectivities of the nodes of each network are given in Tables 1 to 3. The order of each node is also given.

The gross connectivity of the ith. node is the sum of the ith. row of the powered connectivity matrix [19]; the row sum gives the number of trips of length that can be made from the ith node to all other nodes (where n is the diameter of the network). This value indicates, in some way, the degree of centrality of the node. In other words, the larger the number of possible journeys, the greater the centrality. Within the same number of steps, (n) more of the network can be covered from a well connected node.

The gross connectivity value contains a great deal of duplication; this may be excluded by using the nett connectivity, which measures the centrality using the shortest path lengths. The nett connectivity of the ith node is the sum of the ith row of the shortest path matrix, and shows the minimum number of steps needed to reach all the other nodes. In a sense, the distance being

Table 1:

Ranked Connectivity of Welsh Settlements

Name	Nett	Gross	Order
Gobannium	1	15	3
Cicurio	2	10	4
Magnis	3	16	3
Alabum	4	9	3
Bremia	5	10	3
Bravonium	6	17	2
Pennal	7	7	2
Viroconium Cornoviorum	8	7	3
Caer Gai	10	4	3
Moridunum	10	13	3
Mediolanum	11	1	3
Deva	13	2	4
Burrium	13	18	3
Pen-y-darren	14	21	2
Cardiff	15	20	3
Nidum	17	19	2
Isca Silurum	17	23	3
Castel Collen	18	25	1
Clyro	19	26	1
Tomen-y-mur	20	5	3
Lavobrinta	21	22	2
Gelligaer	22	24	2
Canovium	23	3	3
Middlewich	24	6	2
Condate	25	8	2
Glevum Colonia	26	27	1
Segontium	27	12	2
Venta Silurum	28	28	1
Mediomanum	29	29	1

Table 2

Routes of the Antonine Itinerary

Ranked Connectivity

Name	Nett	Gross	Order
Londinium	4	19	4
Verulamium	2	20	2
Colonia Camulodunum	16	29	2
Glevum Colonia	11	25	2
Lindum Colonia	14	9	4
Isca Silurum	17	14	3
Deva	26	3	3
Eboracum.	29	4	4
Isca Dumnoniorum	49	50	1
Durnovaria	46	48	2
Venta Belgarum	24	30	3
Noviomagus Regensum	43	47	1
Calleva Atrebatum	7	23	3
Corinum Dobbunnorm	13	31	2
Venta Silurum	32	27	1
Durnovaria Cantiacorum	33	36	3
Venta Icenorum	24	34	2
Ratae Coritanorum	6	18	2
Viroconium Cornoviorum	4	7	3
Petuaria Parisorum	21	16	2
Isurium Brigantum	32	21	2
Cataractonium	42	28	3
Bremenium	47	41	1
Blatobulgium	50	49	1
Luguvalium	48	44	2
Clanoventa	44	35	1
Bremetonnacum Veteranorum	37	22	2
Mamucium	27	8	3
Mediolanum	10	2	3
Segontium	32	10	1
Moridunum	21	11	1
Nidum	15	5	2
Magnis	5	6	2
Bravonium	9	15	2
Durobrivae II	25	24	2
Durolipons	29	33	2
Abone	38	43	1
Aquae Sulis	30	37	2
Vindocladia	41	42	2
Sorviodunum	34	38	2
Clausentium	35	39	2
Rutupiae	40	45	1
Dubris	40	45	1
Durobrivae I	19	32	2
Derventio	21	16	2
Verterae	45	40	2
Venonae	1	12	3
Condate	18	1	3
Burrium	8	13	3
Spinis	12	26	3

Table 3

Routes of Lowland Britain

Name	Ranked Connectivity Nett	Gross	Order
Londinium	1	1	6
Verulamium	2	5	3
Glevum Colonia	26	31	3
Colonia Camulodunum	28	18	4
Lindum Colonia	35	38	2
Isca Silurum	44	44	1
Isca Dumnoniorum	43	43	1
Durnovaria	29	30	3
Venta Belgarum	14	23	3
Calleva Atrebatum	4	8	4
Noviomagus Regensum	6	16	3
Durovernum Cantiacorum	30	17	5
Venta Icenorum	39	40	1
Ratae Coritanorum	21	33	3
Corinum Dobbunnorum	7	9	5
Venta Silurum	37	42	2
Durocornovium	16	20	3
Spinis	9	19	3
Venonae	6	22	3
Durobrivae II	34	27	3
Durovigutum	20	11	4
Durolipons	22	13	3
Braughing	4	2	5
Braintree	24	14	3
Caesaromagus	11	12	3
Durobrivae I	10	15	3
Regulbium	42	37	2
Rutupiae	41	28	3
Dubris	41	26	3
Lemanis	31	24	3
Clausentium	23	32	2
Vindocladia	8	10	2
"A"	36	38	3
Lindinis	34	34	3
"B"	14	5	4
"C"	25	21	3
Sorviodunum	18	7	4
Aquae Sulis	12	3	5
Abonae	32	29	1
Cunetio	15	6	4
Dorchester	17	35	2
Alchester	19	36	2
"D"	27	25	4
Irchester	38	41	1

measured is the 'useful' distance of the node from the rest of the network, rather than the total number of routes possible.

The difference in these two types of measure can be seen by the different rankings of the nodes on the two types of connectivity.

Lowland Britain

Londinium dominates this network, having the highest nett and gross connectivity. The nett connectivity seems to be measuring centrality within the network; all but one of the ten highest ranking nodes are on the major routes out of Londinium and are linked. The gross connectivity appears to be measuring some sort of accessibility; in general, the highest ranking nodes are those of the highest order, and are not linked to each other. The lowest ranking nodes are peripheral, except for Dorchester, Irchester and Alchester, which are near the centre but are not well connected.

Wales

This network has no strong central node. Gobbanium has the highest nett centrality and Mediolanum the highest gross centrality. The highest ranking nodes lie on the routes out of these two nodes, the nett connectivity is highest in the south and the gross in the north, meeting in the east and west. As might be expected, the lowest ranking nodes are found in the centre and at the periphery.

The Antonine Itinerary

As with the previous network, the Antonine network has no central node, and by contrast to the network in the southeast, Londinium does not rank highest on either measure. Venonae has the highest nett connectivity, and all ten nodes ranking most highly on this measure are linked. Condate ranks highest on gross connectivity, with the ten highest ranking nodes forming a group around, with three separate nodes. For both measures, the ten lowest ranking nodes are at the periphery of the network.

CONCLUSIONS

The present study has shown that the Roman roads in Wales and southwest Britain differ in several respects. The Welsh network is better connected, less redundant, and the average order of its nodes is less. The lowland network has more nodes, yet its diameter is the same, thus indicating, that in one way, its nodes are closer than those of Wales, although the dispersion is greater, showing that the nodes are less well connected than those of Wales in another way. The average path length is the same, but the standard deviation is greater in Wales.

These differences tend to favor the suggestion that, because of the different purposes for which they were built, the networks are different in their final form. A more detailed analysis, cast in a more formal manner, and employing a great deal more historical and archaeological data, will be needed before any firm conclusions can be reached.

This analysis has also shown that, despite the stress put on Londinium as a major centre of communications, [13:103-108;20:61], the city does not appear to have been the most important on the Antonine network. However, the central position of Londinium on the network of lowland roads shows that the choice of routes is of great importance in the apparent status of a centre. In any future study, the roads chosen as part of the network to be analyzed must be chosen very carefully on the basis of their probable importance to trade and travel within the province.

The analysis of the Antonine network has shown its efficiency as a means of connecting the major settlements of the province. The lack of a central node may indicate a balance achieved within a network intended to connect a number of settlements, the presence of one settlement with a very high connectivity will tend to decrease the overall efficiency of the network. This lessening of efficiency may in some cases be outweighed by the advantages gained by the central city (shown for example in Central Place Theory).

This study has attempted to show how network analysis can be applied to the examination of historical networks and how the results of such applications can be useful. The results support the idea that at least two separate subsystems can be distinguished in the network of Roman roads in Britain, and that the structure of these subsystems, and that of the Antonine itinerary, can be profitably examined by these means.

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