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THE ENVIRONMENTAL EFFECTS AND SPATIAL CHARACTERISTICS
OF PROMISCUOUS SOLID WASTE DISPOSAL SITES.

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THE ENVIRONMENTAL EFFECTS AND SPATIAL CHARACTERISTICS

OF PROMISCUOUS SOLID WASTE DISPOSAL SITES

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGEMENTS

Many individuals aided in the completion of this study. Although it is impossible to here cite each, a particular note of graditude is extended to the Solid Waste Management officials of the State of Oklahoma and to the many individuals in Cleveland and McC ain Counties, Oklahoma, who gave of their time and provided materials for the research.

Appreciation is expressed to each member of the Dissertation Committee for his aid and support in the project. The writer wishes to personally thank Professors James M. Goodman, Nelson R. Nunnally, Marvin W. Baker, Jr., Gary L. Thompson, Steven M. Sutherland, Joseph B. Schiel and John W. Morris. A very special note of appreciation is extended to Professor James M. Goodman, the Committee Chairman, for his unwaivering support throughout this project and the graduate career of the author. Also, personal thanks is offered to Professor Nelson R. Nunnally who continually gave of his time and provided encouragement and able council in the project.

Finally, the author wishes to warmly thank his family; his mother, Mrs. Ola Mae Gunter, and his wife, Eva. To Eva this study is addressed.

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THE ENVIRONMENTAL EFFECTS AND SPATIAL CHARACTERISTICS OF PROMISCUOUS SOLID WASTE DISPOSAL SITES

CHAPTER 1

INTRODUCTION TO THE PROBLEM

Solid waste was the last form of pollution to be considered as a serious threat to environment (Hines, 1973, p. 294). Since the mid-1960's, however, great strides have been made in harnessing the pollution potential of waste. This research is concerned with the illegal disposal of solid wastes in rural environments. This practice, termed "promiscuous" dumping, has received only scant attention in contemporary waste management research, but has the potential to degrade our air, land and water resources.

Solid waste takes many forms. It includes, but is not limited to, domestic garbage, commercial refuse of a variety of types, industrial and agricultural residues, incinerator ashes, brush clippings, street and alley sweepings and other refuse items (Oklahoma State Department of Health, 1970, p. 1). It is useless, unwanted or discarded material with insufficient liquid content to be free flowing. The amount of solid-form waste produced by our society staggers the imagination. The results of a 1968 national survey pointed out that over 360 million tons of solid wastes were being generated each year in the United States (Vaughan, 1968, p. 48). Certainly much of this waste is generated in the manufacturing regions, but in total it amounts to slightly more than 10 pounds per person per day. To this figure must be added a per annum increase in solid waste of approximately 4-6 percent (Vaughan), 1968, p. 47).

In the past, our attitudes toward solid waste and our methods of disposal were almost void of ecological consideration. It was reported in the 1968 National Survey of Community Solid Waste Practices that approximately 90 percent of the waste collected in the United States each year was being disposed of in some 12,000 publicly and privately operated land disposal sites (Hickman, 1968, p. 44). At the time of the 1968 survey only 6 percent of these disposal sites were considered sanitary operations (Hickman, 1968, p. 44). The remainder were nothing more than open burning dumps, characterized by conditions conducive to air and water pollution and aesthetic blight.

In 1965 the first broad solid waste legislation was passed: the Solid Waste Disposal Act (Solid Waste Disposal Act, 1966). Under the funding provisions of sections 206 and 207 of this act, many states have established new policies concerning the disposal of solid wastes (Hickman, 1971, p. 7). Some have passed state level solid waste legislation and set forth more stringent standards of waste disposal. State "plans" have been developed in many states to specify guidelines and serve as master plans for future waste management (Hickman, 1971, p. 7). Across the nation public and private organizations are conducting research into new and improved methods of waste handling.

Unfortunately, not all solid waste generated by society is disposed of at authorized disposal sites. Some refuse is simply dumped into the rural environment -- along county roads or in erosion gullies on privately owned land. This illegal disposal practice is termed "promiscuous" dumping; the waste accumulations themselves are referred to as promiscuous dumps (Klee, 1968, p. 27).

The term promiscuous dump is widely used and accepted in the field of waste management to designate an unauthorized deposit of solid waste. Other terms commonly used in reference to this phenomenon include roadside dumps, random dumps, unauthorized dumps, indiscriminant dumps, wildcat dumps and indiscriminate random dumps. An effort was made through literature review and discussions with waste management officials to determine the origin of these terms, but very little data were available on the subject. The earliest use of the term found by this author was by Salvatore (1964, p. 545) in a discussion of solid waste management practices in New York state. The terms are, nevertheless, frequently found in the solid waste and sanitary engineering literature.

For present purposes, a promiscuous dump is defined as "an unauthorized deposit or accumulation of solid waste." A more specific definition is necessary, however, as all unauthorized disposal sites are not necessarily considered as promiscuous dumps. Many municipal dumps in the United States are unauthorized in the sense that they do not conform to state waste disposal criteria. Albert J. Klee (1968, p. 27) made the distinction between the unsanitary municipal dump and the promiscuous dump by regarding the latter as "unauthorized dumps at the roadside or in public or private areas on which dumping occurs on an irregular or infrequent basis."

The specific definition of "promiscuous dump" as it is considered in this study, then, comes more from the connotations of the term than from established definition. The implications are that the promiscuous dump is a small, seemingly random accumulation of solid waste. This dump type is located in the rural areas, usually in borrow ditches at the road side, erosion gullies, or similar depressions. Departing from Klee's statement, this dump <u>may</u> be regularly used, but it is <u>not</u> the established municipal dumpsite of a town or community.

Indiscriminant waste disposal is a potential threat to physical health and environmental quality. Normally, the dumps are small, but if located near a stream, water pollution can occur. The dump serves as a habitat for disease vectors such as flies, rats and mosquitoes. If ignited, it is a fire hazard. If nothing else, the promiscuous dump represents visual blight -- a detriment to the aesthetics of the rural landscape. Lowenthal (1968), in his discussion of the degradation of the Hudson River, included garbage dumps and litter as components of "unmitigated blight." It is to this problem of illegal solid waste disposal in the rural environment that this research is addressed.

Statement of Problem

The general objective of this study is to investigate the "environmental implications and spatial characteristics" of the process of promiscuous dumping in a defined study area of Central Oklahoma. Specifically, the objectives are as follows:

A. to investigate the "reasons for our concerns" with the process of promiscuous solid waste disposal. The intent is to expose the ecological and physical-environmental implications of the process and to investigate socio-economic costs of the problem.

B. to survey the extent of the problem of promiscuous solid waste disposal in a defined study area. The objective is to locate all promiscuous dumps in the specified region and to collect a set of data concerning the dump itself and the site in which it is located.

C. to investigate the different types of waste deposited in the rural environment and to analyze the social and physical setting (site) in which the dump is located.

D. to investigate the spatial distribution of promiscuous dumps within the study area. It is held that the distribution of dumps is not random, but is a function of the distribution of population. It is hypothesized that when the population is viewed as two residential subgroups, an urban sub-population and a rural sub-population, specific dumping patterns can be defined which are attributable to these groups.

E. to survey the coping responses, or control programs currently in operation in the United States to reduce promiscuous dumping.

This study is concerned totally with illegal solid waste disposal. In the state of Oklahoma, individual rural land owners are permitted to dispose of their own wastes on their own property, although this distinction is not explicitly stated in the waste management regulations (oral communication, Calvin Grant, Director, Environmental Health Services, Oklahoma State Department of Health). As such, no refuse accumulations on privately owned land are included in the analysis unless public accessibility to the disposal site could be established. For the most part, the dumps under consideration are those along the rural section line roads.

The Study Area

This research was conducted in Cleveland and McClain Counties, Oklahoma, an area of approximately 1150 square miles in the geographical center of the state (Figure I-1). The two counties are divided in a northwest-southeasterly direction by the Canadian River (Figure I-2). For the sake of expediency in the analysis of the problem, however, approximately 70 square miles of southeastern McClain County was excluded from the study (Figure I-2). The revised boundaries form a rectangular region of 1080 square miles.

The selection of this particular area was based upon several considerations. The region exhibits considerable variation in population characteristics and distribution, physical environments and waste management systems -- all of which are deemed important in understanding promiscuous solid waste disposal. Also, as thorough field investigation was required, the proximity of the two counties to the

FIGURE I-1

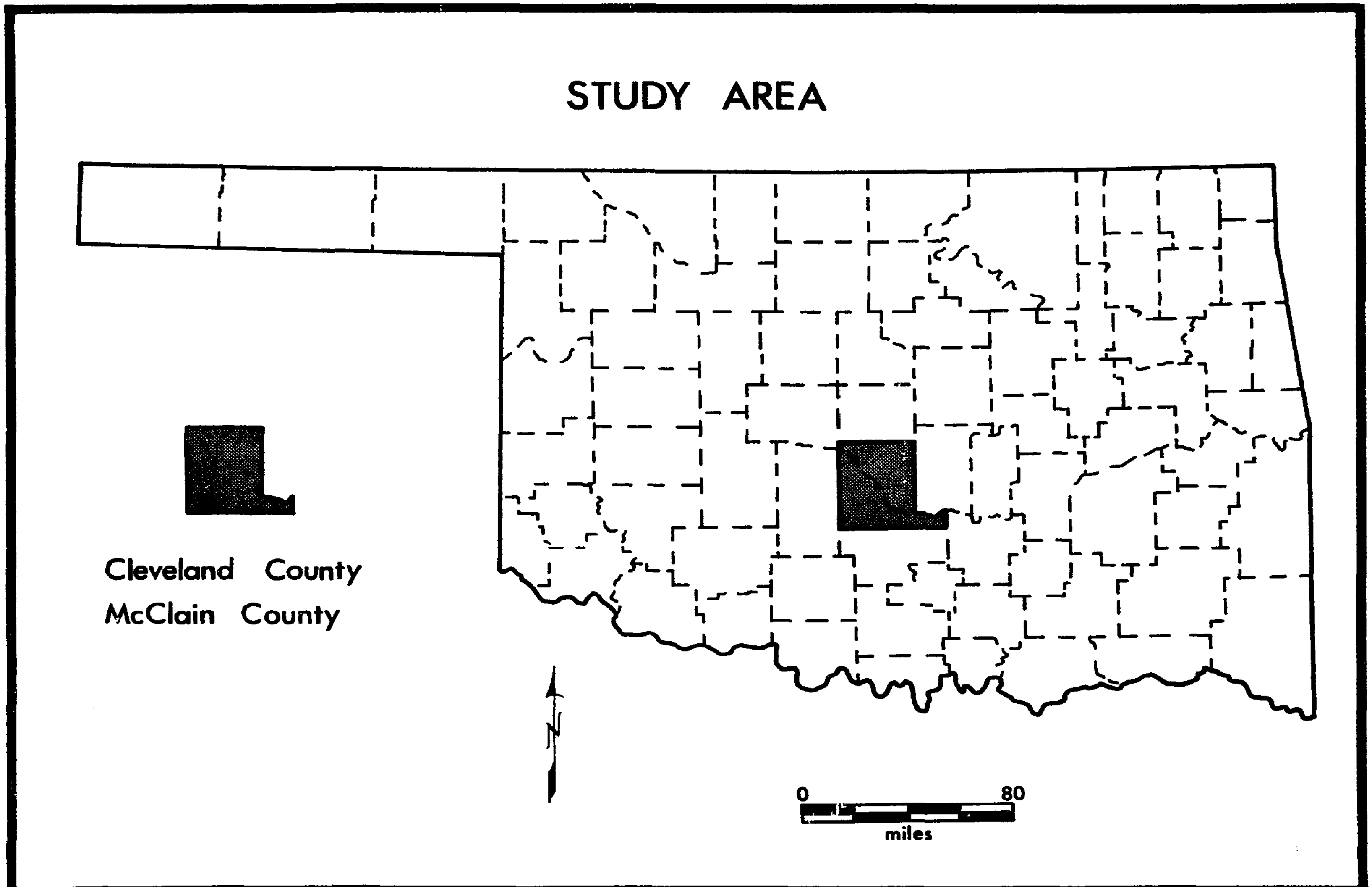
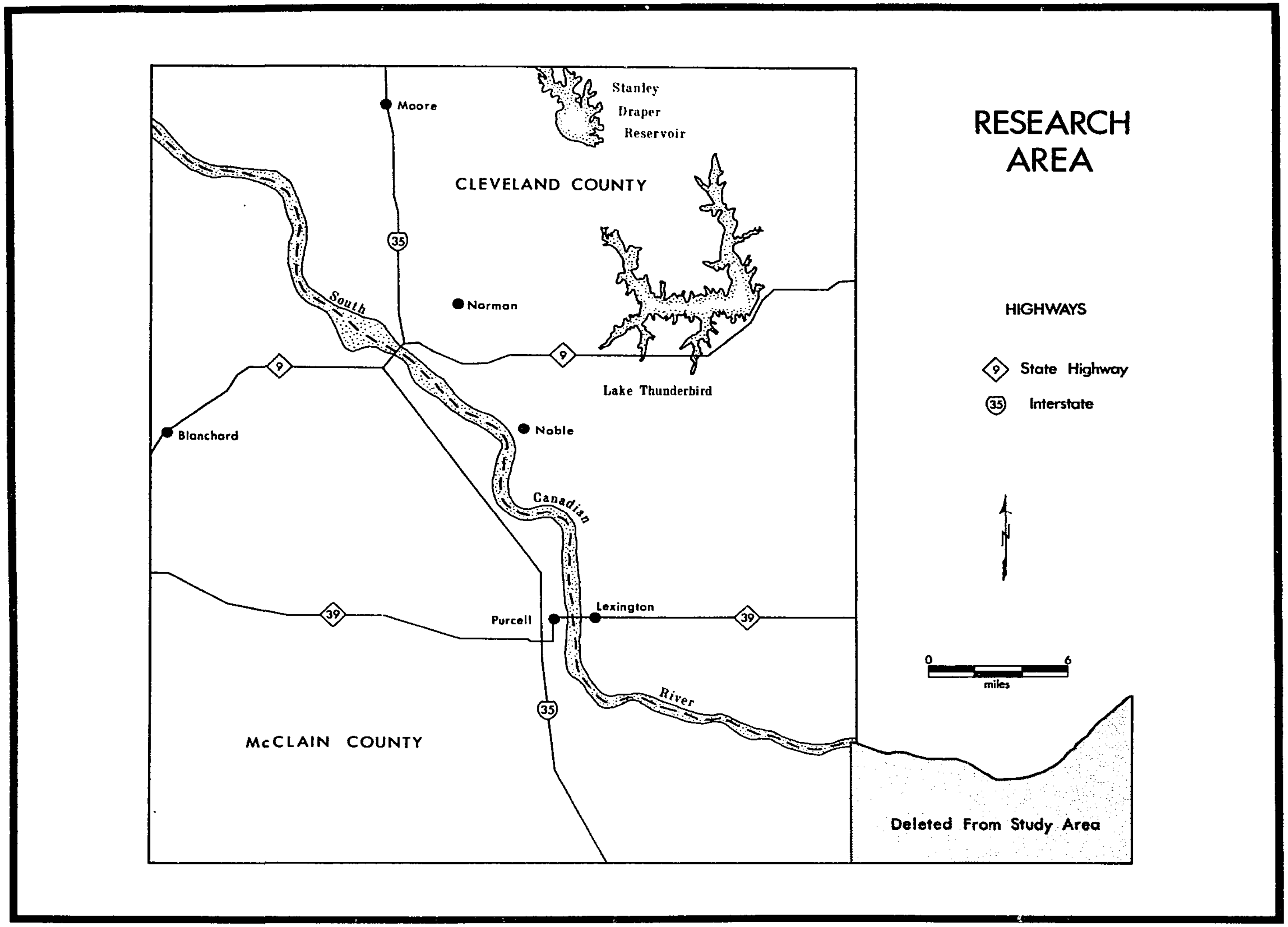


FIGURE I-2



RESEARCH AREA
Moore
Stanley
Draper
Reservoir
CLEVELAND COUNTY
35
Norman
South
9
9
Lake Thunderbird
Blanchard
Noble
Canadian
HIGHWAYS
9 State Highway
35 Interstate
Lexington
39
Purcell
39
0
6
miles
River
35
McCLAIN COUNTY
Deleted From Study Area

University of Oklahoma campus greatly reduced driving time to and from the field.

A majority of the population of the study area is confined to 15 cities, towns and incorporated places. In Cleveland County, 83.3 percent of the population was, in 1970, considered urban by the U. S. Census (Table I-1). In McClain County, however, only 24.8 percent of the population was classified as urban (Table I-1). The largest city in the entire area is Norman, Oklahoma, with a 1970 population of 52,117 (Figure I-3). Oklahoma City is located immediately to the north of the study region and extends into the northern reaches of Cleveland and McClain Counties (Figure I-3).

In recent years, there has been residential movement from the larger towns of the study area to the suburbs. The rural northern reaches have gained population from the cities of Norman, Moore and Oklahoma City. In face of this, most towns have incorporated well beyond their built-up areas and are thus geographically overbounded. The majority of the study area now rests within a city limit (Figure I-3).

The area selected for investigation exhibits considerable diversity in physical landscapes. Geologically, the region is characterized by alternating, north-south striking strata of Permian sandstones and shales, comprising a portion of the Central Redbed Plains of Oklahoma (Figure I-4). Roughly the eastern one-half of Cleveland County is underlain

Table I-1

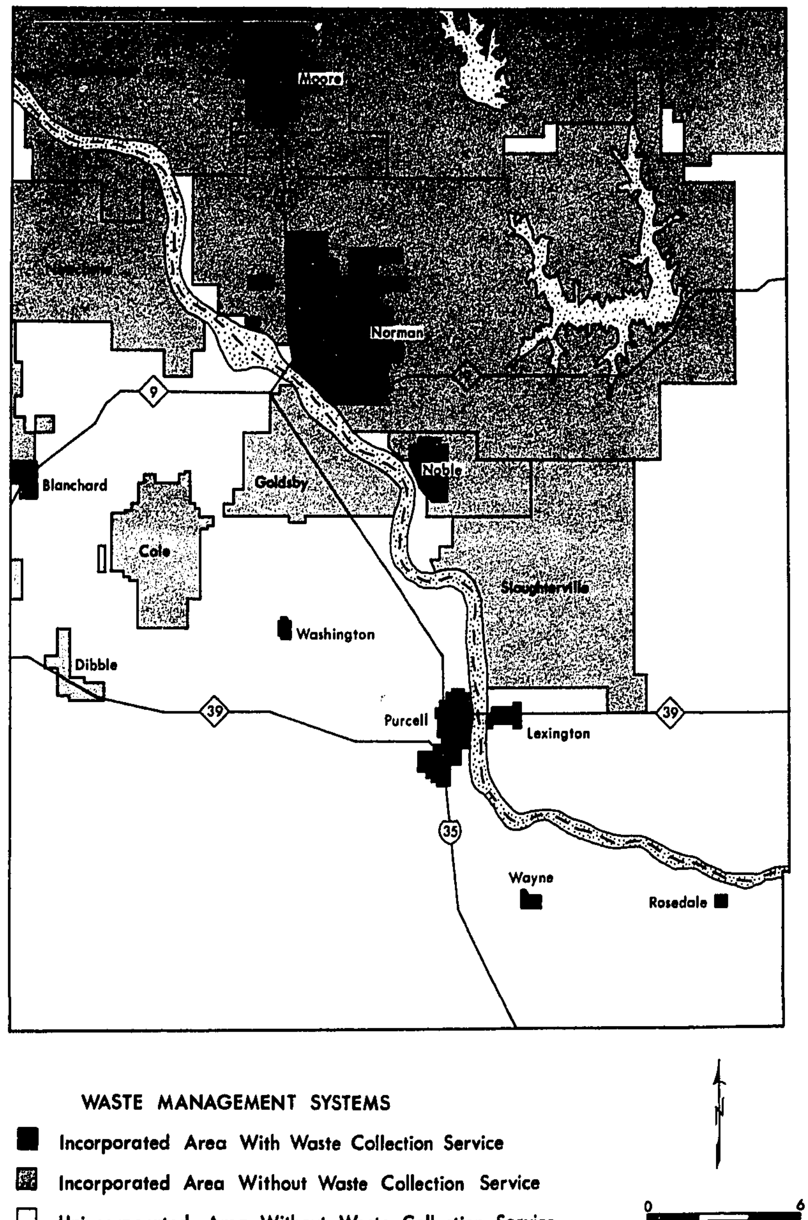
1970 Population Characteristics of the Study Area[a,b]

	Cleveland County	McClain County
Total Population	81,839	14,157
Population Density (persons/sq mi)	155.3	24.7
Total Urban Population	68,159	4,076
Percent Population Urban	83.3	24.8
Population of Places of 1000-2500	3,757	2,851
Total Rural Population	13,606	10,020
Total Farm Population	1,846	2,208

[a]U.S., Department of Commerce, Bureau of the Census, United States Census of Population: 1970, Supplementary Report PC(1)-A38, Number of Inhabitants: Oklahoma, July 1971, p. 16.

[b]U.S., Department of Commerce, Bureau of the Census, United States Census of Population: 1970, Supplementary Report PC(S1)-27, Rural Population by Farm-Non-farm Residence in the United States: 1970, August, 1972, pp. 19-20.

WASTE MANAGEMENT SYSTEMS



SOURCE: CLEVELAND & McCLAIN COUNTY SOIL CONSERVATION SERVICE

FIGURE I-3

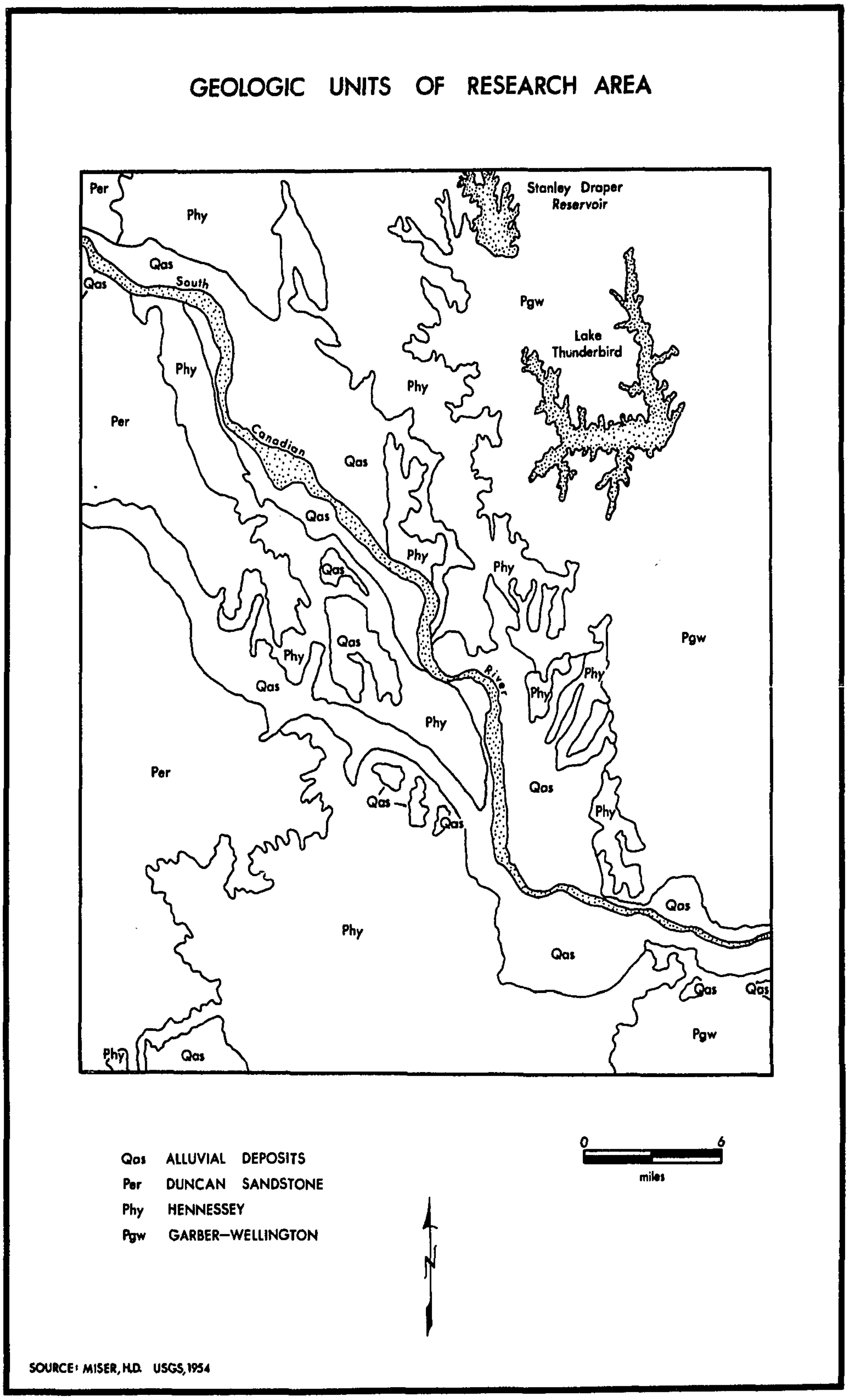

GEOLOGIC UNITS OF RESEARCH AREA
Stanley Draper Reservoir
Lake Thunderbird
South Canadian River
Per
Phy
Qas
Pgw
Qas ALLUVIAL DEPOSITS
Per DUNCAN SANDSTONE
Phy HENNESSEY
Pgw GARBER–WELLINGTON
0
6
miles
N
SOURCE: MISER, H.D. USGS, 1954

FIGURE I-4

by the Garber-Wellington Formation, chiefly sandstone, and the western reaches by the Permian Hennessey shale. In McClain County the Hennessey shale gives way to the relatively younger Duncan Sandstone. Separating Cleveland and McClain Counties are broad alluvial terraces associated with the Canadian River.

These geologic variations have produced several distinct vegetative associations within the study area. This is viewed as particularly important in understanding the process of promiscuous solid waste disposal. The Hennessey Shale supports a tall grass prairie complex with tree-form vegetation confined to stream courses and intermittently outcropping lenses of sandstone (Duck and Fletcher, 1943). In eastern Cleveland County, corresponding with the Garber Sandstone, is an oak-hickory forest referred to as the "Cross Timbers" (Duck and Fletcher, 1943). Galeria forest traces diagonally through the area with the channel of the Canadian River.

Small stream valleys are considered to be a favorite target for illegal dumpers. As such, the drainage system of the research region is of importance. Northern and central Cleveland County is drained by the tributary system of Little River. This stream is dammed at the eastern extreme of the county to form Lake Thunderbird. The streams of southern and western Cleveland County feed into the Canadian River. In McClain County, two distinct drainage systems are represented. Walnut Creek accepts the runoff of the northern one-half of the area and flows itself into the Canadian River near Purcell. The streams in southern McClain County form the northern extremeties of the Washita River drainage system.

The type and quality of waste management systems in the study area varies with the population of the towns. It is logical to assume that the extent of promiscuous dumping in the vicinity of a settlement is in part a function of the type of waste management operation available to the residents. The population of each town and the type of collection system and disposal facilities are outlined in Tables I-2 and I-3. The extent of the system in each town is distinguished in Figure I-3.

Organization of the Study

This study consists of five chapters. Chapter II presents a conceptual discussion of the "niche" of promiscuous disposal in the overall field of solid waste management. It speaks also of the severity of the problem in the study area and in the United States in general and surveys the ecological and socio-economic costs of the practice. Chapter III views individual dump types and environmental settings. Chapter IV is concerned with the spatial distribution of dumps. In Chapter V the methods employed to control illegal dumping in the United States are reviewed and the contributions of this study are discussed.

Table I-2

Waste Management in Cleveland County

City	1970 Population[a]	Collection System[b]	Disposal Facility[c]
Moore	18,671	Municipally operated system. Twice weekly residential collection and three times weekly commercial collection within densely populated area (Figure I-3). Container services available for commercial establishments and multiple dwelling complexes.	None; Waste hauled to the Norman landfill.
Norman	52,117	Municipally operated system. Twice weekly residential collection and three times weekly commercial collection within densely populated area (Figure I-3). Collection service available to rural residents upon posting bond. Container services available to commercial establishments and multiple dwelling complexes. Small volunteer recycling program. An estimated 1400-1500 families participating.	Privately owned and operated landfill.
Noble	2,241	Municipally operated system. Twice weekly residential collection and three times weekly commercial collection within densely populated area (Figure I-3).	None; Waste hauled to Norman landfill.
Hall Park	163	Norman Services	Norman Services
Slaughterville		None	None
Lexington	1,516	Municipally operated system. One time weekly residential collection and twice weekly commercial collection within city limits (Figure I-3	Municipally operated open dump. Burning practiced for volume reduction. Contract periodic use of Purcell landfill.
Oklahoma City	4,382	Municipally operated system. Twice weekly collection for residential developments.	Municipally operated sanitary landfills

[a]U.S., Department of Commerce, Bureau of the Census, United States Census of Population: 1970, Supplementary Report PC(1)-A38, Number of Inhabitants: Oklahoma, July, 1971, p. 19.

[b]This information was gained through interview and correspondence with the following county and city officials and waste management personnel: Mr. August Helmbright, County Sanitarian, Cleveland County, Norman, Oklahoma; Mr. Earle Danner, Director of Sanitation, Norman, Oklahoma; Mrs. Margaret Watkins, City Clerk, Lexington, Oklahoma; Mrs. Naomi E. Williamson, City Clerk, Noble, Oklahoma; Marvin W. Baker, Jr., Associate Professor of Geography, University of Oklahoma, Norman, Oklahoma.

[c]*Ibid.*

Table I-3

Waste Management in McClain County

City	1970 Population[a]	Collection System[b]	Disposal Facility[c]
Blanchard	1,580	Municipally operated system. Twice weekly residential collection and three times weekly commercial collection in densely populated area (Figure I-3).	None; Waste hauled to the Newcastle landfill.
Newcastle	1,271	None	Privately owned and operated landfill.
Washington	322	Municipally operated system. Twice weekly residential and commercial collection within city limits (Figure I-3).	Municipally operated open dump on leased land. Burning practiced for volume reduction.
Purcell	4,076	Municipally operated system. Twice weekly residential collection and three times weekly commercial collection within city limits (Figure I-3). Container services available for commercial establishments and multiple dwelling complexes.	Municipally owned and operated landfill.
Dibble	184	None	None
Rosedale	98	None	None
Wayne	618	Municipally operated system. Once monthly collection (second Tuesday of each month) within city limits (Figure I-3).	Municipally operated landfill on leased land. County assistance with disposal operations.
Cole	154	None	None
Goldsby	298	None	None
Oklahoma City	249	Municipally operated system. Twice weekly collection for residential developments.	Municipally operated sanitary landfills

[a]U. S., Department of Commerce, Bureau of the Census, United States Census of Population: 1970, Supplementary Report PC(1)-A38, Number of Inhabitants: Oklahoma, July 1971, p. 21.

[b]This information was gained through interview and correspondence with the following county and city officials and waste management personnel: Mr. J. H. Redman, Mayor, New Castle, Oklahoma; Mrs. Fancher, City Clerk, Newcastle, Oklahoma; Mrs. Mary Chambers, City Clerk, Blanchard, Oklahoma; Mrs. Mary Ellen Summers, City Clerk, Purcell, Oklahoma; Mr. John Nunnally, Sanitatian Director, Washington, Oklahoma; Mrs. Blanche Woods, City Clerk, Wayne, Oklahoma; Mr. Jerry Miller, County Sanitarian, McClain County, Purcell, Oklahoma.

[c]Ibid.

CHAPTER I

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CHAPTER II

PROMISCUOUS WASTE DISPOSAL: CAUSATION AND CONCERN

There are three basic forms of man generated waste -- gaseous, liquid and solid; there are three environmental resceptacles for waste -- the atmosphere, the land and the water. With the possible exceptions of meteors and moon rocks, all substances used and enjoyed on planet earth are derived from planet earth. After a varying tenure of usage, all are returned to the physical environment.

This study is concerned with the illegal disposal of solid-form refuse. By definition, it is addressed to only one problem associated with one type of waste. The objective of this chapter is to present the rationale on which the study is based. Of particular importance are the causative factors of promiscuous dumping, the spatial distribution of the problem and the environmental and socio-economic reasons for concern.

Causation: A System in Disequilibrium

In theory waste management consists of a three-stage system referred to as the "Solid Waste Stream" (Commonwealth of Pennsylvania Department of Health, 1968, p. 5).

Stage One is the generation of waste, that is the complete exhaustion of the utility of a material or product (Figure II-1). Level Two in the stream is waste handling. In a municipal system, this stage would consist of refuse collection, compaction and transfer. The final level of the stream is disposal. Essentially, the waste is relocated in the environment in such a manner and in such a location that it is no longer the responsibility of the producer. As there is a continual generation of waste, so also must there be continual operation of the secondary and tertiary levels of the system.

In Figure II-1 the movement of waste is from a producing population to an environmental depository. The solid flow line in the chart depicts the waste management stream operating in equilibrium. Waste generated by both a rural and urban population is incorporated into a managed disposal operation. It is then returned to the physical environment via sanitary landfill or incineration or into another economic cycle through any of several recycling avenues. This is not to indicate, however, that present management techniques eliminate all concerns with solid waste. The biodegradable nature of many waste items and the land requirements of the sanitary landfill have produced a new set of problems with which city officials and waste managers must contend.

THE SOLID WASTE STREAM

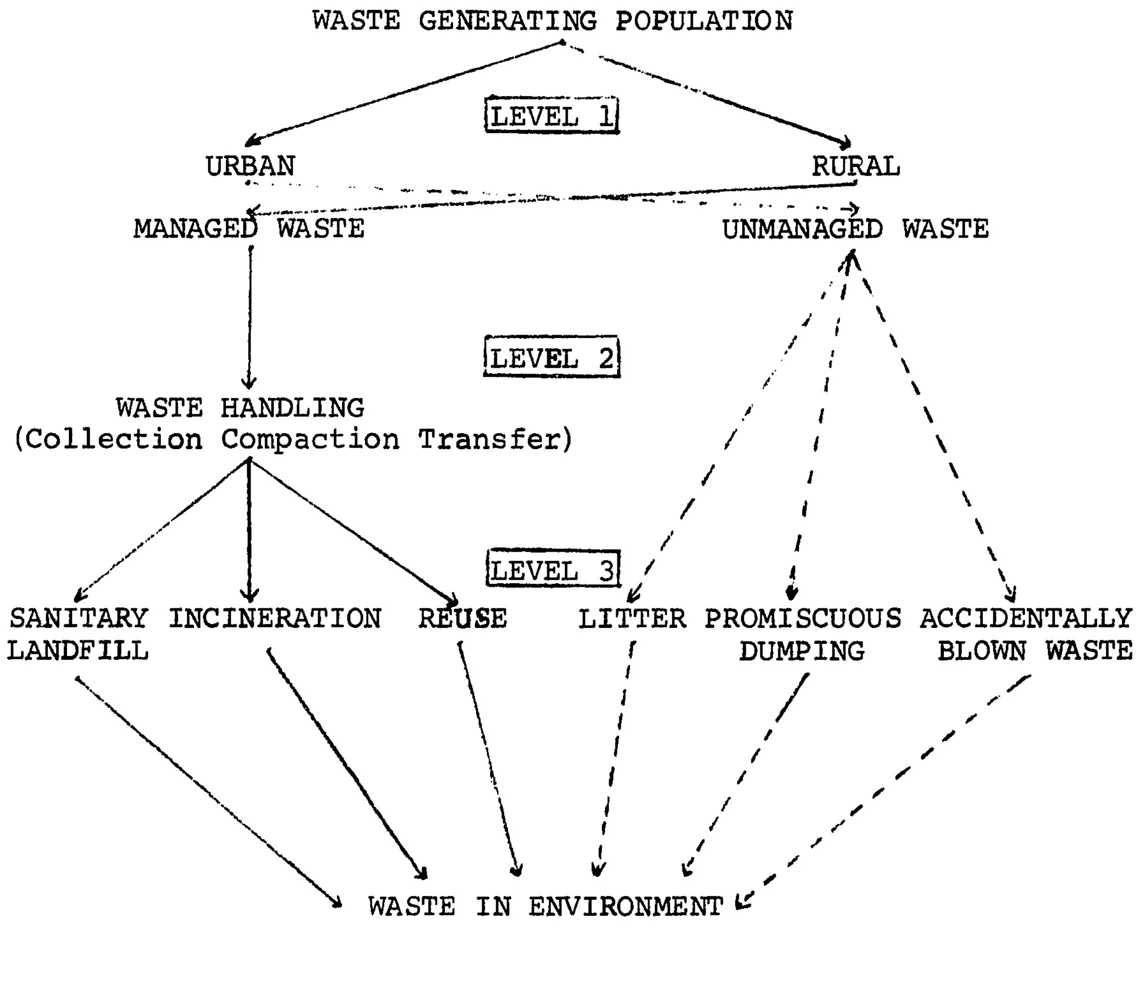

FIGURE II-1

Unfortunately, there is no operational system into which all waste can be incorporated. Much refuse is generated which is beyond the spatial limits of a management system or exceeds the capabilities of the system. As this waste must also be disposed of, it constitutes a "break-down" in the solid waste stream. Promiscuous dumping, litter and accidentally blown waste are symptomatic of this disequilibrium.

The dashed lines in Figure II-1 indicate that unmanaged waste is produced by both the urban and the rural populations. Although promiscuous dumping, as one form of unmanaged disposal, has conventionally been viewed as a rural problem, it is believed that much of the waste is hauled into the countryside from the city. Heavy, bulky items such as appliances, furniture and lumber scraps are incompatible with many municipal waste collection systems. These materials are simply taken to the edge of town and dumped.

The waste managers contacted in this study, however, feel that most promiscuously deposited waste is generated in the rural areas. With no collection system to serve rural residents, they, as a group, are forced to personally rid themselves of their refuse. Several disposal options are available. The waste may be hauled to an authorized collection point or disposal site, it may be burned or buried on premises, or it may be taken to the nearest roadside dump. It is obvious that many rural residents choose the last option.

The Extent of the Problem

Based on the statistics of the 1968 National Survey of Community Solid Waste Practices, the U. S. Environmental Protection Agency estimates that there are possibly as many as 160,000 "unathorized" dump grounds in the United States (U. S. Environmental Protection Agency, 1972, p. 4). In view of other regional surveys, however, this figure may well be an underestimation. An aerial survey of Oklahoma County, Oklahoma, produced 600 illegal dumpsites (Oklahoma State Department of Health, 1972, p. 5). The sanitarian of Lawrence County, Indiana, located 200 dumps in his county (Oral Communication, Paul McBride). In Bullit County, Kentucky, 116 dumps were found and a survey in Humphreys County, Tennessee revealed 40 more (Sorg, 1972, p. 90; Kruth and others, 1972, p. 5). Even our national parks and wilderness areas are not secure from this form of environmental degradation. A sizeable refuse accumulation was recently found on Mt. McKinley at an elevation of 17,000 feet (National Wildlife Federation, 1973, p. 8).

To provide primary data for this research, an automobile reconnaisance of promiscuous dumping in Cleveland and McClain Counties, Oklahoma, was conducted between February and May of 1973. Every public road in the research region was driven and all illegal refuse accumulations were plotted on a map. A total of 828 dumps were found -- approximately one for every 1.3 square miles of area. The distribution of these dumps within the study area is depicted in Figure II-2.

Ecological and Environmental Concerns

Threat to Public Health

One of the fundamental concerns of improperly managed waste is the potential of the refuse accumulation to contribute to the incidence of disease. In reality, however, it is difficult to precisely establish the link between solid waste and disease. This relationship tends to be obscured by the following factors: (1) the complexity of waste components; (2) the biological and chemical changes that occur in waste under varying conditions of storage, handling, treatment and disposal; and (3) the intricate pathways that may underlie human exposure (Hanks, 1967, p. 1).

Despite the difficulties in clearly defining the association between disease and waste, the disease potential is often a critical argument in pleas for improved waste management procedures. The public health hazard was included as one of the basic arguments upon which the Solid Waste Management Act of 1965 was based (U. S. Environmental Protection Agency, 1971, p. 1). The fact that the refuse pile provides a suitable habitat for disease vectors and

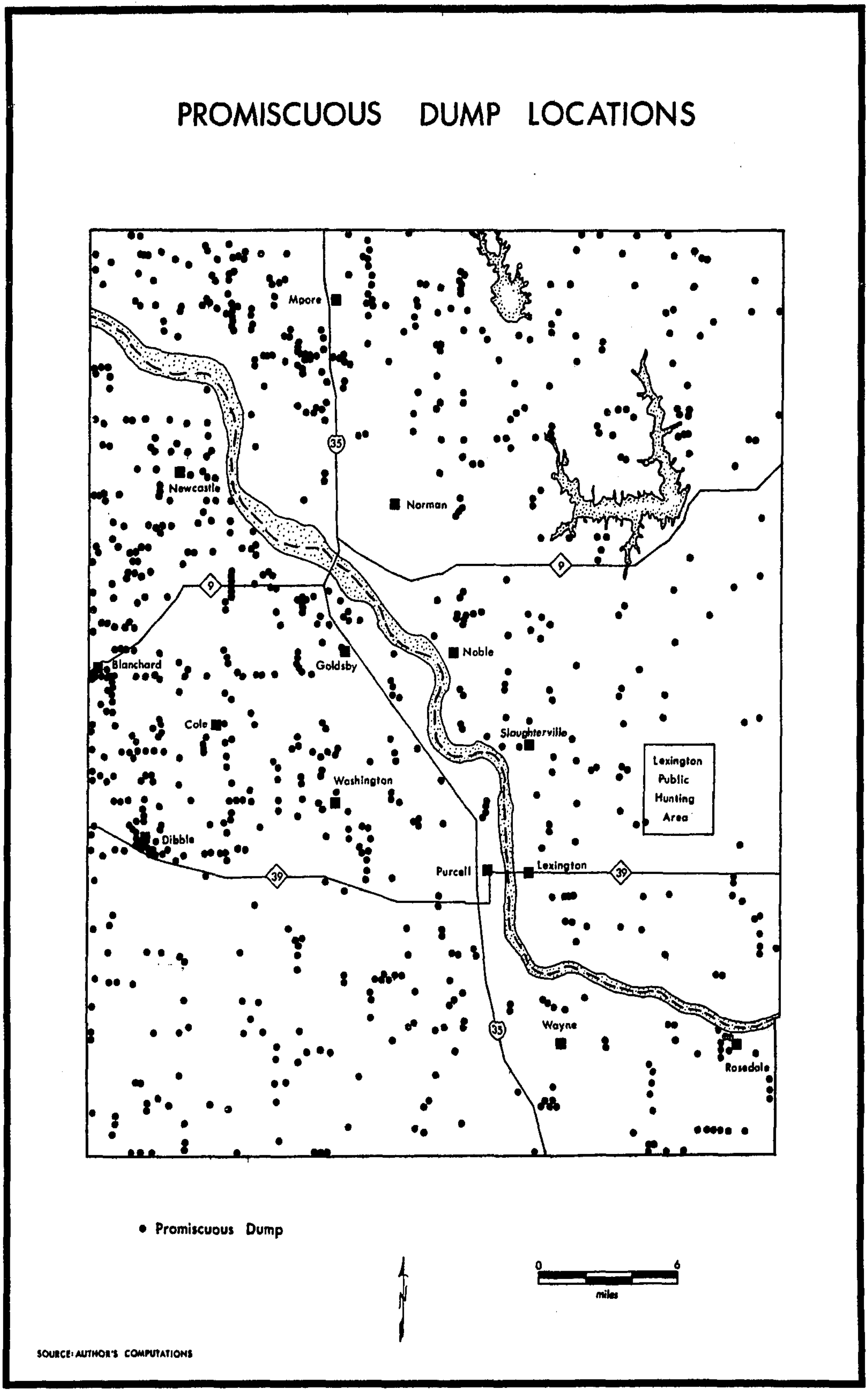
PROMISCUOUS DUMP LOCATIONS
Moore
Norman
Newcastle
Noble
Blanchard
Goldsby
Cole
Slaughterville
Washington
Lexington Public Hunting Area
Dibble
Purcell
Lexington
Wayne
Rosedale
Promiscuous Dump
0
6
miles
SOURCE: AUTHOR'S COMPUTATIONS

FIGURE II-21

that disease transmission may be facilitated through poor disposal practices, renders solid waste "guilty by association" of being a public health hazard. The disease vectors most commonly associated with solid waste are rats, flies and mosquitoes. Of these, rats and flies are of greatest concern.

Flies. Aside from being annoying pests, flies threaten the cleanliness of fresh and processed foods and act as vectors of several diseases. They are extremely prolific and some species are well suited to the dump environment. The *Phaenicia* species, *Muscina* species and *Musca domestica* are common to the open dump (California State Department of Health, 1971, p. VII-3; Hanks, 1967, p. 28). One of the most common diseases transmitted by flies is Shigellosis, or bacillary dysentery (Hanks, 1967, p. 5). Other interic infections, however, such as salmonella enteritis are common (Hanks, 1967, p. 28). Of a more serious nature, the fly is a known, or suspected, carrier of typhoid fever, cholera and poliomyelitis (Hanks, 1967, p. 28).

The potential fly production from solid waste has been well documented. The California State Department of Health in Fresno, California, found that one garbage can, with lid kept intact and lined with newspapers, produced 55,428 flies in a seven-week study period (Walsh and others, 1968, p. 12). The results of other experiments vary, but one similar study indicates that as many as 70,000 flies can be produced in that time span (The American City, February, 1965, p. 36). Marx (1971, p. 31) reports that one cubic foot of garbage can produce 75,000 flies.

The promiscuous dump has all of the qualities of the residential garbage can. Organic waste is often present, the waste is exposed and no control effort is made. In effect, the dump serves as a "source point" for the fly population. When the population becomes too heavy, or the organic refuse is depleted, the flies will migrate out of the dump, perhaps to a nearby residence or town. If any disease organism of which the fly is a vector is present in the dump, there is an excellent opportunity for it being disseminated.

Flies are known to migrate as much as six miles in one twenty-four period (California State Department of Public Health, 1971, p. V-6). During their lifetime, they may travel over 20 miles from their source point (Hanks, 1967, p. 31). Given the number of promiscuous dumps scattered about the rural landscape, no rural inhabitant or city dweller is immune from these wastebred flies.

Rodents. Rodents of several species, primarily rats and mice, are common inhabitants of the open dump. The refuse pile provides the two basic requirements of their livelihood, food and shelter. Waste items such as boxes, crates, canisters and old washing machines offer a sanctuary virtually free from detection. Kitchen wastes indiscriminantly thrown into the dump provide a most nourshing repast. It is quite possible for small rodents to live out their life cycle without leaving their harbarage in search of food.

Each year in the United States, some 14,000 people are bitten by rats (California State Department of Public Health, 1971 p. V-8). Each bite involves the possibility of transmitting one of more than 25 diseases (Scott, 1960, p. 2). Field rodents and their ectoparasites participate in the spread of Bubonic plague, Rocky Mountain spotted fever, scrub typhus, salmonellosis, Russian spring-summer encephaletis, relapsing fever and rat-bite fever -- just to mention a few (Bjornson and others, 1970, p. 2; Hanks, 1967, p. 92). There is reason to be concerned with promiscuous dumps as a nursery for rats and mice.

The Norway rat (*Ratus norvequicus*) is particularly well adapted to the dump environment (Scott, 1959, p. 3). When fully grown the Norway rat approaches one pound in weight and becomes fiercely defensive when antagonized (Bjornson and others, 1970, p. 4). As many illegal dumps are located in close proximity to houses, the possibility of rat bite does exist. Also, when rat populations are large, the rodents may migrate to a nearby house or barn in search of food. Disease transfer from field to domestic rodents greatly enhances the possibility of human infection.

Mosquitoes. The open dump is a breeding ground for mosquitoes. Tin cans, bottles, auto tires and other containers allow water to collect and stagnate in the dump. While this is not a conducive environment for all species of mosquitoes, floodwater species do oviposit in rubbish piles (Herns and James, 1961, p. 154). As with flies and rats, mosquitoes contribute to the transmission of certain diseases.

The mosquito is the sole vector of the malarias, yellow fever and dengue and participates importantly in the spread of filariasis and the encephalalitides (Hunter and others, 1960, p. 17, 20, 217, 658, 659, 661, 662). This insect can easily travel distances of one and one-half miles from its origin and have been known to migrate 50-75 miles (Herns and James, 1961, p. 155). Even without its potential to spread disease, the mosquito is an annoying pest.

Water Pollution

The second major environmental impact of promiscuous dumping is water pollution. Generally speaking solid wastes may impair water quality in two ways: (1) a physical fouling of a water supply when trash is piled into flowing or impounded water; and (2) effecting a chemical or biological change in the water which reduces its utility for use or consumption. Promiscuous dumping achieves both of these results.

Stream beds, gullies and other depressions which constitute elements of drainage systems are ideal locations for dumpers. In periods of highflow, debris may be washed from the original site to other areas of the stream system. In some situations the physical presence of waste could be a hazard to swimmers and boaters. In other cases it only serves as a nuisance factor and aesthetically degrades public and private land.

Chemical and biological pollution is much more serious. When water moves vertically or horizontally through a waste accumulation, a concentrated liquid, leachate, is produced. Leachate is a solution containing dissolved and suspended solid matter and microbial wastes (Brunner and Keller, 1972, p. 3). When leachate seeps into surface water of mixes with the ground water, the contamination of the water supply results.

The composition of leachate from two different studies is shown on Table II-1. The values are percentages of materials, based on weight of refuse received, which are leached from domestic waste. The first column of Table II-1 depicts leachate production from waste deposited in an unsaturated environment and leached only by natural precipitation (Ministry of Housing and Local Government (Great Britain, 1961, p. 75). Column 2 represents the results of a test landfill in Riverside, California (Engineering Science Inc., 1961, p. 39). It is assumed that leachate produced from a large promiscuous dump would be quite similar. The quantity, however, would depend upon the volume of waste present.

TABLE II-1

PERCENTAGES OF MATERIALS LEACHED FROM REFUSE
(Based on Weight of Refuse)

Materials Leached	Percentage Leached	
	Great Britain Study	Riverside Study
Chloride	0.127	0.11
Ammonical Nitrogen	0.037	0.036
Biological Oxygen Demand	0.249	1.27
Organic Carbon	0.163	
Sulfate (as SO_4)	0.084	0.011
Alkalinity (as $CaCO_3$)		0.39
Calcium		0.08
Magnesium		0.015
Sodium		0.075
Potassium		0.09
Total Iron		0.01
Inorganic Phosphate		0.0007
Organic Nitrogen	0.0072	0.016

Source:

Engineering Science, Inc., 1961, Final Report on the Investigation of Leaching of a Sanitary Landfill: Riverside, California, Engineering Science, Inc.

Hughes, George M., 1967, Selection of Refuse Disposal Sites in Northeastern Illinois: Urbana-Champaign, Illinois State Geological Survey, Environmental Geology Notes, No. 17, 18 p.

Ministry of Housing and Local Government (Great Britain), 1961, Analysis of Leachate Deposited in an Unsaturated Environment: London, Ministry of Housing and Local Government.

When promiscuous dumps are located in small streams which serve as a water supply for livestock, there is danger of the animals being adversely effected by leachate. Water wells in the vicinity of a dump could also become contaminated. Due to the laminar flow of ground water, leachate, upon entering the ground water, will not mix readily and tends to remain near the upper margin of the table (Brunner and Keller, 1972, p. 5). Conceivably, this fouled water could be pumped out of the well for domestic use.

Water quality can also be impaired by gas production in the waste accumulation. If a large amount of sulfate (gypsum board) is present in the dump, as is the case in areas where new construction is taking place, hydrogen sulfide may be generated (Brunner and Keller, 1922, p. 7). This gas can impart a particularly pungent odor to a water supply. Mineralization of ground water can occur if carbon dioxide disolves and forms carbonic acid.

Water entering the dump may also serve as a natural transport medium for pathogenic organisms. Dead animals, soiled bandages, and various sickroom wastes are commonly found in the promiscuous dump. If the disease organism is still active, both ground and surface water may become biologically contaminated.

To elucidate the propensity for dumpers to deposit their wastes in small stream valleys, the refuse accumulations found in the McClain County portion of the Walnut Creek drainage basin are depicted in Figure II-3. A total of 170 dumps were found in a basin area of 280 square miles. More importantly, 87 of these were located directly in the stream channels. Fifty-five more were in gullies, borrow ditches or similar depressions draining directly into the nearby streams. Surely water contamination results.

Social and Economic Costs

The mis-management of solid waste also exacts an economic toll. The aesthetic degradation of the rural landscape, reduced land values and the nuisance and hazard of certain insects are all types of "costs" associated with promiscuous dumping. Added to this is the direct economic expense in some states and communities of cleaning up after the illegal dumps.

The President's Council on Environmental Quality has distinguished four categories of environmental costs (Council on Environmental Quality, 1973, p. 75). These are: (1) Damage Costs - those costs which result directly from a polluting activity, such as illness or property damage; (2) Avoidance Costs - those costs incurred in order to avoid or reduce damage costs, such as having to drive further to find an unpolluted beach; (3) Transaction Costs - the cost of resources consumed in making and enforcing policies and regulations, such as the expense of monitoring

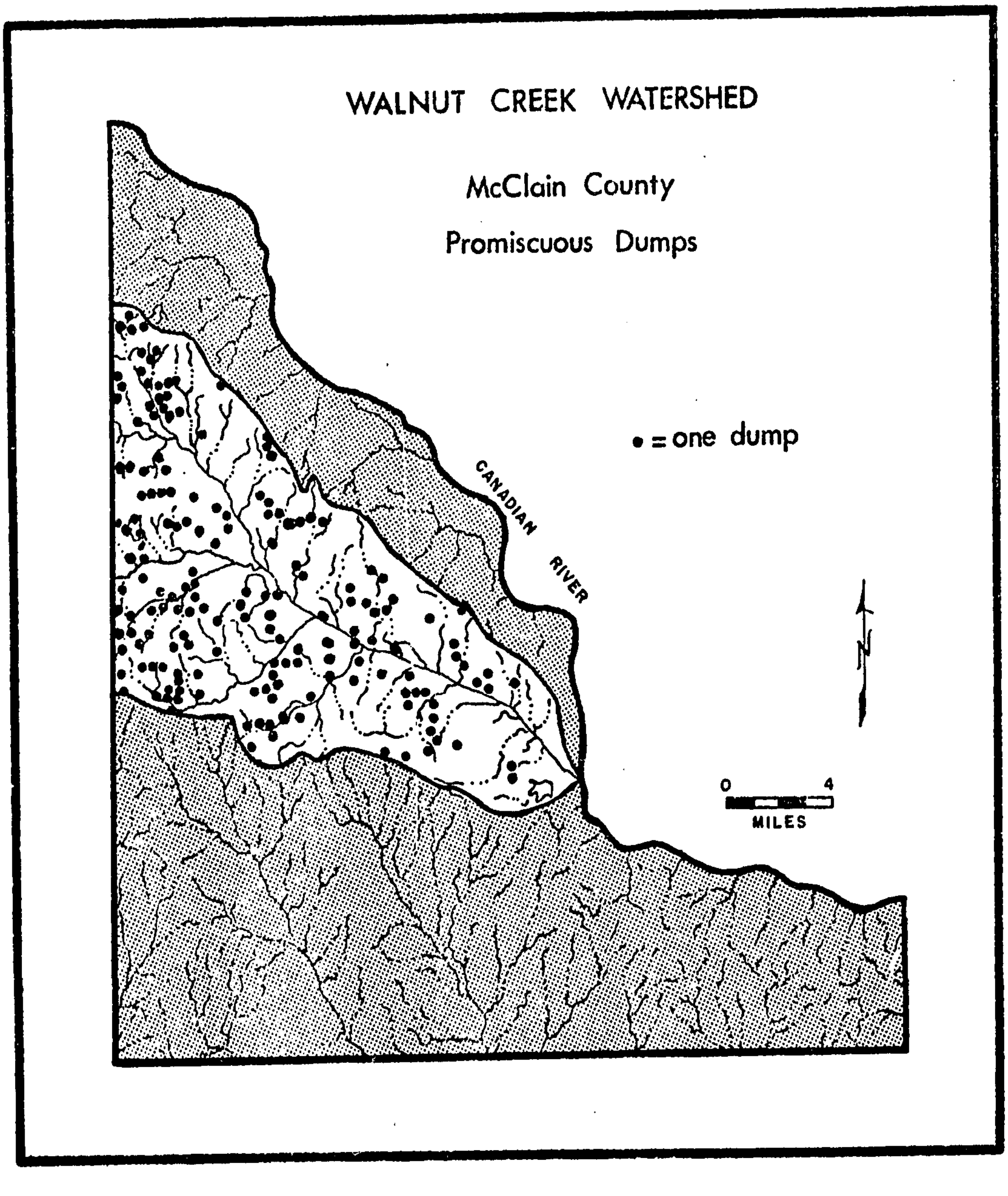
WALNUT CREEK WATERSHED
McClain County
Promiscuous Dumps
• = one dump
CANADIAN RIVER
N
0 4
MILES

FIGURE II-3

air pollution; and (4) Abatement Costs - those costs associated with reducing the amount of environmental degradation; i.e., the cost of sewage treatment plants. The societal expense of promiscuous dumping may be viewed in context of these cost categories.

Damage costs occur when waste is indiscriminantly dumped into the rural environment. These expenses are quantifiable in marketplace values, but very often they are not associated with the actual polluting activity, but are attributed to another cause. As an example, when medical care is required to treat a disease contracted directly or indirectly at the dump, the expense is attributed to the disease, not the process of illegal dumping. Other examples of damage costs associated with dumping would be the reduction in land values due to blight or the reduced value of livestock sickened while in contact with the dump. Very often it is difficult to identify and calculate damage costs, but they do occur.

Anytime a conscious effort is made to reduce damage costs, avoidance costs are incurred. In the example of the blighted land given above, any effort to clean up the land to increase its value would generate avoidance expense. Another case might be the expense of purifying water made brackish by leachate. As with damage costs, avoidance costs are measurable.

Most Federal expenditures in environmental programs are for transaction costs. The transaction costs of promiscuous dumping are incurred indirectly as a result of research and development, policy formulation and monitoring projects aimed at solid waste in general. A primary example of this cost category would be Federal monetary support to develop and operate a regional waste collection system to reduce illegal dumping.

The abatement costs of promiscuous solid waste disposal are those expenditures aimed directly at reducing the environmental impact of the process. In a sense, the expense of all waste management activities could be considered abatement costs in that they reduce the pollution potential of waste. In practice, however, only such direct expenses as cleaning up a dump or maintaining an area-wide collection system should be considered as abatement costs.

The cost of promiscuous dumping may also be viewed in terms of the "opportunity costs" of the practice. Opportunity costs are those resources which are lost from expending a resource in one manner when a choice of allocations is available (Hines, 1973, 118). They are the total values which would have accrued from other uses of the resource. When money is spent to control promiscuous dumping, the opportunity costs would be the value gained if those resources had been on public education, libraries or other projects. It is often difficult to put a dollar and cent value on opportunity costs, but it is important to realize they exist.

The foregoing types of activities all consume the very tangible resource, money. There is one category of environmental cost that is not measurable in marketplace values. This expense, termed "physic" or "social" cost, is associated with environmental degradation beyond the value of physical resource damage. They are measured and defined only the degree of personal insult or loss experienced when landscape disfiguration occurs. To many people, these psychic costs are the most expensive of all -- they, too, are opportunity costs!

CHAPTER II

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CHAPTER III

THE DIMENSIONS OF PROMISCUOUS DUMPING: A DETAILED INVESTIGATION OF CLEVELAND AND McCLAIN COUNTIES, OKLAHOMA

Much can be understood about illegal dumping and the impact of this activity on the environment by discerning the spatial dimensions and characteristics of the process. As with every social activity, there are regularities in promiscuous solid waste disposal. This chapter discusses an investigation of the different "types" of solid waste deposited in the rural environment and the characteristics of sites in which dumps are located.

The Survey

The data collected in the field survey were of two types. They concerned either the attributes of the dump itself or the site (physical and social environment) in which the dump was located. Nine site observations and 12 dump observations were collected at each refuse accumulation (Table III-1). The site variables were selected on the basis of two criteria; that they may be important in the decision making process of the promiscuous dumper when he is looking for a suitable location to dump his waste,

Table III-1

Survey Variables

<u>Dump Characteristics</u>

1. Physical Size of Dump
2. Is Dump in Depression?
3. Can Drainage Occur from Dump?
4. Is Water Pollution Occuring?
5. Is Dump Malodorous?
6. Is Construction or Demolition Waste Present?
7. Is Household Garbage Present?
8. Is Special Waste Present?
9. Are Dead Animals Present?
10. Is Non-Residential Organic Waste Present
11. Has Dump Been Burned?
12. Is Dump Active?

<u>Site Characteristics</u>

1. Dump Location: Distance from the Road
2. Dump Location: Public or Private Road
3. Dump Location: Is Dump Visible from Road?
4. Is Site Vegetated:
5. Is Dump Protected from View?
6. Are "No Dumping" Signs Posted?
7. Has Site Been Burned?
8. Road Quality
9. Distance to the Nearest House

or that they might be important in assessing the environmental impact of the dumping activity.

The initial problem that had to be dealt with in the field reconnaissance was that of defining the size parameters of the illegal waste deposit to be included in the survey. Essentially, this involved establishing criteria which would differentiate the promiscuous dump from the more common waste forms of litter and accidentally blown waste. As this question had not been raised in the waste management literature, it was decided that a waste accumulation would be considered a promiscuous dump if it was (1) the result of an obvious dumping effort; and (2) greater than 10 square feet in surface. Admittedly, these criteria were arbitrary, but they provided a degree of observational standardization and consistency in field decision making.

As the manner in which a variable is measured or observed can influence analysis, the data collection methodology is discussed in some detail below.

Dump Variables

1. Physical Size of Dump. Dump size was measured in feet along the long and short axes of the dump, providing a measure of approximate surface area in square feet. No attempt was made to estimate the volume of waste. In a majority of the cases the dump boundaries were distinct and easily measured. Often, however, smaller waste

accumulations would be found in the vicinity of the principal deposit. If the smaller dump was greater than 10 square feet in size and was separated from the larger deposit by more than 50 feet, it was recorded individually. If it did not meet both of these criteria, its area was computed and added to the surface area of the main dump. Narrow, elongated dumps (as in borrow ditches) were also handled in this manner. If a dump spilled over both sides of the road, it was considered as one accumulation and the surface areas were combined.

2. Is Dump in Depression? If the waste deposit was located in any form of physical depression, this observation was recorded in the affirmative. Borrow ditches, roadside erosion gullies and small stream beds were common locations.

3. Can Drainage Occur from Dump? If the dump was in a depression, it was assumed that drainage could occur into or from it. In other cases, drainage was considered as possible if the waste was deposited on a perceptible slope.

4. Is Water Pollution Occurring? For the purposes of this study, water pollution was defined by debris in the water or discolored or malodorous water in the vicinity of the dump. No water quality analysis was made.

5. Is Dump Malodorous? While standing at the dump, if any odor could be detected that was attributable to to the refuse, the dump was considered maladorous.

6. Is Construction or Demolition Waste Present? This and other waste forms discussed below are recognized as distinct "types" of solid waste. This particular form includes such items as lumber and sheet rock scraps, carpet remnants, cement blocks, roofing materials, etc.

7. Is Household Garbage Present? Household garbage includes all wastes which result from food preparation and other domestic activities. It includes both putrecible and non-putrecible forms. It is often referred to as residential wastes or kitchen wastes.

8. Is Special Waste Present? "Special Waste" refers to those large, bulky items which present unique disposal problems. Such items as large appliances (stoves, refrigerators, washing machines, etc.), mattresses and bed springs are usually incompatible with the waste collection service of a town or city. They are often taken to the "dump."

9. Are Dead Animals Present? This variable was recorded because of the obvious public health implications. Domestic, farm and wild animals were found.

10. Is Non-residential Organic Waste Present? Included in this waste category were such items as tree and lawn trimmings, moving crates, brush, feed and fertilizer bags, etc. Very often these types of refuse are also incompatible with organized waste collection systems.

11. Has Dump Been Burned? If there was evidence that the dump had been burned, this variable was recorded

positively. However, it was often difficult to tell whether the waste had been burned in the dump, or if some rural dweller had emptied his home "burn barrel" into the dump.

12. Is Dump Active? After a short time in the field, it became obvious which dumps were currently used and which were dormant. If the waste appeared fresh and recently deposited, the dump was considered active.

Site Variables

1. Dump Location: Distance from the Road. This distance was measured in feet from the shoulder of the road to the closest edge of the dump.

2. Dump Location: Public or Private Road. Two categories were established: (1) public roads such as section line roads and county roads; and (2) private roads which included all entries to private and commercial property.

3. Dump Location: Is Dump Visible from the Road? The dump was considered visible from the road if it could be viewed from an automobile. This was considered to be an important factor in attracting further dumping. In many cases, however, the dump was shielded by vegetation or hidden under a bridge so that it was not visible from the road.

4. Is Site Vegetated? The dump was considered as vegetated if adequate tree-form vegetation was present to provide concealment.

5. Is Dump Protected from View? While standing at the edge of the dump, if no houses could be ovserved in any direction, the dump was considered to be protected. Terrain vegetation and isolation were the primary protection factors.

6. Are "No Dumping" Signs Posted? The posting of "No Dumping" signs is virtually the only form of control with respect to promiscuous dumping. If a sign was posted anywhere in the immediate vicinity of the dump, this characteristic was noted.

7. Has Site Been Burned? This observation was included in an effort to define the fire hazard associated with promiscuous dumping. Evidence of site burning included such factors as charred branches and trunks of trees, burned grass, etc.

8. Road Quality. Four road categories, which generally eluded to their quality and usage, were established. Starting with the poorest quality road, these categories are: (1) dirt section line; (2) gravel section line; (3) asphalt section line; (4) county or state maintained highway.

9. Distance to the Nearest House. This distance was measured from the dump itself to the nearest occupied dwelling in one-tenth mile units.

Association of Dump Variables: Dump Typology

While the field work was in progress it became apparent that there were indeed identifiable regularities to the process of illegal dumping. No two dumps or sites were exactly alike, but there were similarities in environmental elements and in waste material in the dumps. These similarities suggested that the different types of waste management systems in the study area, and the varying social and physical environments have produced categories of dumps which are quite similar in overall characteristics. This is not to imply that these are rigorous classes of dumps, and that no variation exists, but only that similar disposal needs are manifested in the environment in like ways.

To investigate this hypothesis, R-mode principal component factor analysis was applied to the dump variable data set. If the speculation is valid, then the variables which characterize each of the dump types should load together as orthogonal factors. It is important to note that many of these dump variables were dichotomous, i.e., either they were present in the dump or they were not. This presents no particular problem in the factor model, however, as long as the frequency of any one value is no greater than 90 percent (Rummel, 1970, p. 216).

The representative results of the factor analysis are presented in Table III-2. All factors with eigenvalues >.75 were rotated and seven dimensions were drawn from the data

Table III-2

MATRIX I: Dump Variables, Representation of Rotated Factor Loadings

Variables	Factors 1	2	3	4	5	6	7
Percentage of Variance	20	15	11	11	13	10	10
1 Physical Size							.961
2 Dump in Depression		.840					
3 Drainage from Dump		.880					
4 Water Pollution					.884		
5 Odor				.805			
6 Construction Waste	.724						
7 Household Waste	.480		-.610		.424		
8 Special Waste	.311		.855				
9 Dead animals				.817			
10 Organic (Non-residential) Waste	.778						
11 Dump Burned						.958	
12 Dump Active	.678				.491		
	General Purpose Dump	Drainage	Special Waste Dump	Odor	Residential Garbage Dump	Dump Burned	Size

set. As expected, three distinct dump types were indicated in the factor pattern (factors 1, 3 and 5). This typology is discussed below.

General Purpose Dump

The first and strongest dimension emerging from the factor analysis defined an active refuse accumulation, here referred to as a "general purpose dump." This dump type contains a variety of waste forms including construction waste, non-residential organic refuse, domestic garbage, and, to a lesser degree, special waste. The photographs in Figure III-1 are general purpose dumps in McClain County (identified by high factor scores).

To gain an appreciation of this dump type, and perhaps explain causation, all factor scores >1.5 on factor 1, Matrix I are mapped in Figure III-2. Notice that the dumps are not confined to any one area of the study region, but do form definite "clusters" in several locations. Dumping is particularly heavy to the east and west of the city of Moore, to the north of Lake Thunderbird, immediately south of Norman in McClain County, around the town of Washington and the north of Lexington.

The concentration of sites around Moore may help explain this general purpose dump. According to the Cleveland County waste management officials, these are dumping areas with a lengthy history (oral correspondence, August Helmbright, Cleveland County Sanitarian). The area

General Purpose Dump

FIGURE III-1

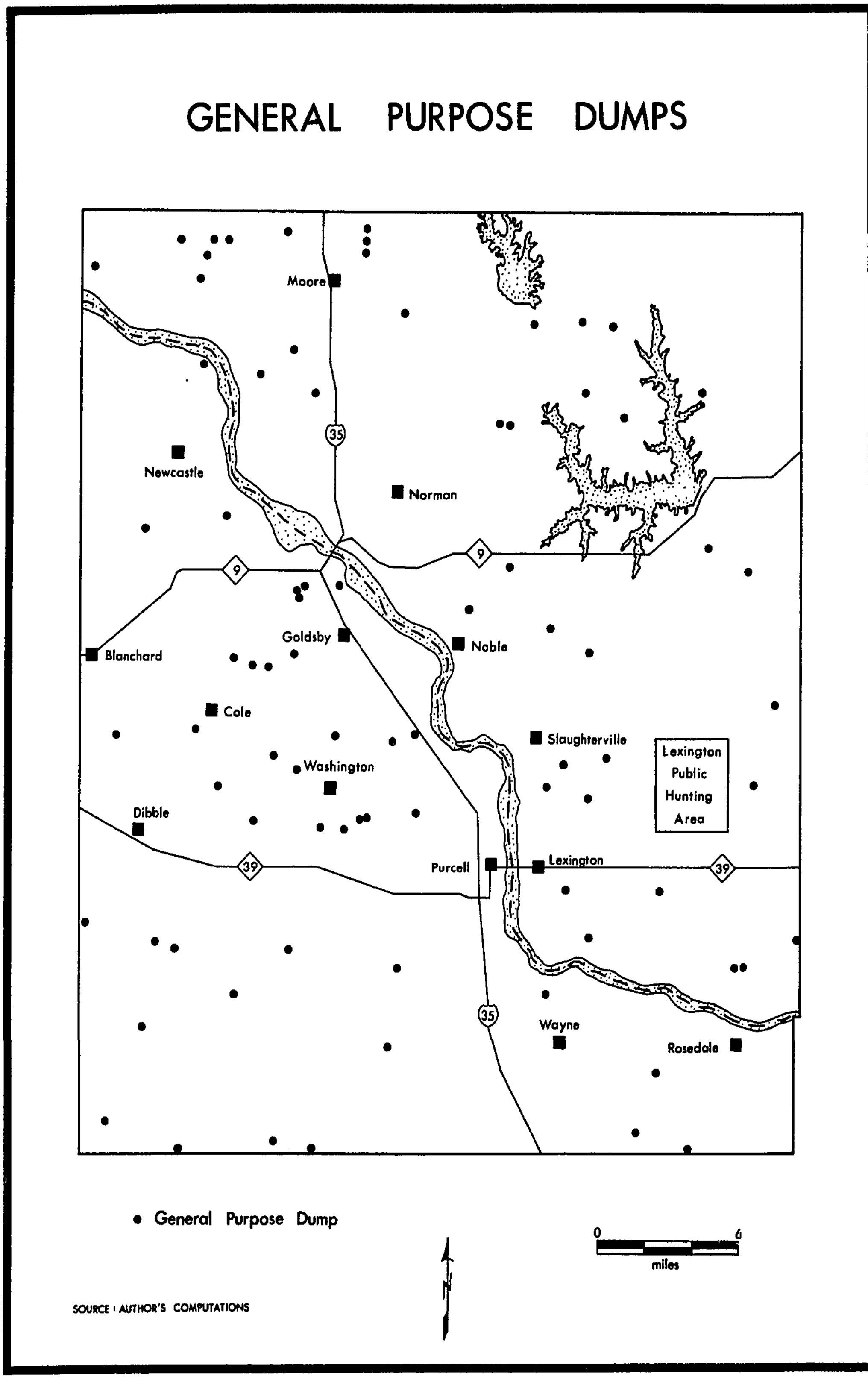
GENERAL PURPOSE DUMPS
Moore
Newcastle
Norman
Blanchard
Goldsby
Noble
Cole
Washington
Slaughterville
Lexington Public Hunting Area
Dibble
Purcell
Lexington
Wayne
Rosedale
35
9
39
General Purpose Dump
0
6
miles
N
SOURCE: AUTHOR'S COMPUTATIONS

FIGURE III-2

to the east of Moore is referred to as the Bryant Street dump and the cluster to the west is the South Oklahoma City dump. They have been in existence for several years and their locations are well known by rural and urban dwellers alike. The variety of waste types included in these dumps indicated that they are indeed used as all-purpose regional dumps. The concentration of general purpose dumps to the south of Norman and around the town of Washington are probably of similar origin. The clusters north of Lake Thunderbird and north of Lexington can be attributed to the dumping activities of the rural population.

Residential Garbage Dump

The general purpose dump discussed above may be located in a stream, and in many cases may contribute to water pollution, but a specific water polluting, active dump dimension was drawn from the factor analysis. Factor five on Matrix I refers to a small accumulation of household wastes, here designated as a residential garbage dump. This dump is commonly located in a small stream valley and the waste is often thrown directly into the water (Figure III-3).

The factor scores 2.0 on this dimension are mapped in Figure III-4. There appears to be a small cluster around the town of Dibble, but, with this exception, the dumps appear to be randomly distributed over the study area. It is suggested that this dump is a private disposal site for

Residential Garbage Dump

FIGURE III-3

RESIDENTIAL GARBAGE DUMPS

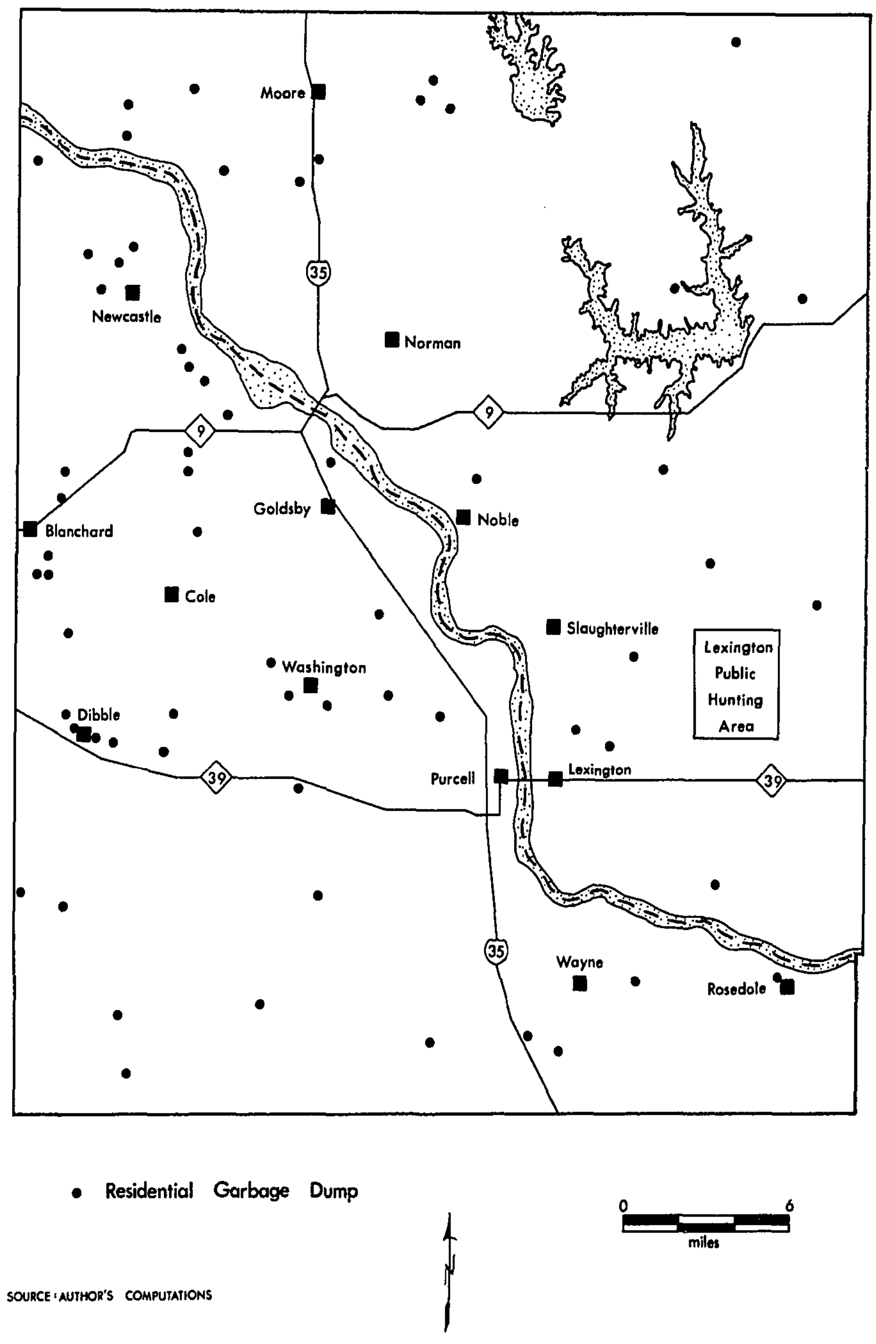

FIGURE III-4

a small group of rural residents -- perhaps only one family. It is simply a convenient disposal site for the daily production of residential wastes.

The Special Waste Dump

Different considerations are involved in the promiscuous disposal of special waste. Included within this category is any refuse which presents an unusual collection or disposal problem. Items such as sofas, washers and dryers, automobiles, etc. are, in most cities in the United States, completely incompatible with the waste collection system. When this waste accumulates, the individual is faced with the choice of paying to have it hauled away, or disposing of it himself. Obviously, many people choose the latter and the waste is carried to the outskirts of town and dumped.

Dimension three on Matrix I refers to the special waste deposits. In reality, the factor depicts a waste type dichotomy; the presence of special waste and the absence of household refuse. The high scores (>1.0) on this factor are plotted on Figure III-5. The map indicates that this isolated dumping practice is more prevalent in the densely settled northern reaches of the study region, but does occur throughout the area. Again, special waste is likely to be found in any dump, but the deposits referred to here seem to reflect only the occasional need to dispose of a large, bulky refuse item. As indicated in the photographs of

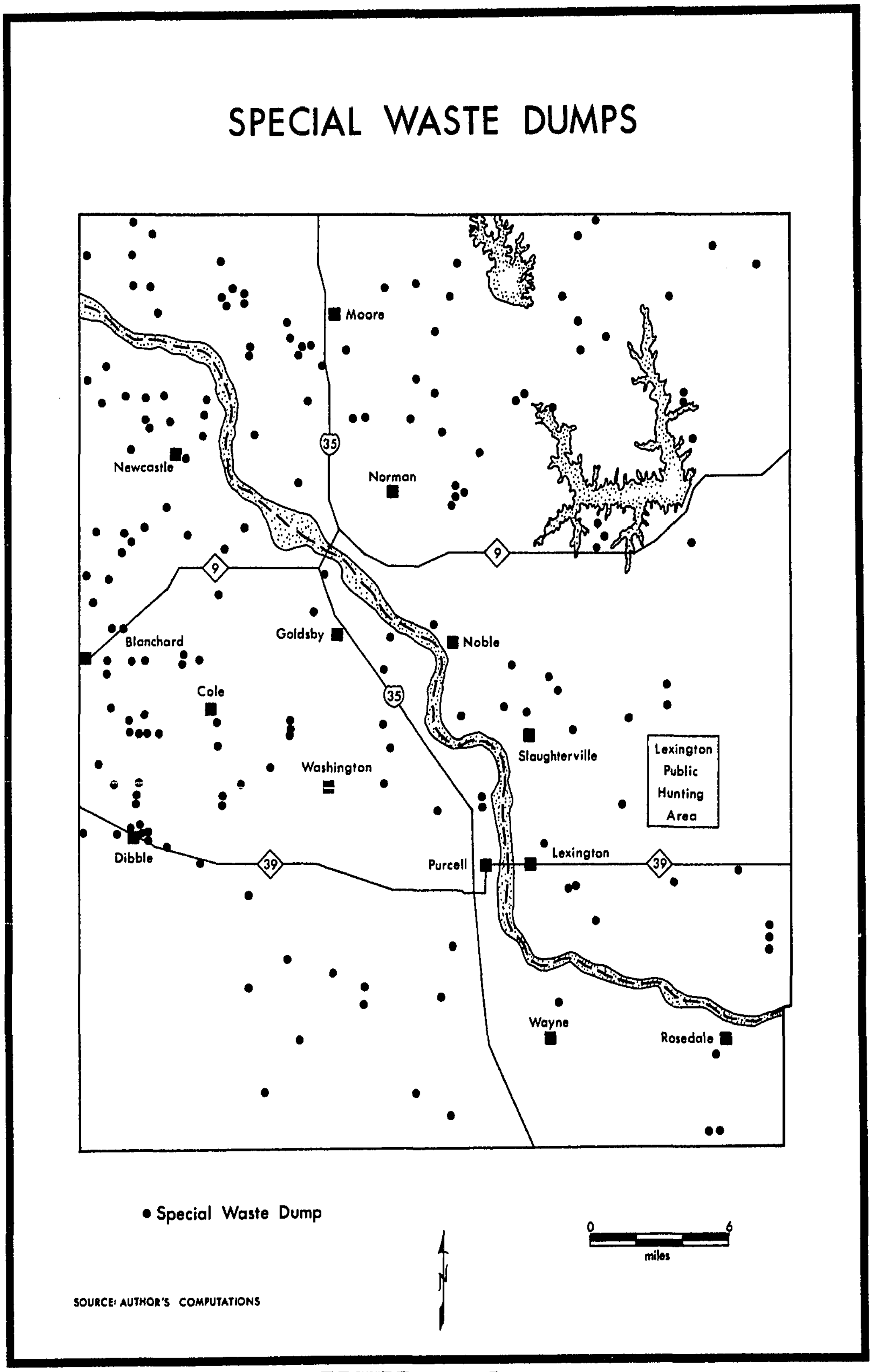
SPECIAL WASTE DUMPS
Moore
Newcastle
Norman
35
9
Blanchard
Goldsby
Noble
Cole
Washington
Slaughterville
Lexington
Public
Hunting
Area
Dibble
39
Purcell
Lexington
Wayne
Rosedale
Special Waste Dump
0
6
miles
N
SOURCE: AUTHOR'S COMPUTATIONS

FIGURE III-5

Figure III-6, this illegal dumping of special waste represents litter on a grand scale.

There is conceptual argument for each of the dump types discussed above. The general purpose dump serves the same function for people without waste management services as the community landfill does for residents of the city. The residential garbage dump accepts the daily waste production of nearby residents. The special waste deposit reflects the occasional need of all members of society to rid themselves of bulky unwanted items. To show the spatial relationship of the dump types to each other, all are depicted with different symbolization in Figure III-7. It must be emphasized, however, that there is considerable variation in each of these dump types. This arrangement is only an attempt to present an orderly explanation of the problem of promiscuous waste disposal.

Several other dump characteristics aligned themselves independently of the dump type factors. Dimension two was identified as a drainage factor. It simply indicated that drainage is commonly associated with dumps in depressions. Factor four, termed an "odor" factor, indicated that those dumps judged to be odorous very often contain dead animals. This is probably a reflection of bias on the part of the investigator -- a dump containing a dead dog was expected to have a foul odor. Dimension six, a "burn" factor, and dimension seven, physical size, emerged independently of all other variables.

Special Waste Dump

FIGURE III-6

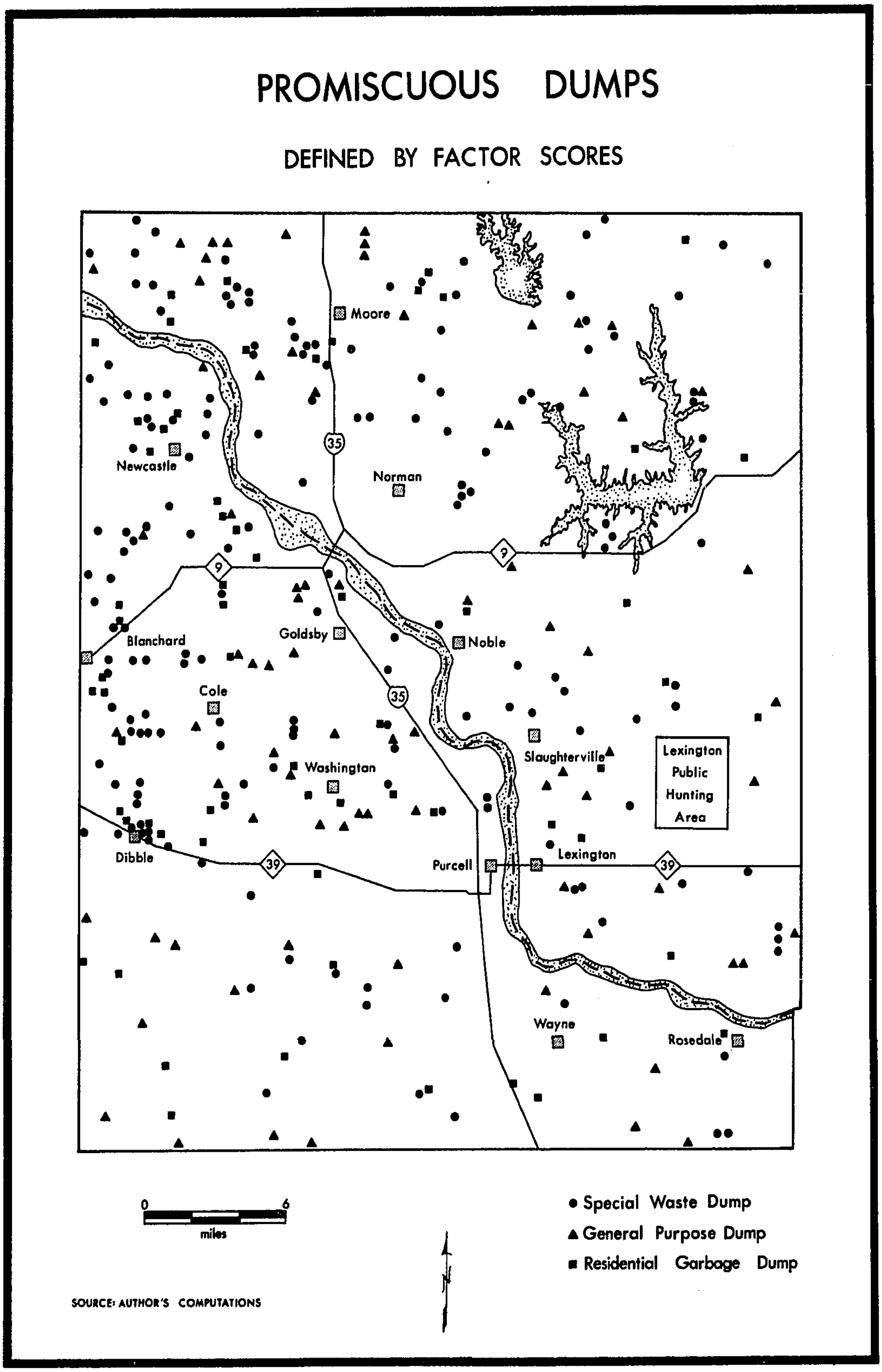
PROMISCUOUS DUMPS
DEFINED BY FACTOR SCORES
Moore
Norman
Newcastle
Blanchard
Goldsby
Noble
Cole
Washington
Slaughterville
Lexington Public Hunting Area
Dibble
Purcell
Lexington
Wayne
Rosedale
35
9
39
0
6
miles
• Special Waste Dump
▲ General Purpose Dump
■ Residential Garbage Dump
SOURCE: AUTHOR'S COMPUTATIONS

FIGURE III-7

Association of Site Variables:

The Environment of the Dump

In the formulative period of this study it became apparent that there were "characteristic" environments in which promiscuous dumps were located. The refuse accumulations were commonly found in remote, wooded areas, often in depressions and seldom in the immediate view of traffic or rural residents. These locations were chosen, it was surmised, because of some social consciousness on the part of the waste depositor, or perhaps a fear of legal admonishment if he was caught dumping his waste. In any event, an understanding of the elements of the promiscuous dump site would certainly broaden our appreciation of the process of illegal waste disposal.

The nine site variables collected in the field (Table III-1) were imput into the principal component factor analysis model discussed earlier in this chapter. Theoretically, if there were characteristics of site which were commonly associated with each other, these should load together as factors. Again, all factors with eigenvalues >.75 were rotated and seven orthogonal dimensions were produced from the nine variable raw data matrix. These results are included as Matrix II, Table III-3.

A majority of the site characteristics emerged as independent, one variable factors, indicating that there is little association between them and other measured

Table III-3

MATRIX II: Site Variables, Representation of Rotated Factor Loadings

Variables	Factors 1	2	3	4	5	6	7
Percentage of Variance	14	13	12	10	10	10	10
1 Distance from Road	-.846						
2 Public/Private Road	.847						
3 Dump Visible from Road				.993			
4 Site Vegetated			.932				
5 Protected from View		.696	.524				
6 Signs Posted						.998	
7 Site Burned					.999		
8 Road Quality							.983
9 Distance from Nearest House		.919					
	Seclusion	Protection - Distance	Protection - Vegetation	Visibility	Site Burned	Control - Signs Posted	Road Quality

attributes of site. Factors four (visibility), five (site burned), six (signs posted-control) and seven (road quality) all appear unrelated to the other characteristics. The first factor, here termed a seclusion dimension, indicated that dumps located on private roads are located at greater distances from the shoulder of the road than dumps on public roads.

Factors two and three, however, do provide some interesting comments on the environment of the promiscuous dump. These dimensions refer to the concept of protection -- whether or not the dumper is protected from the view of nearby residents when he is standing at the dump. Factor two supports an association between the protection of the site and distance to the nearest house. Factor three indicates a relationship between protection and vegetation. These two variables loading with protection on two independent factors suggest that both are determinants of privacy. The dumper feels protected at some distance away from a rural dwelling, or he may gain this same security in a heavily vegetated area.

There are certainly many other combinations and variations of site which afford protection to the promiscuous dumper. A physical depression or a sloping hillside out of immediate view would serve the same purpose. Nevertheless, the alignment of the distance and vegetation variables on the protection factors indicate that these are considerations in the search for a suitable dumpsite.

The Relationships of Dump and Site

The foregoing pages represent an attempt to uncover some of the less obvious dimensions of the process of promiscuous dumping. Matrix I indicates the association between characteristics of the dump itself. Matrix II views the relationships of variables of the dump environment, or site. To further explore this general theme, an attempt was made to relate the characteristics of the dump to the attributes of site. Two specific methodologies were used; the relationships between the dump and site characteristics were measured by canonical correlation and the overall dimensions are viewed by factor analyzing both data sets in one run.

The dimensions drawn from factor analyzing the dump and site variables can now be viewed as two separate sets of observations on related subjects; one on the dump itself and the other on the site in which it is located. As there is more than one variable in each set, the association between the two can be measured by canonical correlation. Essentially, this technique indicates how much variation in one set of variables is accounted by the variation in another (Aaker, 1971, p. 156). The factor score matrices of the dump and site factor analyses provided a metric value for each case on each factor. The dump factors were considered to be the left hand variables and the site factors the right hand variables (Table III-4).

Table III-4

Dump And Site Variables for Canonical Correlation

Left Hand: Dump Variables

1. General Purpose Dump
2. Drainage
3. Special Waste
4. Odor
5. Stream Bed Dump
6. Fire Hazard: Dump Burned
7. Physical Size

Right Hand: Site Variables

1. Seclusion
2. Protection: Distance from Nearest House
3. Protection: Vegetation
4. Visibility
5. Fire Hazard: Site Burned
6. Control: Signs Posted
7. Road Quality

The canonical analysis can be interpreted in much the same way as the results of a factor analysis. The two matrices are rotated until the alignment is found which accounts for the highest percentage of common variation between variables in the two sets. This alignment defines the first vector set. Each vector contains canonical variates, or weights, which function like weights in a regression equation. The value of each canonical variate indicates how much the variable contributes to the canonical vector. After the first vector set is defined, the matrices are again rotated until the alignment explaining the second highest percentage of common variation among the two sets of variables is found. The total number of vector sets defined is equal to the number of variables in the smaller of the two input matrices.

For present purposes, only the first vector set was extracted (Table III-5). The canonical correlation was not high (.392) and fell off rapidly in the second rotation. The variable most influential in defining the left hand (dump variable) vector was the burned dump factor (-.886). The right hand vector was defined primarily by burned site (-.746). This can be interpreted in two ways. Very simply it states that if the site has been burned, then chances are that the dump has been burned. More importantly, however, it indicates that dump fires very often spread out of the waste accumulation itself into the surrounding environment. This is apparent in the field.

Table III-5

Canonical Correlation: First Vector Set

Left Hand Weights: Dump Factors		Right Hand Weights Site Factors	
General Purpose Dump	-.322	Seclusion	.173
Drainage	.044	Protection-Distance	-.247
Special Waste Dump	-.093	Protection-Vegetation	-.469
Odor	-.153	Visibility	.049
Residential Garbage Dump	-.275	Burned Site	-.746
Burned Dump	-.886	Control-Signs Posted	-.356
Physical Size	.040	Road Quality	.061

The only other influence in the vector alignment is the suggestion that general purpose dumps, the established historical dumps spoken to earlier in this chapter, are generally found in a protected, vegetated environment. This association is logical and does help explain the longevity of some dumps and the demise (dormancy) of others. When a dump is protected by a shield of vegetation, it is used.

To take this relationship of dump and site attributes one step further, and to supplement the canonical correlations, all variables included in Matrix I and II were factor analyzed together. All observations were entered in the same way as previously and rotation was again halted at an eigenvalue of .75. In this run, 12 orthogonal dimensions emerged (Matrix II, Table III-6), two less than the combined total of Matrix I and II.

The factor structure in Matrix III is only slightly different than the two previous analyses, and most of the associations indicated earlier are reinforced. The three dump types of Matrix I are evidenced as factor I (general purpose dump), factor 6, the special waste accumulation) and factor 8, (the residential garbage dump). The drainage remains the same as presented earlier, as does the relationship of dead animals and odor. Surprisingly, however, the protection affiliations of the site variable matrix is not evident. The distance, vegetation and protection factors all load independently of each other. Vegetation does remain a characteristic of the residential garbage dump.

Table III-6

MATRIX III All Dump and Site Variables, Representation of Rotated Factor Loadings

Variables	Factors 1	2	3	4	5	6	7	8	9	10	11	12
Percentage of Variance	23	15	15	16	15	12	13	14	10	12	10	11
1 Physical Size										-.894		
2 Distance from Road					.856							
3 Public/private Road					-.822					-.427		
4 Dump Visible from Road									.983			
5 Site Vegetated								-.729				
6 Site Protected			-.808									
7 Dump in Depression		.802										
8 Drainage from Dump		.893										
9 Water Pollution								-.683				
10 Odor				.811								
11 Signs Posted											-.977	
12 Construction Waste	-.623											
13 Household waste	-.590					-.605						
14 Special Waste	-.317					.830						
15 Dead Animals				.818								
16 Organic (Non-residential) Waste	-.744											
17 Dump Burned							-.678					
18 Site Burned							-.884					
19 Dump Active	-.784							-.330				
20 Road Quality												
21 Distance from Nearest House												.933
	General Purpose Dump	Drainage	Protection	Odor	Seclusion	Special Waste Dump	Burn	Residential Garbage Dump	Visibility	Size	Control - Signs Posted	Distance

Summary

The objectives of this chapter were three-fold. First, an attemtp has been made to look at the types of waste in the rural environment. This was accomplished by defining categories of dumps which reflect the waste disposal needs of a population. Second, the site of the promiscuous dump was analyzed. The intent was to define the environmental elements of the promiscuous disposal site. Overall, the site variables appeared relatively independent of one another. It was pointed out, however, that the "protection" afforded by a site was heavily influenced by the tree-form vegetation of the area and the distance of the site from the nearest rural dwelling.

A third objective was to look at the relationships between the dimensions of the site and the attributes of the dump itself. Canonical correlation was employed to measure the association and the results were checked with a third factor analysis. The only strong association between the dump and site factors was the effect of burning. It is evident that dump fires often spread out of the refuse itself to the surrounding site. There appeared to be little correlation between the individual dump types and any specific environmental characteristics; i.e., no site characteristic is more commonly associated with one dump type than another. This finding is supported by both the canonical correlation and the factor analysis.

CHAPTER III

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CHAPTER IV

THE SPATIAL DISTRIBUTION OF PROMISCUOUS DUMPS: CLEVELAND AND McCLAIN COUNTIES, OKLAHOMA

This chapter is addressed to the spatial distribution of promiscuous dumps within the Central Oklahoma study area. It was hypothesized that promiscuous dumps are not a randomly occurring phenomenon, but are a spatially patterned reflection of the disposal needs of a population. The objective of this section is to describe this distribution and to identify and explain the variables which are important in the establishment of patterns. Unlike the preceeding chapter where individual dump types were defined and analyzed, Chapter IV makes no distinction as to the size or characteristics of dumps, but views the population of 828 refuse accumlations in total. The basic question is "How are the promiscuous dumps distributed within the study area and what factors are influential in the establishment of the pattern?"

In the statement of problem in Chapter I, it was asserted that as promiscuous dumps are a socially generated phenomenon, their distribution in the landscape is related to the distribution of human population. It was further stated, and discussed conceptually in Chapter II, that this population may realistically be viewed as two residential sets: an urban population which, for present purposes, includes the residents of the built up areas of all towns and cities, and a rural population contingency. These sets may be considered as waste generators which contribute in a spatially definable manner to the overall problem of promiscuous solid waste disposal. With respect to the above, a general hypothesis is stated which provides a structure for investigating the distribution of dumps.

> There are definable patterns to the distribution of promiscuous dumps in the study area. These patterns reflect the influence of the rural and urban population sets. As both of these populations are mobile, the landscape manifestations of their disposal practices constitute promiscuous dumping "regions." Dumping is more intense in the vicinity of the towns and cities and less severe in the rural environment.

Inherent in the above proposition is the assumption that there is a definable limit to the urban influence upon promiscuous dumping. The urban dweller will drive out into the rural-urban fringe of his town to dispose of refuse, but there is a point beyond which it is not convenient, nor necessary, for him to travel. This limit, then, defines an "interface" between the pattern of dumping generated primarily by the urban resident and that by the rural resident.

Beyond this simple statement of problem and concept, there are a number of complicating factors. Not the least of these is that, with respect to an urban influence, no two cities are alike. They differ markedly in population, physical size, efficiency of waste management systems, litter and dumping regulations and the enforcement of these regulations, and in many other ways. All of the characteristics influence the types and amounts of waste that are dumped promiscuously in the periphery of towns.

There are also many factors which influence the disposition of waste generated in the rural environment. Essentially, the countryside is inhabited by two types of residents, the farmer and the rural non-farm dweller. As alluded to earlier in this study, it is legal for the rural landowner in Oklahoma to dispose of waste on his own property. It is evident that many farmers do dump on premises and that this has the effect of reducing the amount of waste that would have to be disposed of in other ways.

The rural non-farm resident presents a different problem. He also must rid himself of his refuse, but he may have little, if any, land on which to dispose of it. Some of the volume of waste is certainly reduced in the individual burn barrel, but there is always a quantity remaining to be disposed of in another manner. If no authorized disposal site is convenient, the waste is often dumped promiscuously in the vicinity of his home or along routes of frequent travel.

Even if these deterministic variables could be indexed, there is one further problem with which to contend. Illegal dumping involves decision making on the part of each individual in the study area. This behavioral component is woven inextricably into the fiber of the problem. It involves ethics and values which were beyond the scope of this study, but which must be included in a more specific analysis of this form of environmental impact.

All of these problems, the complexities of city differentation, the relative influence of rural sub-populations and the behavioral characteristics of individuals all mitigate against the development of a general model to explain the distribution of promiscuous dumps. It is evident, however, that illegal disposal is more prominent in the vicinity of cities. It is evident also that there are promiscuous dumps in the rural environment which are realistically beyond the influence of the urban area. It is for these reasons that a regional explanation of the dump distribution is attempted here. The sequence of analysis was to first delineate the regions of urban impact and from that define the dumping patterns of the rural residents.

Analysis

The conceptual base of this aspect of the study is that illegal dumps are not randomly distributed, but are a function of the relative densities and characteristics of the population. The first step in the analysis, therefore, was to establish that the distribution is in fact, non-random. To accomplish this, the study area was divided into 120 nine-square mile cells and the dumps within each cell were counted (Figure IV-1). A Chi-squared goodness of fit test was then employed to compare this observed distribution to the theoretical Poisson distribution (Table IV-1). The calculated χ^2 of 32.37 was significant at an alpha level of .05, and the null hypothesis of no difference was rejected.

Looking first at the urban impact, the dump distribution map (Figure II-2) and the cell frequency map (Figure IV-1) attest to the concentration of dumps around towns and cities. To the west and south of Moore there is a high density of dumps. In McClain County, across the Canadian River from Norman and in the vicinities of Newcastle, Blanchard, and Dibble, the incidence of dumping is high. There is a limit to this urban influence, however, beyond which the effect of the city is negligible. The definition of this threshold would allow delineation of the urban and rural dumping regions.

In a theoretical sense, this urban impact can be viewed as a decreasing density of dumps outward from the

Table IV-1

Frequency Distribution (Dumps/cell)

Interval (Dumps/cell)	Observed	Expected
0-3	32	10
4	1	11
5	9	16
6	16	18
7	13	18
8	9	15
9	7	12
10	20	12
11+	20	12

$\chi^2 = 32.37$

Degrees of freedom = 8

$\delta = .05$

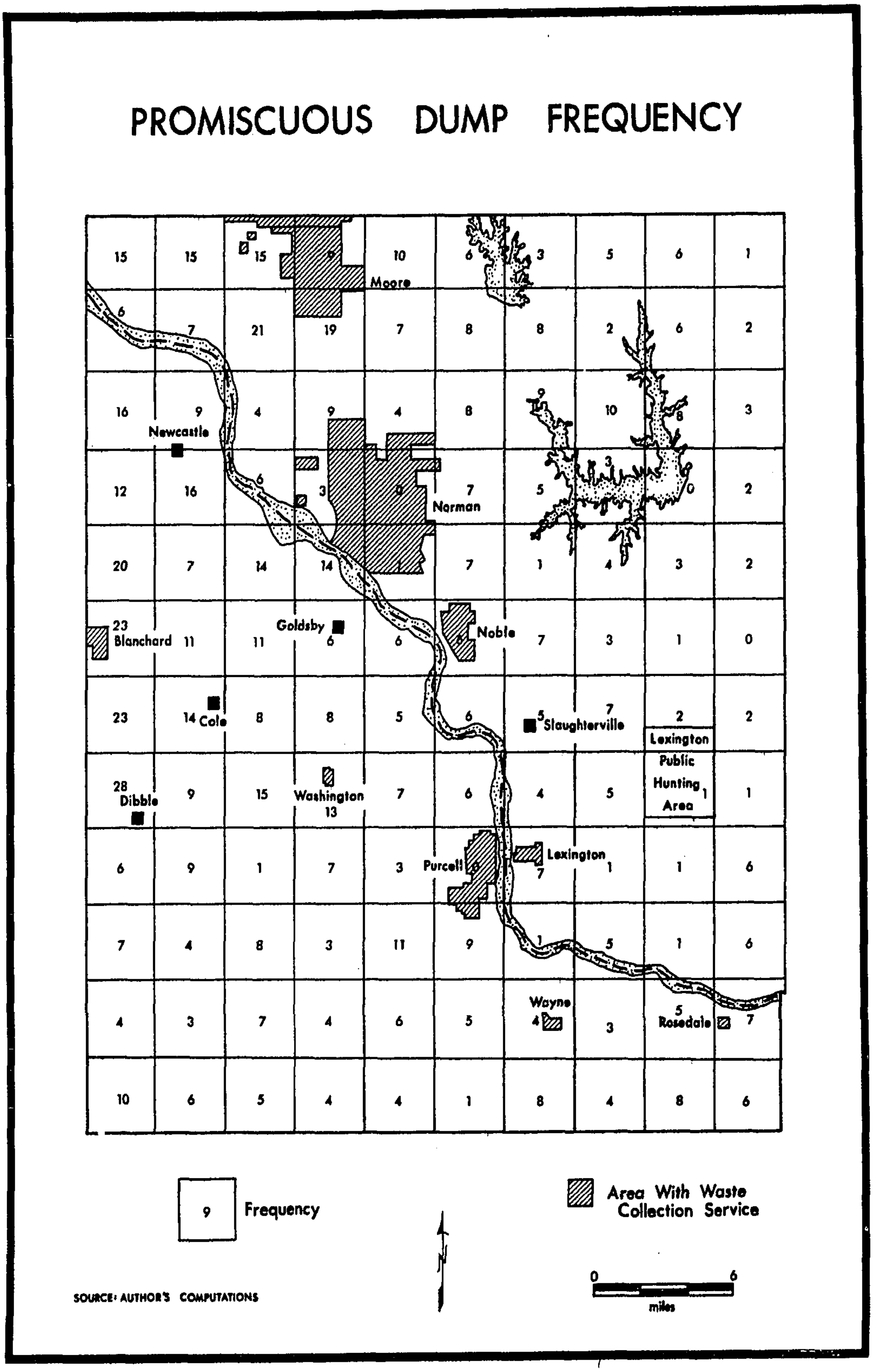
PROMISCUOUS DUMP FREQUENCY
Moore
Newcastle
Norman
Goldsby
Noble
Blanchard
Cole
Slaughterville
Lexington Public Hunting Area
Washington
Dibble
Purcell
Lexington
Wayne
Rosedale
Frequency
Area With Waste Collection Service
SOURCE: AUTHOR'S COMPUTATIONS
miles

FIGURE IV-1

city. In other words, there is a distance decay function involved. This outward decay is conceptualized in Figure IV-2 below.

HYPOTHESIZED DISPOSAL REGIONS

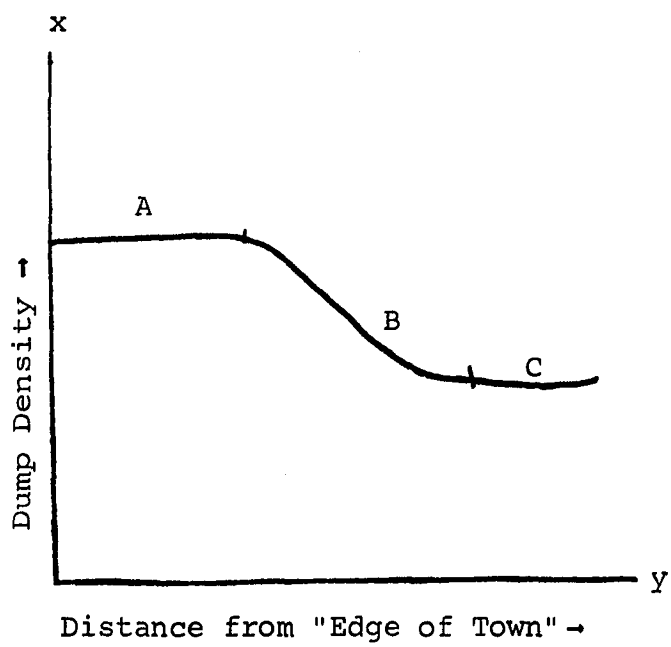

FIGURE IV-2

With the density of dumps increasing along the x axis, it is logical to view the decay function as consisting of three component parts. For the purposes of this study, the x axis is taken to be the limit of the waste management system of an urban area, i.e., the extent of waste collection services. Area A on the graph, then, might logically be viewed as a marginal, less densely settled zone on the periphery of the city. This area is referred to in the geographical and planning literature as the "rural-urban fringe" (Firey, 1946, p. 411). It is here where dumping is held to be most intense. Area C represents the rural environment at some distance from the city. This region is beyond the influence of the urban waste depositor. Area B represents a zone of transition from the urban impact region to the rural area.

Robin Pryor (1968, p. 206) presents a model which conforms in many ways to the conceptual argument of Figure IV-2. He suggests that in the gradation from the urban to the rural landscape it is possible to identify two components of the rural-urban fringe; an <u>urban</u> fringe in which the landuse is more like the urban area than the rural, and a <u>rural</u> fringe in which the landuse is similar to the rural hinterland of a city. Using this concept, Figure IV-2 may be reconstructed as below.

HYPOTHESIZED DISPOSAL REGIONS

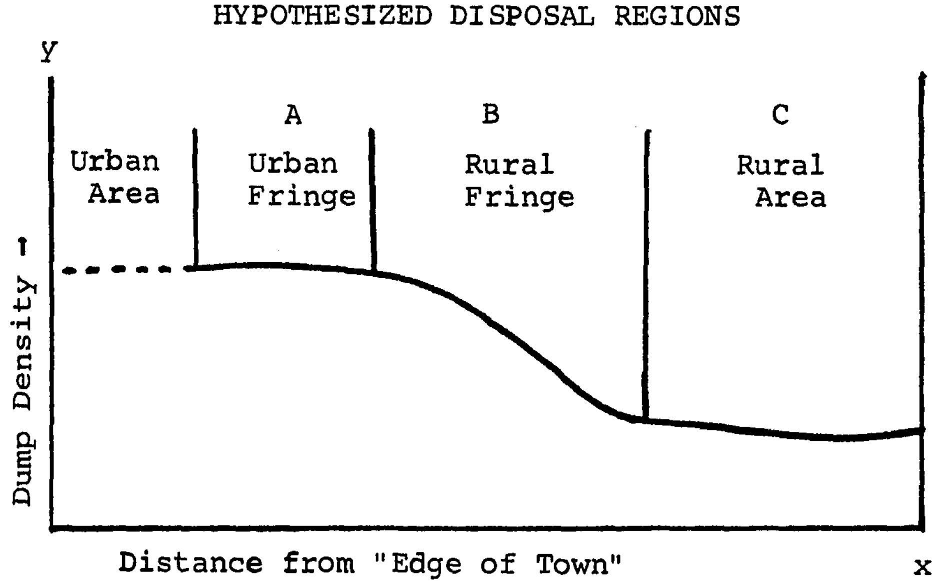

FIGURE IV-3

Pryor's concept of an urban fringe-rural fringe zonation is not totally applicable to the hypothesized disposal regions, but it does provide a format for discussing why the regions are held to exist. Region A is a zone of heterogeneous landuse, residential, agricultural and vacant land, in which the density of dwellings is less compact than that of the compact, built-up city. This area provides some secluded environments in which promiscuous waste disposal may take place. Region B is geographically beyond the urban impact region (urban fringe) and, at its outer margin, shades into the rural zone (Pryor, 1968, p. 206). It is regarded in Pryor's model as being more like the rural area than the urban area. For present purposes, it is considered a transitional zone between the urban dumping environment and the rural waste depository. The promiscuous dumps in region C accrue from the waste that is generated within that region. This zone is beyond the driving distance of the urban promiscuous dumper and, with no external material being transported into the area, the density of dumps is less.

The difference in cities alluded to earlier now begins to assume new proportions. The extent of the urban impact region (region A) should be determined by the characteristics of the town itself. The more populous a city, the gereater the dumping potential. The better the waste management system, the lower the dumping potential. Where two cities are situated close together, perhaps combined influence comes into play. If there is a physical or a political barrier, the urban influence may be rechannelled into a more hospitable dumping environment.

To establish an index of the dump distribution, it was necessary to group the 120 cells in Figure IV-1 into three dump density categories. The categories could then be mapped to see if they conform spatially to the hypothesis presented in Figures IV-2 and IV-3. As the mean dump density was seven dumps per cell (6.9), the transitional region (region B, Figure IV-2) was established around this point. The lower limit of the high density category was then set at nine dumps per cell and the upper limit of the low density group was drawn at a density of four dumps per cell. These categories are shown below.

Category	Dump Density
I	9+
II	5-8
III	0-4

The density categories were mapped in Figure IV-4 and are now referred to as Regions I, II and III. The high density cells are generally confined to the western and northwestern portion of the research area and the low density cells to the eastern and southeastern reaches. The mid-density category traces diagonally through the study area from northeast to southwest. The boundaries of the regions, however, are very imprecise.

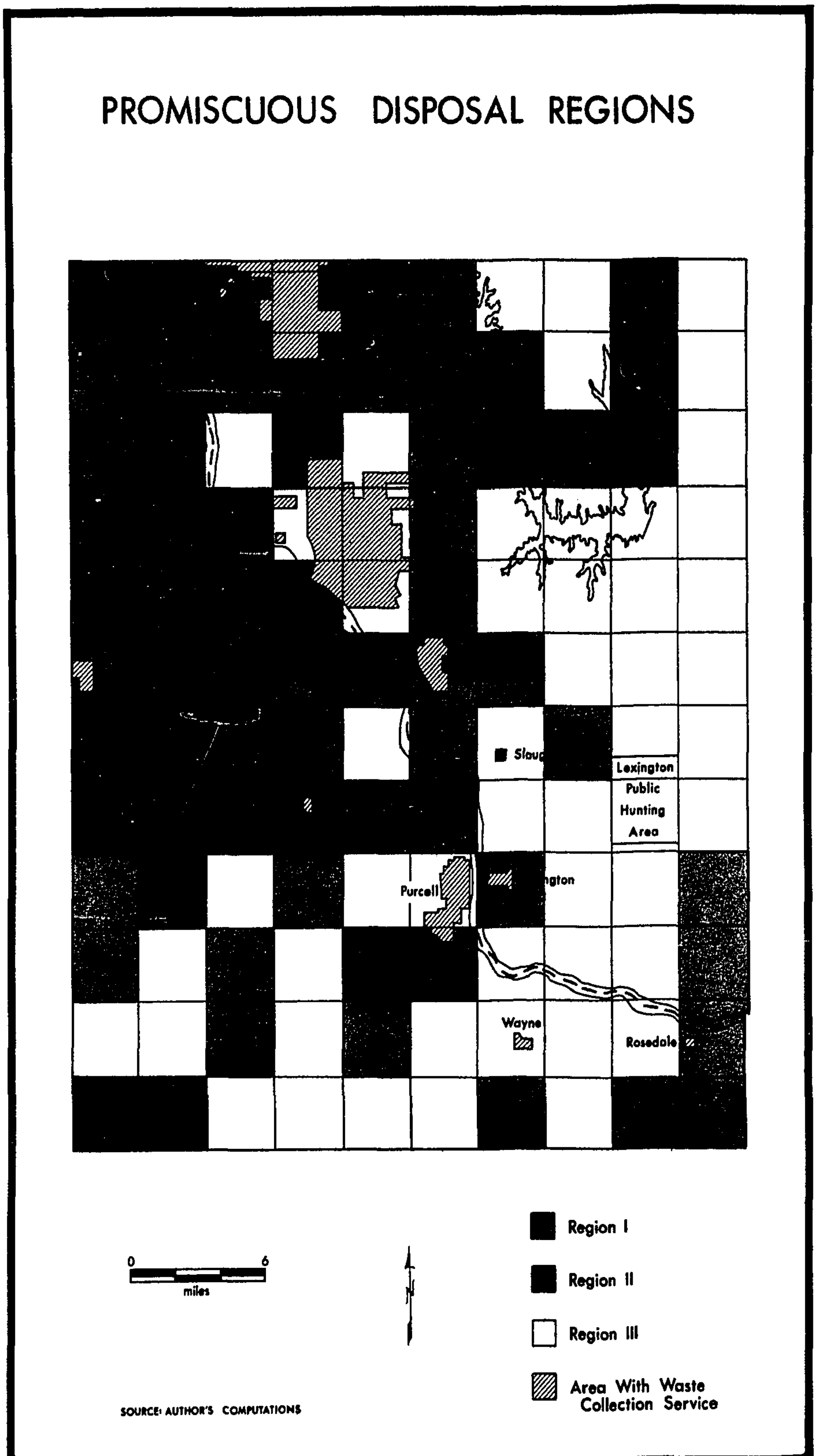
PROMISCUOUS DISPOSAL REGIONS
Slau
Lexington
Public
Hunting
Area
Purcell
ngton
Wayne
Rosedale
0
6
miles
Region I
Region II
Region III
Area With Waste Collection Service
SOURCE: AUTHOR'S COMPUTATIONS

FIGURE IV-4

The outlying cells of high dump density present an interesting pattern. To the north of Lake Thunderbird two contiguous dense cells are situated incongruously among low and medium density cells. In all likelihood, this reflects the suburban construction taking place in the area. Similar causation is advanced for the two high density cells south of Purcell. The one high density cell in the southwestern corner of the study region is contiguous with town limits of Lindsey, Oklahoma, south of the study area and probably reflects the dumping influence of that town.

In an effort to rid the patterns of peripheral noise, and facilitate a more exact delineation of regional bounds, a binomially weighted smoothing program was applied to the matrix of cell density values. This program, SMOTH, contained in the University of Oklahoma, Department of Geography Program Library, employes a nine point binomially weighted smoothing operator to remove high frequency spatial components from a matrix of geographical data (Krause, Paul, 1973, p. A-47). In the fundamental equation

$$B_{ij} = \sum_{m=-1}^{1} \sum_{n=-1}^{1} A_{i+m\ j+n} W_{mn}$$

W is a set of weights (3x3), A_{ij} is the original data point and B_{ij} is the smoothed value. The local smoothing operator is passed over each A value (input) to produce a set of B values (output). Essentially, the smoothing program reduces intra-regional variability.

Using the same class intervals as in the regions in Figure IV-4, the smoothed data were mapped in Figure IV-5. The regional boundaries were more generalized and the spatial patterning of the dump density regions was much more evident. Again, the regions were aligned from north-west to southeast as regions I, II and III, respectively.

Analysis of the Disposal Regions

In many ways the regions conformed to the pattern of dumping that was expected. They were related spatially to each other as was hypothesized, with the high and low density areas separated by a broad transitional zone. New perspectives must be investigated, however, in explaining causation. Some of the quantifiable characteristics of the regions are presented in Table IV-2 and, with latitude in conjecture, the units are discussed below.

Region I

Region I was a 270 square mile area comprising approximately the northwest one-quarter of the study area. It was characterized by high dump density, 12.9 per cell, and the heaviest single cell density of 28 dumps. The northern boundary of the region coincided with the margin of development of southwest Oklahoma City. It included the whole of the developed portion of Moore, plus the smaller towns of Newcastle, Blanchard, Dibble, Washington and Cole.

PROMISCUOUS DISPOSAL REGIONS
(Smoothed)

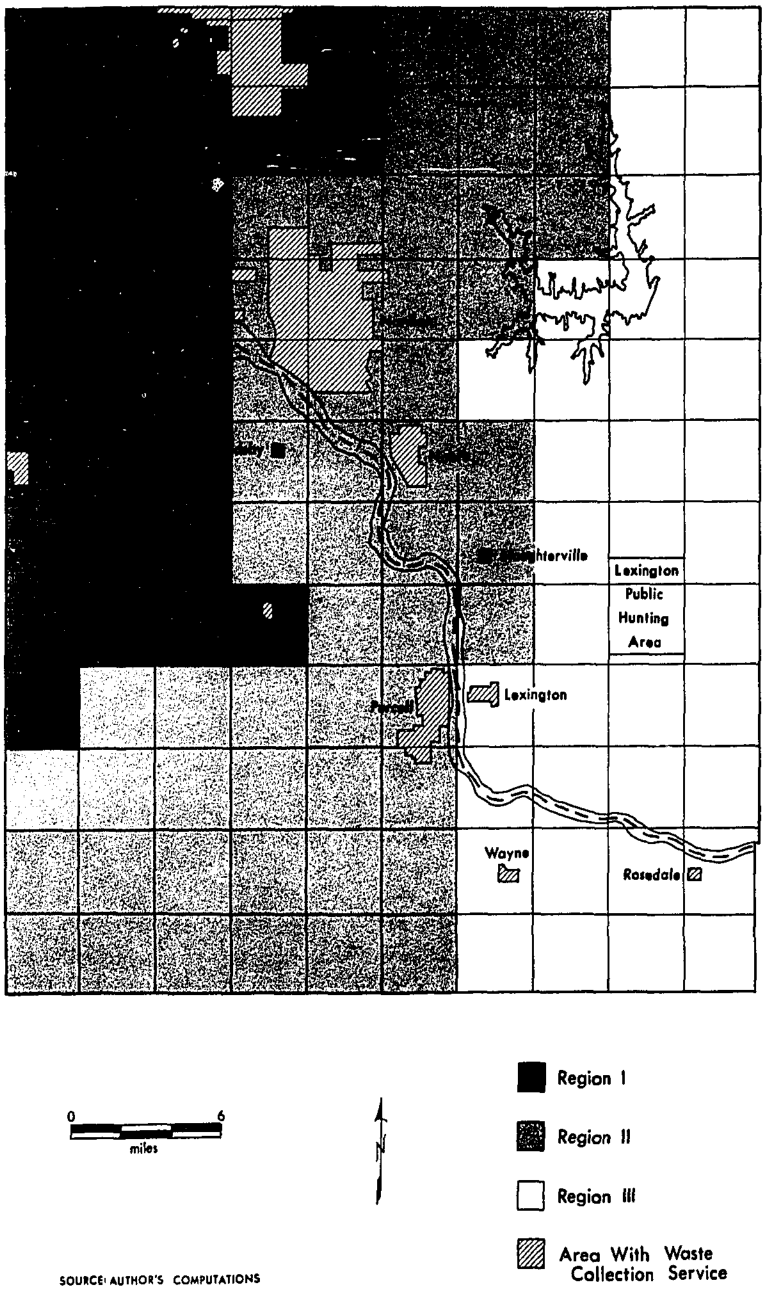

FIGURE IV-5

Table IV-2

Regional Characteristics

	Region I	Region II	Region III
number of cells	30	52	38
area (sq. mi.)	270	468	342
total dumps	387	300	140
dump density (per cell)	12.9	5.7	3.7
dump density (per sq. mi.)	1.4	.64	.41

In its northern reaches, region I conformed quite readily to the concept of an urban impact region (A in Figures IV-2 and IV-3). This area _is_ the rural periphery of southwest Oklahoma City and Moore and appeared to serve as a dumpground for those two cities. The section line roads in this part of the research area were literally lined with illegal waste deposits. As the landuse was largely agricultural, it was assumed that a major portion of the waste was funnelled out of the urban area.

The southern portion of region I, however, did not adhere as neatly to the scheme of the urban impact zone. It comprised a mosaic of towns and rural settlements interspersed with agricultural areas and vacant land. The towns varied significantly in types and qualities of waste management systems. Newcastle had a landfill and no collection service, the Blanchard collection service was available only in parts of the town and Dibble had no system at all. Perhaps, then, there was an overlapping urban influence evidenced in region I. In the introduction to the concept in Figure IV-2, the emphasis was placed on a single urban area, but when several towns are in close proximity to each other, it is logical to assume that their respective impacts will coincide or even overlap and result in the dump density observed in region I.

A further explanation is in the nature of the rural population. The McClain County portion of this region is quickly becoming a bedroom commuter environment for nearby towns and cities. Residents from the cities of Norman, Moore, Oklahoma City and Blanchard are spilling out into the rural reaches in search of a "country" lifestyle. As the rural environment becomes more heavily populated, and more waste is generated, this refuse must be added to that of the transient urban dumper. This combined rural-urban influence could easly culminate in large numbers of dumps.

Region II

The explanation of the pattern of Region II was less straightforward. It was stated that a transitional region should exist which separates the areas of rural and urban dumping influence. In the overall spatial scheme this hypothesis has been realized, but there are anomalies which complicate explanation. Included within this area was the densely settled portions of Norman, Noble and Purcell. It was thought that these cities should reveal an urban impact, but such was not the case. Areally, Region II was the largest of the three groups. It comprised a 468 square mile diagonal swath through the center of the study area. The dump density was less than half that of the urban impact zone, with 5.7 dumps per cell.

The inclusion of the three towns in region II was certainly a function of the quality of their waste management systems. All three towns have twice-weekly collection services and container privileges for outlying apartment complexes and commercial establishments. In addition, Norman provides an optional rural collection service. Thus it appears that efficient waste management programs in cities and towns have the effect of reducing the density of dumps in the surrounding rural areas.

Region III

The 342 square mile area defined as region III fits the conceptual expectations of a rural region. The dump density was low, 3.7 per cell, and the region was confined to the remote slowly growing eastern extremities of the study area. It may be safely stated that this area was beyond the necessary or convenient driving distance of the urban waste depositor. Even though three small towns are included in the region, Lexington, Wayne and Rosedale, the influence of these was not great enough to seriously effect regional dump densities. The promiscuous disposal in this area appears to have been conducted largely by the rural residents.

Review

In the general hypothesis presented at the beginning of this chapter, it was stated that there were definable patterns to the distribution of promiscuous dumps within the study area. These patterns, it was held, were a function of the population distribution. It was further suggested that in viewing dump density outward from cities, the regional organization might consist of three units; an area of heavy dumping near the city, a less dense rural pattern beyond the urban influence and a transitional region which represented an interface between the rural and urban area. The dumping regions that were generated conformed structurally to the postulated pattern.

CHAPTER IV

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Pryor, Robin J., 1968, Defining the Rural-Urban Fringe: Social Forces, V. 47, no. 2, p. 202-212.

CHAPTER V

THE CONTROL OF PROMISCUOUS DUMPING

The point was made in Chapter II of this study that there is no operational system which provides for the complete management of solid waste. Refuse invariably slips through the seams of the system and ends up in a roadside gully. There are management programs in force in the United States, however, which are designed to reduce the incidence of illegal dumping. The objective of this fifth chapter is to present a discussion of the types, cost and utility of those programs and to demonstrate where the findings of this research can contribute to the control of promiscuous dumping in the Cleveland and McClain Counties study area.

Coping Responses

In the solid waste stream depicted in Figure II-1, it was noted that promiscuous dumping is one form of disposal which occurs when refuse is not included within a waste management system. It was referred to as "unmanaged" waste. The approaches to the control of promiscuous dumping are attempts to bring all refuse generated within a defined area back "in stream" -- to include it within an organized system whereby it may be disposed of in a more environmentally sound manner.

There are two basic types of control programs. The first of these, referred to here as a public awareness-legal deterrent program, places the burden of control on the waste generator. He is asked to personally assume the responsibility levels II and III of the waste stream, handling and disposal. The second approach, a facilities provision program, seeks to remove a portion of the responsibility from the waste generator and allocate it to an authorized waste management authority. In this scheme the waste producer is relieved, to one degree or another, of the responsibility for level II of the stream, waste handling and level III, disposal. In effect, the two coping responses represent different levels of commitment to the control of promiscuous dumping. The characteristics of these control approaches are discussed below.

Public Awareness-Legal Deterrent Approach

This coping response is the most common method of control employed in the United States (oral communication, 1973, George Putnicki, Director Categorical Programs Division, Region VI, EPA). Such an approach consists of one or more of four components: (1) a set of anti-dumping laws or anti-litter statutes; (2) a public awareness program conducted by local officials to educate the public to the dangers of illegal dumping, and perhaps the punishment for violating the laws; (3) a monitoring program whereby local law enforcement personnel, sanitation officials or some other authorized public official makes periodic trips to common dump sites, to discourage would-be dumpers; and (4) some form of ex post facto control such as the posting of "no dumping" signs in established disposal areas. This approach is only an effort to treat the symptoms of illegal dumping and does nothing to alleviate the cause.

Interviews were held with the County Sanitarians of both Cleveland and McClain Counties to gain some insight into the effectiveness of the public awareness approach. Both waste managers agreed that the efforts were largely a waste of time (oral communication, 1973, August Helmbright, Sanitarian, Cleveland County; Jerry Mitchell, Sanitarian, McClain County). If a dump was closed in one location, and the site carefully monitored, another would be formed in some other area.

The only real deterrent in such a system is the fear of apprehension and punishment. Every state in the union has some type of statute that governs the defacement of public property. Illegal dumping is usually considered a violation of a "litter" law and is often classified as a misdemeanor (personnal correspondence, 1973, Sally

Steventon, Communications Department, Keep America Beautiful, Inc.). In Oklahoma a convicted dumper is subject to a fine of $200 and/or 30 days in jail (Oklahoma State Department of Health, 1971, p. 6). The punishment is more severe in some areas, less stringent in others.

An interesting question is posed by the system of punitive deterrence. There is a disagreement among waste managers and judiciary officials concerning the most effective "punishment." The official attitude is that the heavier the fine levied against a violater, the more effective the deterrent (oral communication, 1973, Leroy Rachels, Head, Solid Waste Management Section, Oklahoma State Department of Health). In practice, however, judges are very hesitant to administer harsh punishment for such a minor offense as dumping, and many cases never come to court (oral communication, 1973, Leroy Rachels). There is another view that a smaller fine, perhaps a $20.00, levied summarily against anyone convicted of dumping would be more effective, but there is no strong evidence to support either view.

There is one further component of control that may be included within this category of deterrent techniques. Many residents of rural areas try to deter illegal dumping on an individual basis. As discussed in Chapter II, when privately owned land is inundated with the refuse of others, it can represent a loss to the individual land owner.

While conducting the field reconnaisance, this investigator found a number of privately posted warning signs and on several occasions had to explain his activity at the dump to concerned land-owners.

Facilities Provision Approach

The second approach, or coping response, to the problem of promiscuous dumping assumes the perspective that people dump illegally because they have no choice. The waste generator must dispose of his refuse, but without a collection service or disposal facilities available to him, he is forced to dump on the roadside, As illegal disposal is considered a rural phenomenon, at least in effect, there have been a number of regional or "area-wide" waste management systems established in the United States. These systems vary in kind and quality, but all provide some alternative to promiscuous dumping.

Any form of a regional control system represents a shift in the responsibility for waste management from the waste generator to some authorized public organization. The perfect arrangement would be to relieve the individual of all responsibility, but, as this is neither economically feasible nor physically possible, most operational programs represent some arrangement of shared responsibility. Within this context, two types of systems are presently operational. The basic tenents of these are discussed below.

Provision of Disposal Sites

By far the most common form of regional system is one in which an authorized disposal site is provided for the waste generator, but he personally must assume the full responsibility for handling the waste until it reaches the disposal site. He is asked to carry the waste to the dump. The variations of this system type range from the concept of a "regional landfill" to the very popular containerized disposal approach. The costs and effectiveness of the systems vary as widely as the methods themselves.

In the formulative stages of the regional concept, much emphasis was placed on the central, or regional, landfill approach. This was evident in a perusal of the proposals submitted to the EPA for funding (U. S. Environmental Protection Agency, 1971c). The philosophy was to locate a fill where it was convenient to the largest number of people. As some driving and effort was involved in any waste disposal activity, the people would now simply drive to the landfill instead of the promiscuous dump.

An in depth study conducted in Humboldt County, California, however, drew attention to some of the negative aspects of the regional fill (Andres and Cope, 1970). First of all, the system is quite inflexible. A landfill is a permanent facility that cannot accommodate shifts in population. If all care was given to the convenience of the location with respect to population at one point in time, this convenience factor may be quickly eroded with shifts in population. In such a case the system would begin to breakdown.

Overall, the concept of a regional fill presented no real compliance incentives to an environmentally unaware public. Individuals still had to haul their waste to the dump. Also, the landfill might only be open a few hours a day and this could cause inconvenience. Certainly, the number of waste deposits is reduced, and this is ecologically desirable. But, if elimination and not reduction is the goal, then this approach fails, as does any system which requires individuals to handle their own waste.

To circumvent some of the problems associated with the regional landfill concept, the container system or "green box" control program was formulated. In this approach, the convenience and inflexibility objections are nullified by a regional network of small waste containers. Under this system the waste generator is only required to haul his waste to the nearest container to dump. The waste management authority assumes the responsibility of transporting the waste to the landfill. In one sense, the dump is being brought closer to the waste generator.

The green box system obviously offers many advantages over the central landfill program, but it is no panacea. There are several negative aspects which must be accepted. First, the operation is more expensive. There is an initial cost for containers and transportation equipment which was not associated with the regional fill system. Second, the program has the effect of creating a network of "mini-dumps." Unless the containers are attended carefully, they can create the same health hazard as the promiscuous dump they were designed to alleviate. One system in Baton Rouge Parish, Louisiana, had to be disbanded when the container sites created a whole new network of open dumps (Mackay, 1971). Flies, odor and aesthetic blight are often negative components of this system type.

Provision of Collection Service

The most elaborate form of regional waste management scheme is referred to as the "mailbox" system. Under this arrangement the waste generator has been relieved of virtually all waste handling responsibility. The producer is required only to bag is waste and set it beside the road; a collection crew then collects the garbage and hauls it to the landfill.

There are several mailbox systems operational in the United States, largely within the Tennessee Valley Authority (personal communication, 1973, Phillip Hyatt, Program Planning Staff, Tennessee Valley Authority). The programs are not nearly so widely used, however, as the rural bulk container systems mentioned previously. Probably the largest single deterrent to their widespread use is the operating costs, but there are also other drawbacks. As each rural resident sets his waste by the road, there is ample opportunity for the waste to be scattered. Wild and domestic animals will tear into the unprotected garbage in search of food and the rural landscape suffers an aesthetic decline. Another problem arises when the collection system is interrupted or breaks down, as for example, in bad weather. The waste simply accumulates on the roadside and the chances of it being scattered are accentuated.

Costs and Effectiveness of Regional Systems

Interviews, correspondence and literature search were conducted to gain an appreciation of the cost and effectiveness of rural waste management systems. Both these factors vary widely with the type of program, but enough information was available to provide an idea of their utility. Emphasis was placed on the bulk container program as this is apparently the most successful rural waste management approach.

There are two categories of expenses associated with the regional system. There is an initial cost to establish the program and an on-going operating cost to maintain the services. The initial expense would include the cost of land for a landfill (viewing the disposal area as a component of the system) and landfill equipment such as a bulldozer, fencing and other materials. The initial cost would also include compactor type waste hauling vehicles, bulk containers and any other facilities at the container site. All of these would vary from area to area and with type and quality of equipment.

From the information provided by waste managers involved with the regional systems, the financial problems are associated more with the establishment of the system than the operation. This initial cost can run from $50,000 to $300,000, depending upon the types of equipment purchased and the amount of equipment needed (personal communications, Leroy Rachels, 1973). Although this sum of money would not be exhorbitant for a city, it is a difficult sum for the rural region or small town to raise.

There are sources of funding for the establishment of area-wide systems, however. Even though the rural region does not have ready accesses to the bond market, general obligation and revenue bonds may be issued to provide the capital (Zauzner, 1971). In addition, the Farmers Home Administration has funded several regional waste management programs (personal communication, Dean Brokaw, Director Arbuckle Trust Solid Waste Management System). Larger regional authorities, such as the TVA, have in some cases included waste management programs (personal communication, Phillip Hyatt, 1973). Nevertheless, the initial cost in establishing the system is often a very difficult obstacle.

Once the initial funding problem is solved, the cost of operating the containerized system is surprisingly low. On a dwelling basis (3.5 people/household), the systems investigated by this author ranged in per annum costs from \$3.50 in Lawrence County, Indiana, to approximately \$23.00/year in Berkely County South Carolina (Berkely-Charelston-Dorchester Regional Planning Commission, 1971, p. 28; personal communication, 1973, Paul McBride, Sanitarian, Lawrence County, Indiana). A widely publicized and widely copied system in Chilton County, Alabama cost approximately \$7.50/dwelling/year (Bogue, 1971, p. 4). This operational expense varies from system to system, but in no case does it seem unreasonable.

How effective are these programs? To get some idea of how well the systems worked to reduce illegal dumping, several program directors were contacted personally. For the most part, the officials agreed that the area-wide systems were <u>very</u> effective in reducing promiscuous dumping. Two managers stated that the problem had been "completely eliminated." Only in one case, however, did the waste manager conduct periodic surveys to monitor illegal dumping.

The scarcity of data on the management systems makes appraisal very difficult. With no pre-control and post-control surveys, any evaluation of effectiveness is highly subjective. Certainly the programs reduce some of the illegal dumping, but, as stated earlier, some waste invariably escapes system. Most waste managers contacted in this study are of the opinion, however, that the regional system, specifically the bulk container approach, is the best available method to control illegal dumping.

Control in Cleveland and McClain Counties

Within Cleveland and McClain Counties, the responsibility for the control of promiscuous dumping is shared by county and city level authorities. The ultimate responsibility rests with the Sanitarian in each county (oral correspondence, Leroy Rachels, Head, Solid Waste Management Section, Oklahoma State Department of Health). Within the sparsely populated areas of some overbounded cities, however, the city also assumes responsibility for control, but this does not negate the authority of the county official.

There are no area-wide control programs, such as the container systems discussed earlier, in force in the study area. There are, however, management systems administered by several cities which extend into the sparsely settled areas. The town of Newcastle operates under a regional landfill system. The residents, including those beyond the built-up area, are asked to transport their refuse to a privately operated landfill (oral correspondence, J. H. Redman, Mayor, Newcastle, Oklahoma). The city of Norman has a rural collection system which is available to all residents, even those in the remote reaches of the city.

This approach is similar to the mailbox system discussed earlier, but cooperation is optional (oral correspondence, Earl Danner, Director of Public Sanitation, Norman, Oklahoma). The municipal landfills of the other towns within the study area exist as regional disposal sites for the residents in the vicinity (Tables I-2 and I-3).

There is nothing unique about Cleveland and McClain Counties, Oklahoma, which would prohibit the establishment of a regional waste management system. To investigate the feasibility of instituting such a program in the study area, data was drawn from operating systems in Jefferson and Humphreys Counties, Tennessee; Berkely and Charleston Counties, South Carolina; Bladen County, North Carolina; Lawrence County, Indiana; and Chilton County, Alabama. The emphasis was placed on the rural bulk container approach because of the availability of data.

To obtain information on the population of the study area which are not presently served by a waste collection system, discussions were held with the waste management officials in Cleveland and McClain Counties. An exact delineation was made of each operational collection system and the residences served by existing programs were deleted from the survey. An automobile reconnaisance was then made of the remainder of the study area and all residents counted. In the rural fringe of Norman, where rural collection is available, the Director of Public Sanitation provided the addresses of the outlying residents of the city which were served by waste collection. These were also deleted. It was determined that 22,198 people within Cleveland and McClain Counties were without waste collection services. Using an average of 3.5 residents/household, 6,342 residences were eligible cooperators in a regional control program.

In the container approach, one of the most critical factors is determining the container requirements for the region. For present purposes, the formula employed in Berkely County, South Carolina, was used (Berkely-Charleston-Dorchester Regional Planning Commission, 1971, p. 16). In the equation

$$R_c = \frac{P \cdot V_e \cdot V_c}{C \cdot W_y}$$

R_c is the container requirements (number of containers) for a given population, P is the population to be served, V_e is the estimated daily per capita production of waste V_c is the cumulated volume of waste for an established collection period, C is the cubic yard displacement of a container and W_y is the weight/cubic yard of uncompacted refuse.

Basing the present system on a per capita waste generation rate of 1.5 pounds/day (a figure commonly used for rural waste generation) on an uncompacted refuse weight of 300 pounds/ cubic yards, the number of containers required for the study area would be

$$\frac{22,198 \cdot 3.5 \cdot 1.5}{4 \cdot 300} = 197 \text{ containers}$$

A second critical factor is the size of the region in which a management is instituted. If the area is small, but densely populated, each residence might be only a short distance from a container site. If the area is larger, with a lower population density, each resident might have to drive further to find a container. The present research region comprises 1,080 square miles. With a container requirement of 97 receptacles, the area served by each container would be approximately 11 square miles. The data available on other systems indicates that this is an acceptable ratio. Using a sectionline road network, each resident would be no further than 3.3 miles from a container site.

The above values represent a uniform distribution of population and a uniform placement of containers. It was demonstrated in Chapter IV of this study, however, that waste disposal within Cleveland and McClain Counties, does not occur uniformly. It was assumed that the generating population was likewise non-uniform. As this fact can obviously influence the effectiveness of the system, the values discussed above are broken down in Table V-1 by the waste disposal regions delimited in Chapter IV.

As indicated in Table V-1, the values for the area as a whole do not adequately reflect the influence of the

TABLE V-1

REGIONAL WASTE MANAGEMENT SYSTEM
(Bulk Containers - Twice Weekly Collection)

	Study Area	Region I	Region II	Region III
Population Served	22,198	6,927	10,122	5,149
Residences Served	6,342	1,979	2,892	1,471
Container Requirement (4 cu. yd. container)	97	30	44	23
Square Miles/ Container	11	9	11	15
Maximum Driving Distance to Container	3.3	3	3.3	4.0

population distribution. The area served/container in Region III, for example, is much greater than for Region I. This is reflected in a 33 percent increase in maximum driving distance to containers, 4.0 miles in Region III as opposed to 3.0 miles in Region I. The point to be emphasized is that even though the research area would require 97 containers to serve the population, residents of the sparsely populated areas will find the disposal sites less convenient than the residents in the densely populated areas.

The cost of instituting and operating a rural collection system is difficult to determine without specific information on routing, price of equipment, costs of land for landfills, labor costs and many other factors. However, the average cost figures for the seven systems mentioned previously allow a crude determination of expenses. The use of the three established landfills at Newcastle, Norman and Purcell would negate the cost of having to establish a landfill. The costs, then, would fall into three categories: (1) initial expense for containers and waste hauling equipment; (2) operating costs for collection; and, (3) operating costs for disposal. The itemized expenses in Table V-2 are averages and estimates taken from reports on other systems.

The $10.35 annual cost/residence shown in Table V-2 is well in line with the reported operating costs of established programs. The model regional system in Chilton County,

TABLE V-2

COST ESTIMATES - REGIONAL WASTE

MANAGEMENT SYSTEM

INITIAL COSTS:	
4 cu. yd. Containers (97 @ $350)	$33,950
20 cu. yd. Compactor Trucks (2 @ $25,000)	$50,000
Miscellaneous Expenses ($75/container site)	$ 7,275
TOTAL INITIAL COSTS	$91,225
OPERATING COSTS:	
Collection (97 Containers @ $520/container/yr.)	$50,440
Disposal (6,076 ton/yr. @ $2.50/ton)	$15,190
TOTAL OPERATING COSTS/YEAR	$65,630
COST/RESIDENCE/YEAR	$ 10.35

Alabama, operates for $7.50/residence/year (Bogue, 1971, p. 35). It is emphasized that the cost figures applied to the study area are only estimates. They would certainly have to be adjusted for inflation and modified to precisely fit the characteristics of the region. They do indicate, however, that it is not beyond reality to institute a waste management system in Cleveland and McClain Counties, Oklahoma.

If control of promiscuous dumping can be secured for a reasonable fee, why is nothing done? Discussions with two Cleveland County Sanitarians provided some of the answers (Terry Hill, Steve Williams, Sanitarians, Cleveland County). First, the County Sanitarian is the logical official to head a control program. His activities, however, are outlined by agreement between the County Commissioners, County Board of Health, the State Board of Health and the State Health Department. Any program in which he is involved must be sanctioned by these authorities. The control of promiscuous dumping has a lower priority than the many other health and sanitation programs.

Second, the priority niche of promiscuous dumping is determined by the amount of concern voiced about the problem. The sanitarians recieve some complaints about illegal dumping, but they come largely from a few landowners whose land has been repeatedly violated. There appears to be, in the view of the officials, a general lack of concern about the problem. There needs to be some active publicity campaign to make people aware of the issue.

A third factor which inhibits the institution of a control program is the fact that a proposal would have to be decided by public referendum. County Commissioners, being elected officials, are very hesitant to support any program which would increase the tax burden of their constituents. Many rural residents have never paid for waste management and any proposal to do so might be very unpopular.

In sum, there is simply no starting point to get a control program in operation. Everyone is dependant upon someone else, and no one is willing to "rock the boat." In the opinion of this investigator, the proceedings must be initiated by some one outside of the system -- someone who is aware of the problem and concerned enough to spend the time and effort to force the issue. There needs to be some igniting spark.

Summary

This research represents an initial inquiry into the problem of illegal solid waste disposal. This disposal practice, termed "promiscuous" dumping, is but one small issue in the overall field of solid waste management. This study has indicated, however, that uncontrolled waste is potentially a dangerous environmental element. The work has also revealed that the problem has been seriously neglected in the waste management and civil engineering literature, and in the author's own discipline of geography.

The major objective of the study was to ascertain the nature and dimensions of the problem. As such, the research centered upon several different aspects of the problem. In the order of inclusion, the environmental hazards of the problem were documented, the types of waste dumped and the environments in which it was dumped were investigated, the spatial dimensions were analyzed and, lastly, the methods of controlling the problem were discussed. To provide data for the analysis, a mile by mile automobile survey was conducted in the Central Oklahoma study area and all dumps were documented.

Chapter II was concerned with the ecological or environmental ramifications. The literature revealed that there are possibly as many as 160,000 promiscuous dump sites in the United States. Each one of these sites has the potential to contaminate the environment in several different ways. There is, first of all, a definite public health hazard. The dump serves as a potential habitat for flies, rats, mosquities and other potential vectors of disease. If the disease agent is available, the malady may be disiminated from the promiscuous dump. There is also reason to be concerned with the contamination of ground and surface waters from illegally deposited waste. In many of the dumps located in the research area, the waste was thrown directly into the streams. In other situations the dumps were located in physical depressions -- areas of potential access to ground water. Given the nature of solid waste, the dumps undoubtedly contribute to water pollution.

The characteristics of the dumps themselves and the environments in which they were located, were investigated in Chapter III. The analysis revealed that there are identifiable categories of dumps in the rural areas which reflect the disposal needs of society. A general purpose dump was identified which represents the "historical" dumping area. A special waste accumulation was found which is largely attributable to the urban resident. A smaller residential garbage dump was found scattered throughout the study area and thought to be a product of the rural residents.

The analysis of dump environments was conducted under the assumption that there are elements of site which might be conducive to illegal dumping. It was found that the privacy of a site was provided by either a shield of vegetation or distance away from an occupied rural dwelling. All other site characteristics seemed relatively independent of one another. The dump types above appear not to be strongly associated with any particular site elements. They are as likely to be found in one location as another.

There is a distinct pattern to the distribution of dumps in the study area. Three dump density regions were defined which conform to the distribution of rural and urban population sub-groups, There is a region of high dump density on the periphery of cities which may be viewed as an urban dump ground. At some distance outward from this zone of urban impact is rural dumping region characterized by low dump densities. This area is beyond the driving distance of the urban waste depositor and the dumping is thought to be carried out by the rural residents. Separating these two regions is a zone of mid-range dump density which serves as a transition from the urban to the rural regions.

Chapter V notes that the control programs employed to reduce illegal dumping range from a virtual "do nothing" approach to very elaborate systems of waste management. The most functional method is thought to be a rural bulk container system whereby a network of waste receptacles is established to accept the refuse of rural residents. The programs now in operation appear to be effective and the cost to the rural resident is reasonable.

This study did not, nor was it intended to, solve the problem of promiscuous solid waste disposal. This must be accomplished through some compatible arrangement of engineering and environmental education. It is hoped, however, that contributions have been made -- contributions to both the understanding and appreciation of the problem and to the investigative discipline of geography.

CHAPTER V

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Subsequently, Sathe, Kulkarni, and Kelkar[2] demonstrated that, in most instances, the C-10 methyl was responsible for the abnormally high field absorption. They also attributed the shielding to the transannular π-system, but pointed out that the presence of oxygen substituents caused considerable variability in the chemical shifts of the vinyl methyl signals because of deshielding effects. These observations were also made without taking into account the geometry of the endocyclic double bonds, or the conformation of the 10-membered ring.

In the interim, the absolute configurations of a vast number of germacrane-derived natural products have been determined and the endocyclic double bonds are now known to occur in either the cis or trans forms at either site.[3,4]

A useful rule[5] which correlates the high field chemical shift noted above with trans double bond geometry is presented herein.

RESULTS AND DISCUSSION

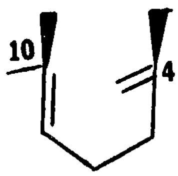
Table I shows the chemical shifts of the vinyl methyl pmr signals of 81 natural products (Structures in Table II) which possess the germacrane ring system. The geometry of the associated double bond is also listed where known. As shown by the first 34 entries in Table I, a vinyl methyl absorption occurring at δ 1.55[6] or higher field is invariably associated with trans geometry for the double bond to which the methyl group is attached. The illustration below shows the correlation graphically. If the vinyl methyl signal occurs between δ 1.12 and δ 1.55 then the methyl group resides on a trans double bond. If the signal is between δ 1.55 and δ 2.26 then the double bond may be *cis* or *trans*.

Double Bond Geometry	Cis or Trans	Trans	
Chemical Shift (ppm)	2.26	1.55	1.12

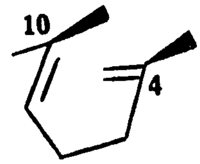
This relationship holds not only for hydrocarbons in the series, but also for compounds possessing most of the commonly encountered types and patterns of oxygen substitution. Thus, it appears that the dominant parameter resulting in strong shielding must be close approach of the shielded methyl to the transannular π-system,[8] and that the effects of oxygen substituents are of secondary importance.

Of the first 34 entries, the high field absorption is invariably associated with the C-10 methyl[9] in compounds possessing (with the exceptions **15**, **20**, and **34**) *trans*, *trans* configurations. The signals of methyl groups situated on *cis* double bonds (17 examples) all lie downfield from the δ 1.55 limit, as do those of a large number of methyl groups on *trans* double bonds.

Although it is impossible to make conformational arguments embracing all of these observations, certain conclusions may reasonably be drawn concerning those compounds displaying highly shielded methyl signals. The common preferred conformation for the *trans*, *trans* system (to the extent known) is the crossed conformation[10-15] in which the two methyl groups are *syn*, and disposed either *alpha* or *beta*. In the idealized form of this conformation, the planes of the two π-systems are perpendicular to the plane of the ten-membered ring, and are



A



B

roughly parallel to each other. In such a conformation (A), the two methyl groups would be equidistant from the shielding zones of the opposed π-systems, and would be equally shielded. The identity of the chemical shifts of the germacrene hydrocarbons 24 and 25 suggest that these compounds prefer this conformation in solution; this conclusion is reinforced by the extreme ease with which they undergo the Cope rearrangement,[16,17] the transition state for which requires precisely this geometry.

The predominance of examples of highly shielded C-10 methyls appear to be explainable in terms of a variation on this idealized conformation in which the planes of the two π-systems remain roughly parallel, but tilted with respect to the plane of the ten-membered ring, as in B. In this conformation, the C-10 methyl preferentially confronts the opposing π-system and is shielded, whereas the C-4 methyl is not shielded. Models suggest that this conformation (B) is readily accessible, but that the converse one, resulting from tilt of both planes in the opposite direction, is not, thus explaining the infrequent observation of a highly shielded C-4 methyl group.

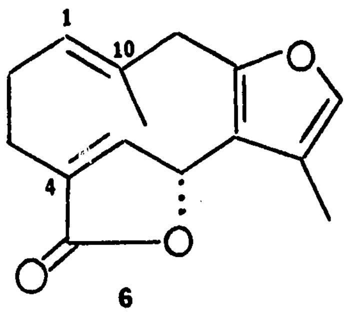
Models further suggest that the planes of the two π-systems can be separately tilted from the perpendicular in opposite directions, resulting in conformations in which neither of the methyls confronts the shielding zone of the transannular π-system, thus accounting for lower field signals. The influence of substituents on conformational preferences is extremely obscure in this system, and it is impossible at this time to correlate substituent types and positions with conformational preferences.

Incorporation of the transannular double bond into a conjugated system increases the likelihood of shielding of the opposed methyl group (see examples 1, 2, and 3). This probably results both from an increase in the area of the shielding zone of the opposed π-system[18] as well as increased rigidity of the ring which would restrict outward tilt of the methyl group.

In systems in which one of the double bonds has the *cis* configuration, published drawings[13,14] suggest a superficial similarity to to the crossed conformation with respect to the disposition of the two vinyl methyl groups toward the opposed double bonds. Models suggest, however, that in *cis*, *trans* systems, the center of the *cis* double bond is farther from the average plane of the ten-membered ring than that of the *trans* double bond, thus increasing the distance of the *cis* methyl group from the face of the opposed double bond (even though the planes of the two double bonds can adopt roughly parallel orientations). This conformational effect is consistent with the failure of any *cis* methyl group to be strongly shielded.

Using the rule presented above, the methyl group at C-10 in laserolide (13), a germacranolide of unestablished stereochemistry,[19] can be predicted with a high degree of certainty to reside on a carbon atom which forms part of a trans double bond system.

The rule is further brought into focus when two compounds, which differ only in configuration of one trisubstituted double bond, are compared directly. Linderalactone (6)[20] and neolinderalactone (44)[21] differ only in the configuration of the double bond at C-1, C-10.



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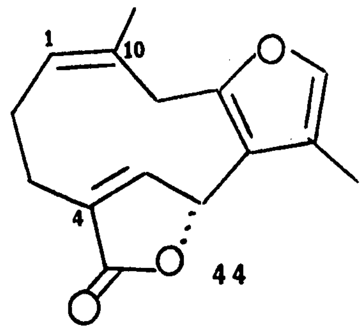

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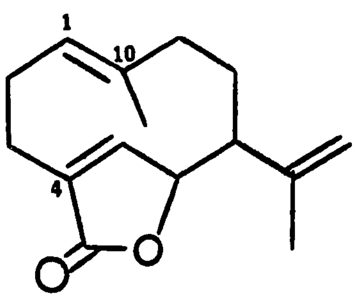
The C-10 methyl signal of 6 ($\Delta^{1(10)}$ trans) occurs at δ 1.27, while that of 44 ($\Delta^{1(10)}$ cis) is at δ 1.60. The latter signal is at remarkably low field, considering that the methyl group is across the ring from two conjugated π-systems. Aristolactone (27)[22] and isoaristolactone (38)[22] also differ in geometry at $\Delta^{1(10)}$. The signals in question occur at 1.48 and 1.59 ppm in the trans and cis cases, respectively.



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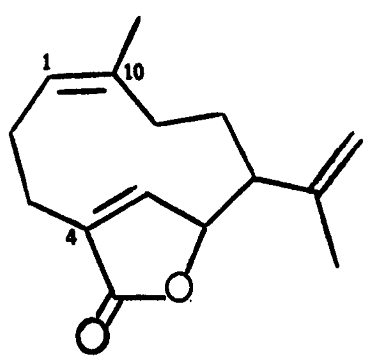

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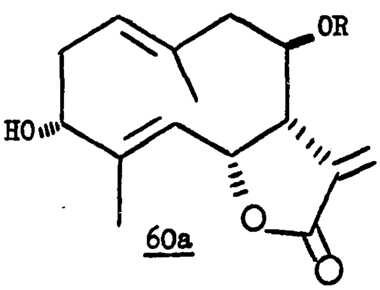
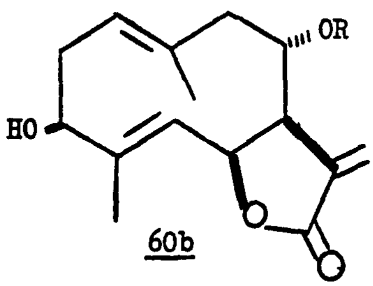
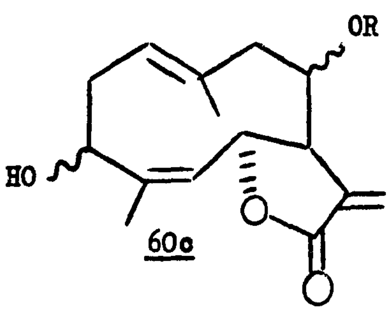
The only germacranolide reported to possess trans, trans geometry and methyl groups on both endocyclic double bonds, and which does not possess one vinyl methyl signal at relatively high field (δ1.68 or higher), is nobilin (60a or its enantiomer 60b).[23] The simplest and most probable explanation for this apparent anomaly is that the geometrical arrangement of the 10-membered ring at present assigned to nobilin is incorrect. We suggest that nobilin, which was isolated by Sorm, et al., from a plant of the compositae family is most probably represented by 60c. This view not only accords with the low field vinyl methyl signals (1.83 and 1.86 ppm), but is supported by the recent work of Hertz and Wahlberg who demonstrated that Samek's rule, which was used in assigning cis-fusion to the lactone ring in nobilin, is inoperable in germacranolides possessing Δ^4 cis.[24-25] The pmr spectrum of nobilin (60)[23] bears a striking resemblance to that reported for provincialin (55) and eucannobinolide (57),[25] germacranolides containing Δ^4 cis, $\Delta^{1(10)}$ trans and a trans fused γ-lactone as in 60c, and both of which are seen to be situated very near nobilin (60) in Table I.



60a



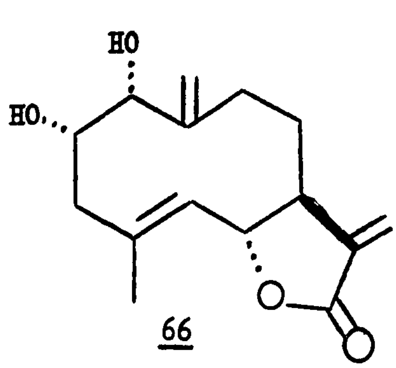
60b



60c

$R = -\overset{O}{\overset{\|}{C}}-\overset{Me}{\overset{|}{C}}=CHMe$

The compounds verlotorin (66),[26] artemorin (67),[26] artevasin (76),[27] and ridentin (77),[28] comprise an interesting array of structures, all of which possess a single endocyclic double bond of unknown configuration at Δ^4. It is interesting to speculate on the geometry of these unknown configurations based on the data revealed by Table I. Compounds 66 and 67 possess C-4 methyl signals at δ1.69 and δ1.71, values which are quite in accord with a large number of compounds in Table I with Δ^4 *trans*. The corresponding methyl signals in 76 and 77 are at δ1.85 and δ1.93, respectively. The rather low field at which these latter signals occur appears to be inexplicable by deshielding of their adjacent hydroxyl groups alone,[29] suggesting that the methyl groups in 76 and 77 reside on *cis* double bonds. These observations await corroboration by other techniques.



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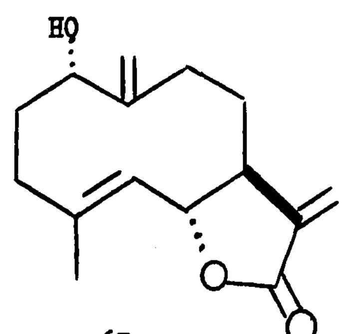

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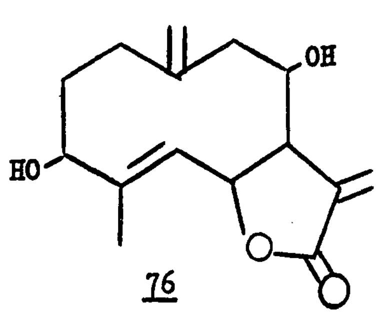

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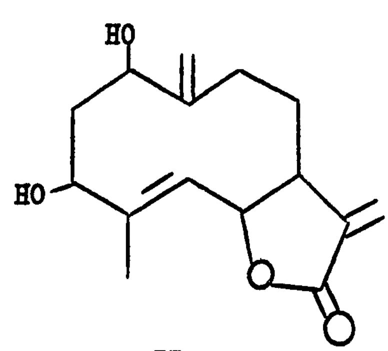

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Table I

Chemical Shifts of the Vinyl Methyl PMR Signals in Some Naturally Occurring Germacrane-Type Rings[a]

Compound	Solvent[b]	C_{10}-Me[c] (δ)	Geometry[d] $\Delta^{1(10)}$	C_4-Me[c] (δ)	Geometry[d] Δ^4	Ref.
1 Acoragermacrone	A	1.12	*E*	1.97	*E*	1
2 Germacrene-C	B	1.15	*E*	1.56	*E*	2, 3
3 Pregeijerene	B	1.17	*E*	1.55	*E*	4, 5
4 Neosericenine	C	1.20	*E*	----	*E*	6
5 Neosericenyl acetate	C	1.25	*E*	----	*E*	6, 7
6 Linderalactone	C	1.27	*E*	----	*E*	8
7 Furanodiene	C	1.28	*E*	1.59	*E*	9
8 Furanodienone	C	1.30	*E*	1.99	*E*	10
9 Salonitenolide	E	1.3	*E*	----	*E*	11, 12
10 Litsealactone	C	1.35	*E*	----	*E*	8
11 Salonitolide[e]	D	1.37	*E*	----	*E*	45, 81
12 Preisocalamendiol	B	1.37	*E*	----	-	13, 14
13 Laserolide	C	1.40		1.73		15
14 Dihydrocostunolide	B	1.41	*E*	1.67	*E*	16, 17
15 Sericenine	C	1.41	*E*	----	*Z*	18, 19

Table I (continued)

Compound	Solvent[b]	C_{10}-Me[c] (δ)	Geometry[d] $\Delta^{1(10)}$	C_4-Me[c] (δ)	Geometry[d] Δ^4	Ref.
16 Onopordopicrin[e]	E	1.41	*E*	----	*E*	12,20,21
17 Costunolide	C	1.42	*E*	1.70	*E*	22, 23
18 Balchanolide	I	1.43	*E*	1.66	*E*	24, 25
19 Tamaulipin-B	C	1.44	*E*	1.63	*E*	26
20 Sericenic acid	C	1.44	*E*	----	*Z*	18, 19
21 Bicyclogermacrene	F	1.46	*E*	1.63	*E*	27
22 Cnicin	D	1.46	*E*	----	*E*	12, 28
23 Agerol	C	1.47	*E*	[f]	*E*	29
24 Germacrene-A	B	1.48	*E*	1.48	*E*	30
25 Germacrene-B	I	1.48	*E*	1.48	*E*	31, 32
26 Hedycaryol	B	1.48	*E*	1.57	*E*	33, 34
27 Aristolactone	B	1.48	*E*	----	*E*	35
28 Arctiopicrin[e]	C	1.48	*E*	----	*E*	20, 36
29 Tamaulipin-A	C	1.49	*E*	1.74	*E*	37, 38
30 Eupatoriopicrin	C	1.50	*E*	1.78	*E*	22, 39
31 Scabiolide[e]	C	1.50	*E*	----	*E*	12, 21
32 Epitulipinolide	C	1.52	*E*	1.76	*E*	39
33 Germacrene-D	I	1.52	*E*	----	-	40
34 Isofuranodienone	C	1.55	*E*	1.89	*Z*	10
35 Tulipinolide	C	1.58	*E*	1.71	*E*	39
36 Linderane	C	1.58	*E*	----	-	41, 42
37 Chihuahuin	C	1.59	*E*	1.63	*E*	43

Table I (continued)

Compound	Solvent[b]	C_{10}-Me[c] (δ)	Geometry[d] $\Delta^{1(10)}$	C_4-Me[c] (δ)	Geometry[d] Δ^4	Ref.
38 Isoaristolactone	I	1.59	*Z*	----	*E*	35
39 Germacrone	B	1.60	*E*	1.42	*E*	32, 44
40 Artemisiifolin	C	1.60	*E*	----	*E*	12, 45
41 Zederone	C	1.60	*E*	----	-	46
42 Dehydrocurdione	B	1.60	*E*	----	-	47
43 Curdione	B	1.60		----	-	48
44 Neolinderalactone[g]	I	1.60	*Z*	----	*E*	49
45 Isabelin[g]	C	1.60	*E*	----	*E*	12
46 Eupatolide	C	1.63	*E*	1.73	*E*	22, 40
47 Ketopelenolide-B	C	1.63	*E*	----	-	50
48 Shiromool	C	1.64		----	-	56
49 Ketopelenolide-A	C	1.65	*E*	----	-	50
50 Chamissonin	G	1.67	*E*	2.26	*E*	51, 52
51 Laurenobiolide	C	1.68	*E*	1.68	*E*	53
52 Hydroxypelenolide	C	1.71	*E*	----	-	50
53 Dihydroparthen-olide	C	1.71		----	-	54, 58
54 Parthenolide	C	1.72		----	-	54
55 Provincialin	C	1.77	*E*	1.83	*Z*	55
56 Shiromodiol diacetate	C	1.78	*E*	----	-	56, 57
57 Eucannabinolide	C	1.79	*E*	1.82	*Z*	22, 55
58 Lanuginolide	C	1.80	*E*[h]	----	-	58

Table I (continued)

Compound	Solvent[b]	C_{10}-Me[c] (δ)	Geometry[d] $\Delta^{1(10)}$	C_4-Me[c] (δ)	Geometry[d] Δ^4	Ref.
59 Baileyin	I	1.80		----	-	59
60 Nobilin	D	1.83		1.86		60
61 Zeylanine	C	1.89	*Z*	----	*E*	61
62 Zeylanane	C	1.91	*Z*	----	-	61
63 Eupacunin	F	1.97	*Z*	1.80	*Z*	62
64 Eupatocunin	C	1.97	*E*	1.89	*Z*	62
65 Frutescin	C	----	*Z*	1.69	*E*	65
66 Verlotorin	I	----	-	1.69		66
67 Artemorin	I	----	-	1.71		66
68 Chrysanolide	C	----	-	1.76	*E*	67
69 Woodhousin	C	----	-	1.77	*Z*	73
70 Anhydroverlotorin	I	----	-	1.77		66
71 Heliangin	C	----	-	1.8	*Z*	64,68,69
72 Deoxyelephantopin	C	----	*E*	1.83	*E*	80
73 Erioflorin	C	----	-	1.84	*Z*	55, 70
74 Pyrethrosin	I	----	-	1.86	*E*	44, 71
75 Calaxin[i]	C	----	-	1.87	*Z*	72, 73
76 Artevasin	H	----	-	1.88		74
77 Ridentin	I	----	-	1.93		75
78 Liatrin	C	----	-	1.94	*Z*	76
79 Uvedalin	C	----	*Z*	1.96	*E*	77, 78
80 Polydalin	C	----	*Z*	2.00	*E*	77, 78
81 Melampodin	C	----	*Z*	2.10	*E*	63, 64

Footnotes for Table I

[a]The data compiled in Table I were obtained from the references cited. Chemical shifts are in ppm (δ) from tetramethylsilane. Various authors have assigned configurations to the double bonds based on the results of acid catalyzed cyclizations, Cope rearrangements, x-ray analyses, chemical correlations, circular dichroism, and nuclear Overhauser effect studies. [b]A = benzene-d_6, B = carbon tetrachloride, C = chloroform-d_1, D = dimethylsulfoxide-d_6, E = dimethylsulfoxide-d_6 plus chloroform-d_1, F = acetone-d_6, G = pyridine, H = pyridine-d_5, I = unspecified solvent. [c]A dash indicates the absence of a vinyl methyl group. [d]Cis double bonds are denoted by *Z*, and trans double bonds by *E*. A dash indicates the absence of a double bond, and unknown configurations are left blank. [e]Ref. 12 established trans configurations for the double bonds in 9 and 22. The 10-membered rings in 9 and 22 had previously been correlated with 16, 28 and 31 via 11.[20,21] Therefore, all of these compounds possess trans, trans double bonds. [f]The C-4 methyl signal in 23 is uncertain: it is either δ 1.56 or 1.77. [g]Only the major conformer is listed for 44 and 45. The minor (20%) conformer of 44 (C-10 Me δ 1.46 at -40°C) constitutes the single exception to the generalization presented herein; however, the abnormally high field chemical shift could be anticipated owing to the strained geometry in this conformer, and the anisotropic effect of the transannular α,β-unsaturated lactone.[79] [h]The trans assignment was based on a conformational analysis. [i]75 has been correlated with ciliarin.[72] Ciliarin possesses Δ^4 cis.[73]

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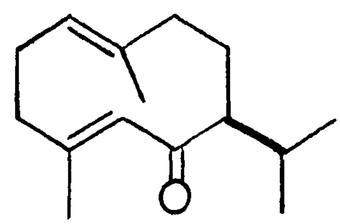
Table II

Structures For The Compounds Listed In Table I



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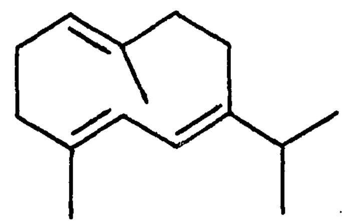

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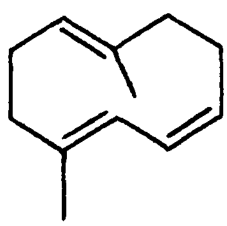

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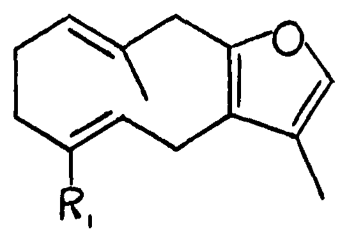

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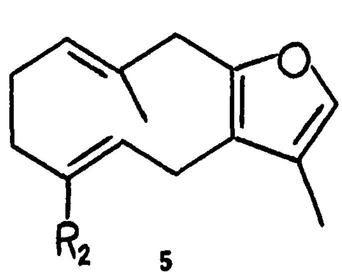

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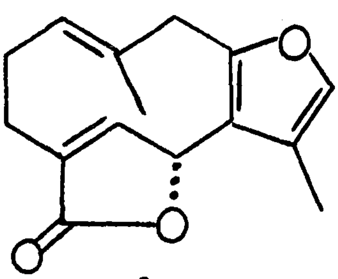
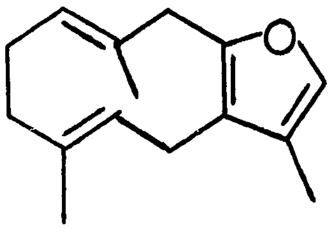


6

$R_1 = CO_2CH_3$, $R_2 = CH_2OAc$

Table II



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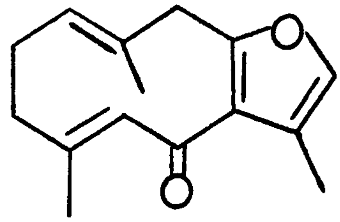

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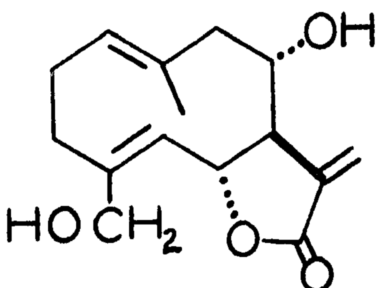

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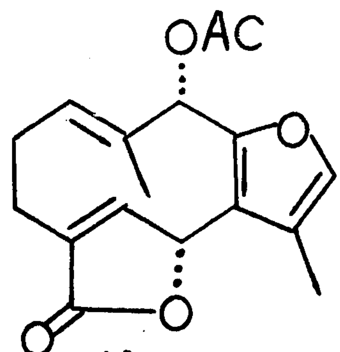

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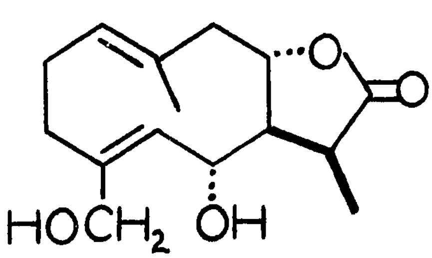

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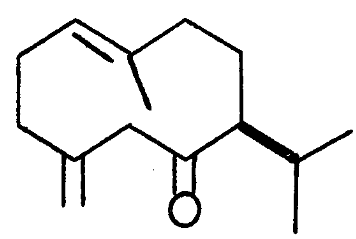

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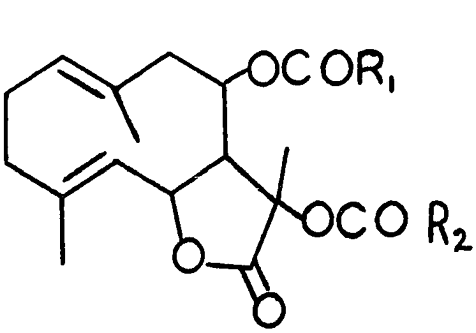

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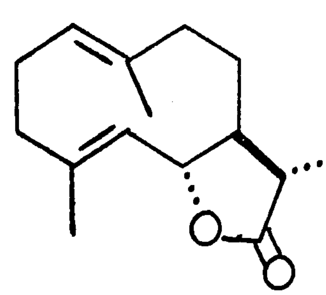
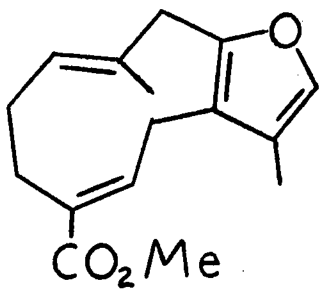


14

$R_1 = C(CH_3){=}CHCH_3$, $R_2 = CH_3$

Table II



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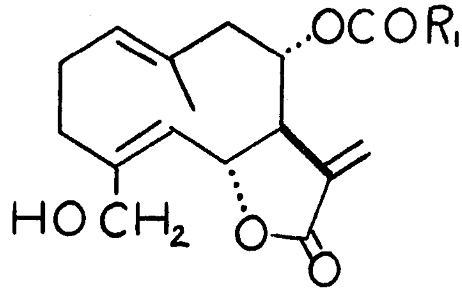

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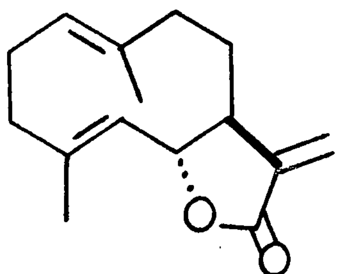

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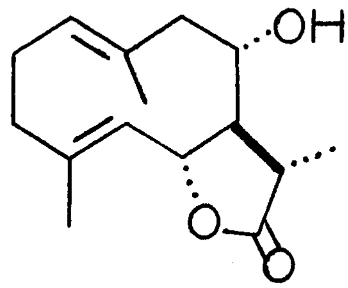

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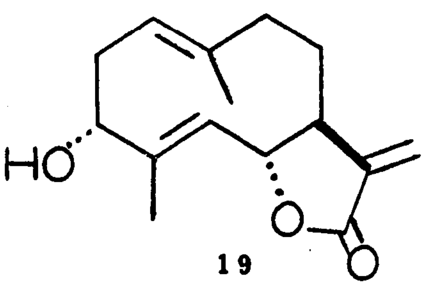

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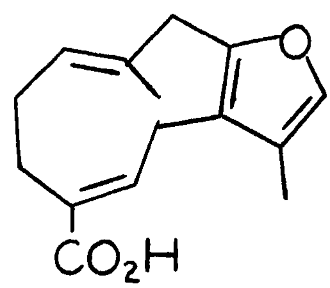

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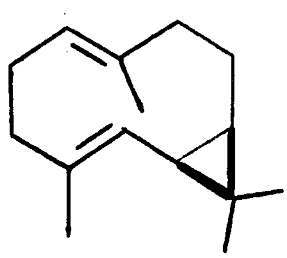

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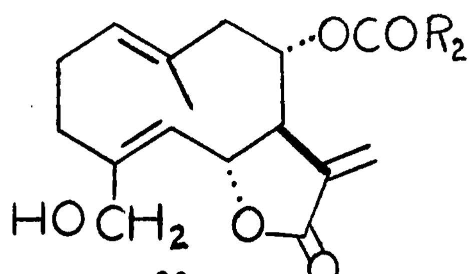
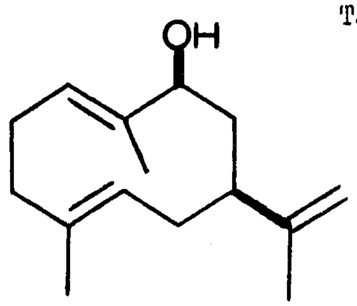


22

R_1 = $C(=CH_2)CH_2OH$, R_2 = $C(=CH_2)CHOHCH_2OH$

Table II



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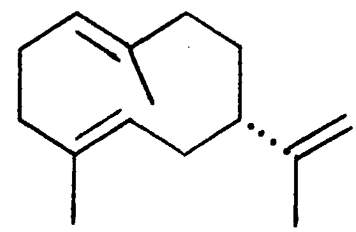

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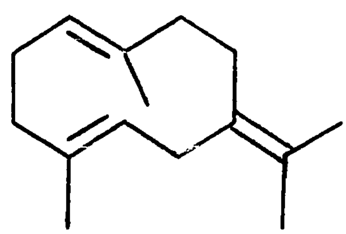

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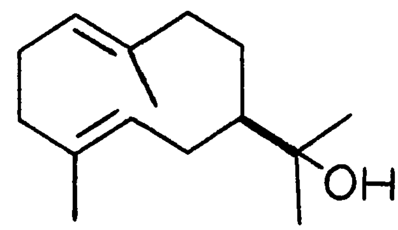

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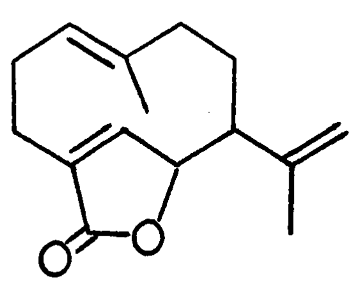

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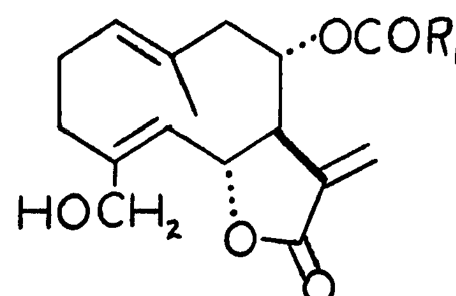

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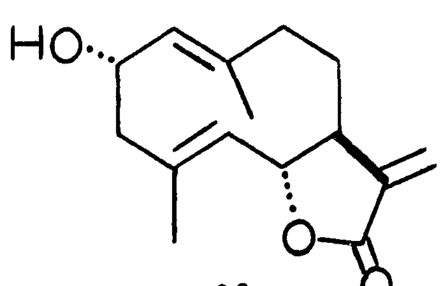

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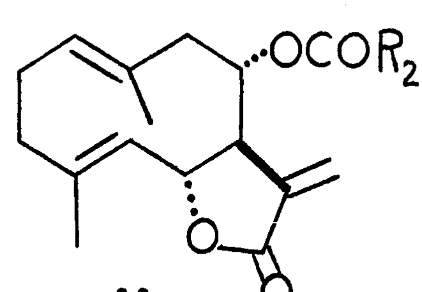
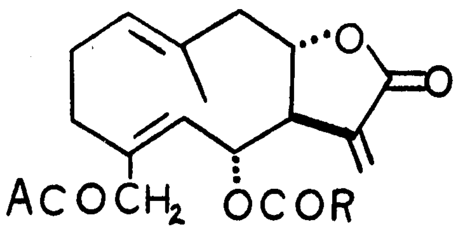


30

$R_1 = CH(CH_3)CH_2OH$, $R_2 = \underset{CH_2OH}{\cdot C}{=}CHCH_2OH$

Table II



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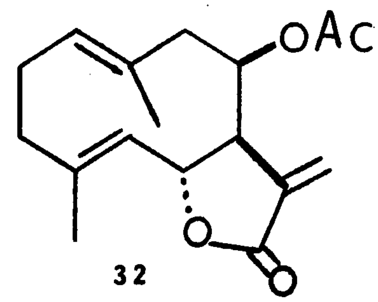

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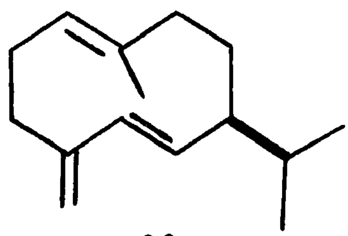

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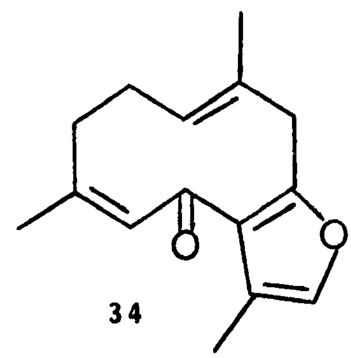

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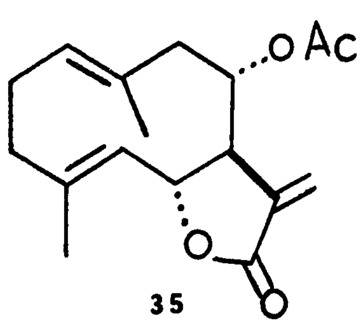

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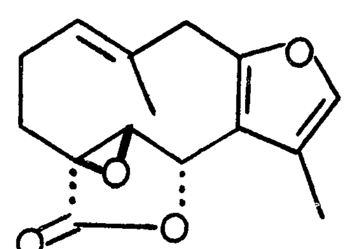

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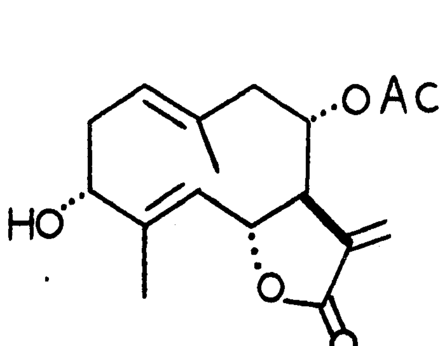

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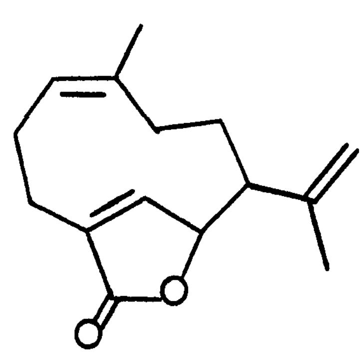

38

R = $C(CH_3)OHCH_2OH$

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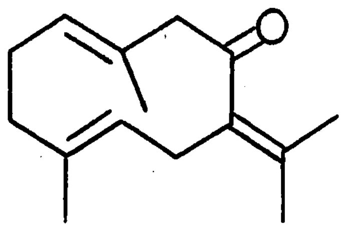

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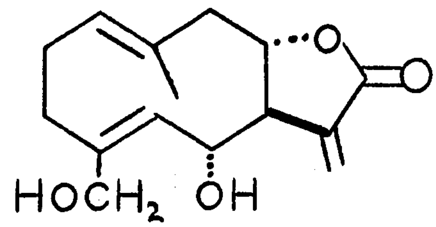

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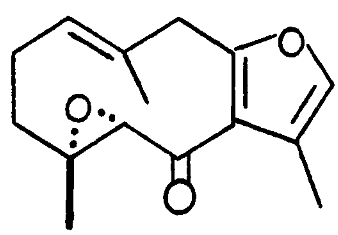

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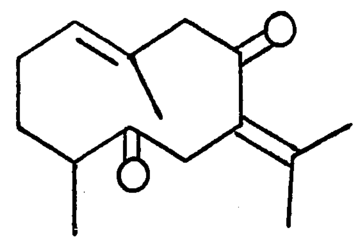

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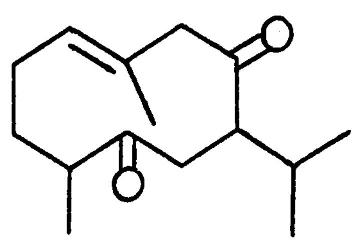

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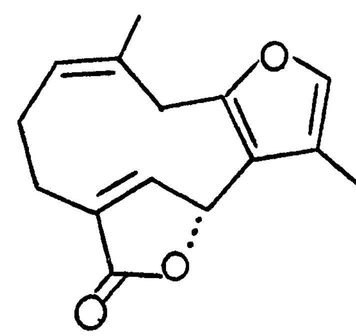

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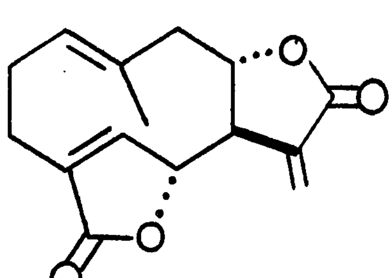

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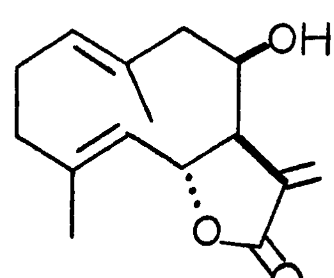

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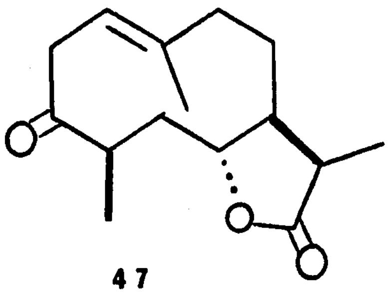

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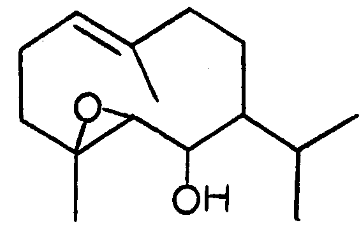

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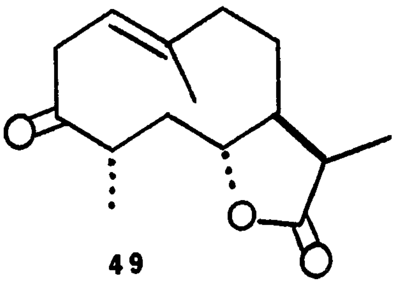

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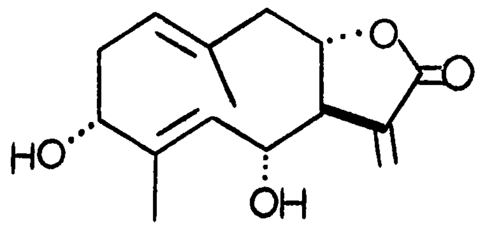

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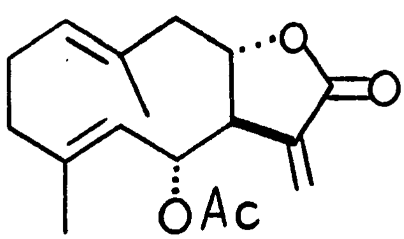

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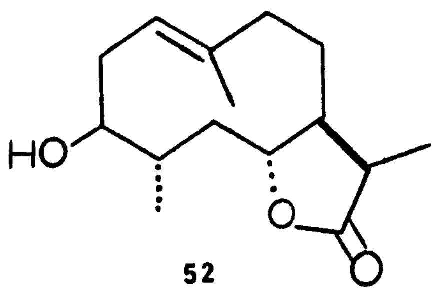

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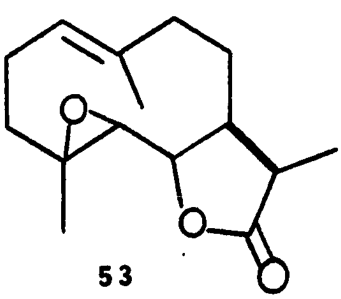

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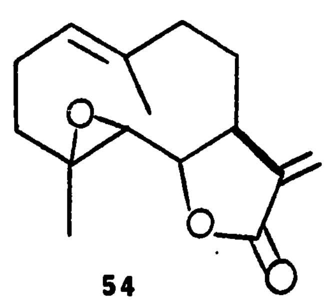

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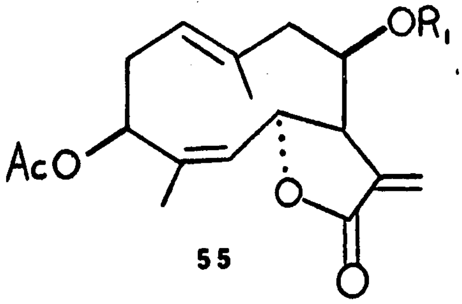
Table II



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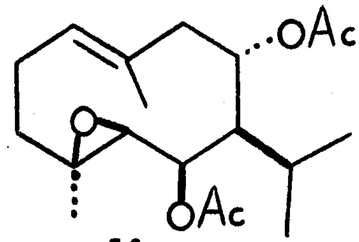

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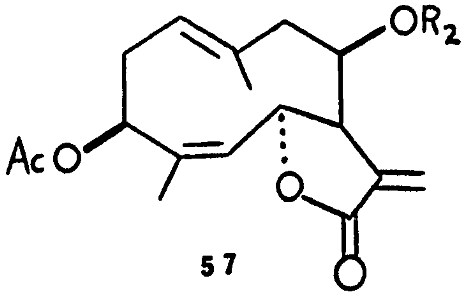

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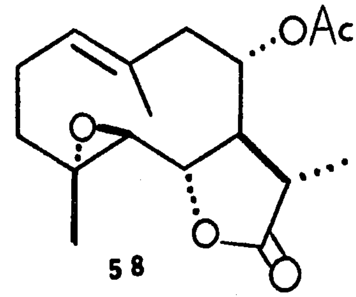

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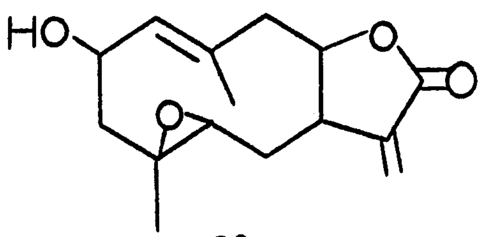

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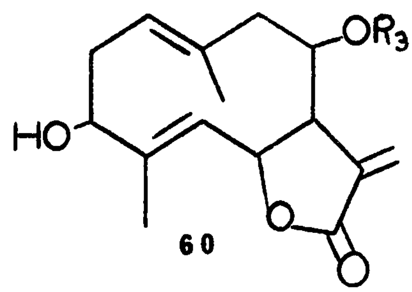

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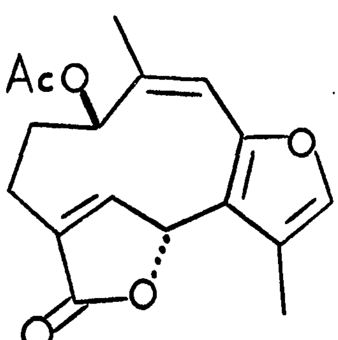

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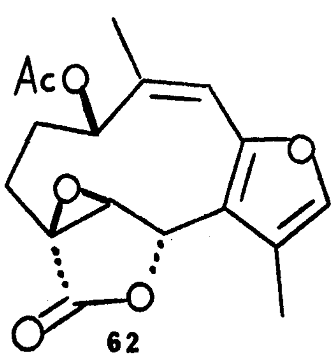


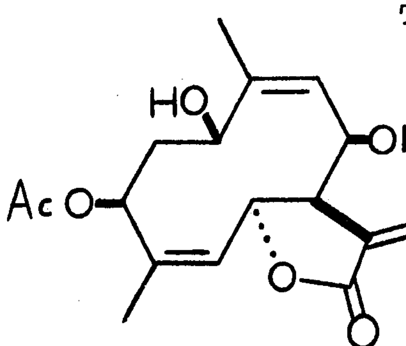
62

R_1 = $-C(=O)-C(CH_2-O-C(=O)-C(CH_2OH)=CHCH_3)=CHCH_2OH$

R_2 = $-C(=O)-C(CH_2OH)=CHCH_2OH$

R_3 = $-C(=O)-C(CH_3)=CHCH_3$

Table II



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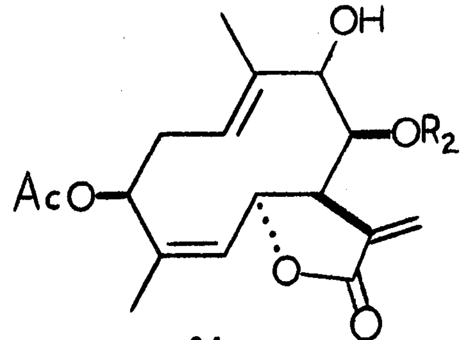

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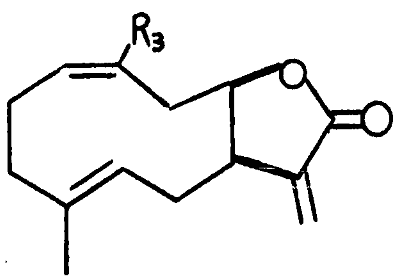

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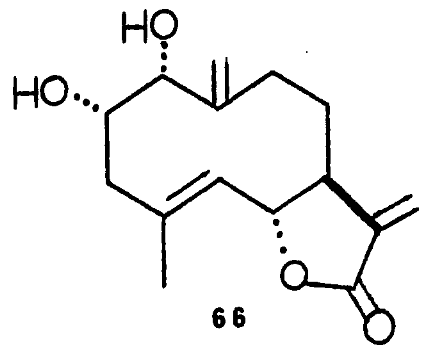

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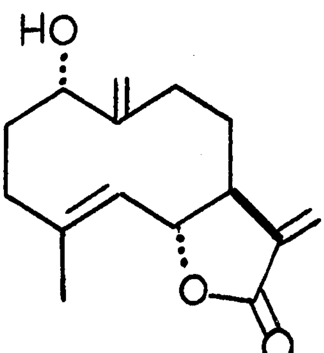

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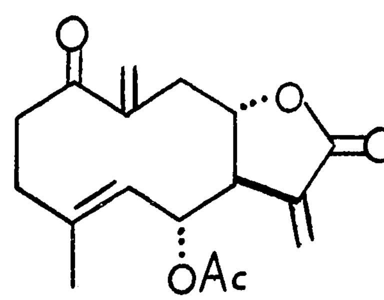

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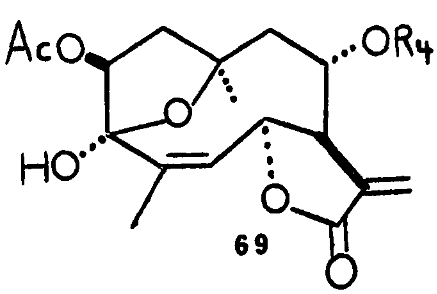

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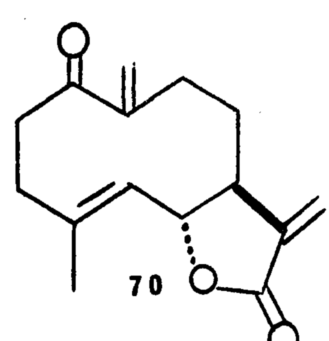
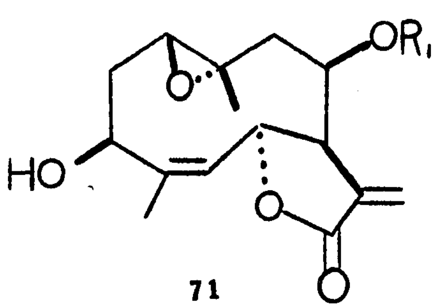


70

$R_1 = R_2 = -\overset{\overset{O}{\|}}{C}-\underset{\underset{CH_3}{|}}{C}=CHCH_3$ $\quad R_3 = -\overset{\overset{O}{\|}}{C}-H$ $\quad R_4 = -\overset{\overset{O}{\|}}{C}-CH(CH_3)_2$

Table II



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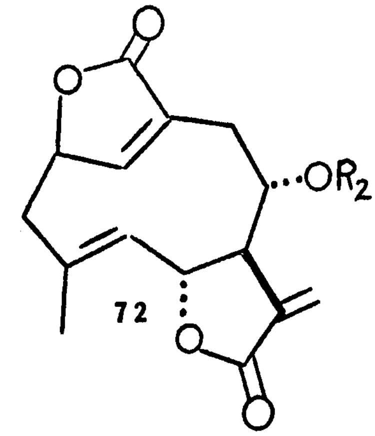

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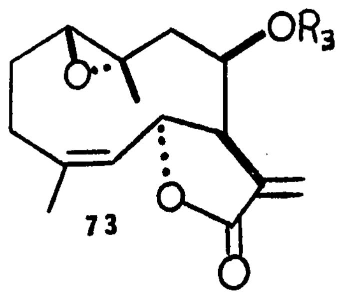

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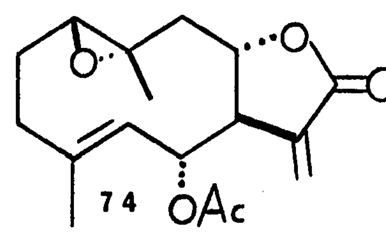

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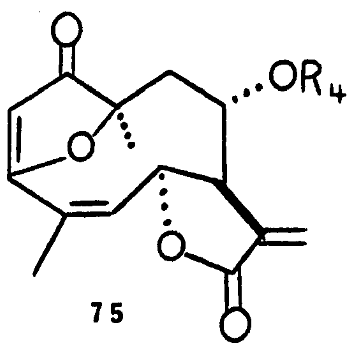

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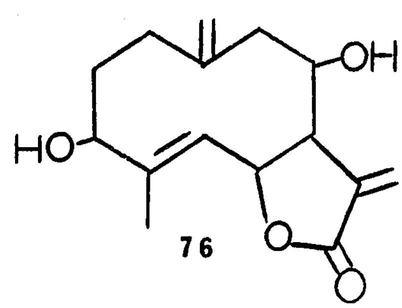

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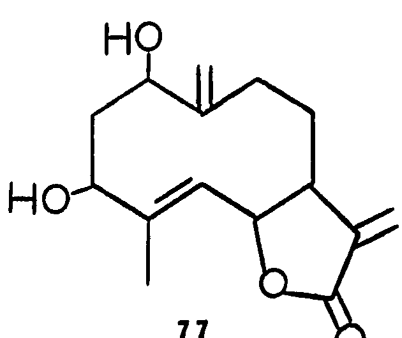

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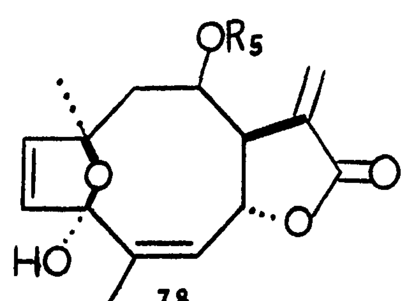
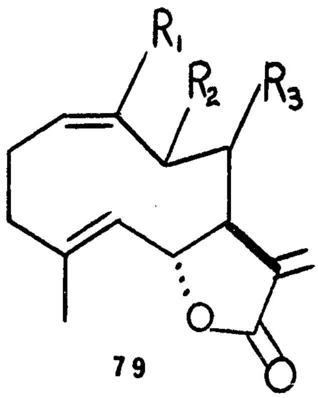


78

$R_1 = -\mathrm{C(=O)-C(CH_3)=CHCH_3}$ $R_2 = R_3 = R_4 = -\mathrm{C(=O)-C(=CH_2)-CH_3}$ $R_5 = -\mathrm{C(=O)-C(CH_2OAc)=CHCH_3}$

Table II



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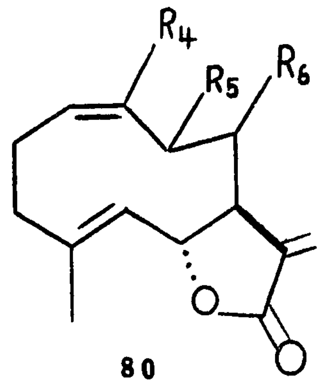

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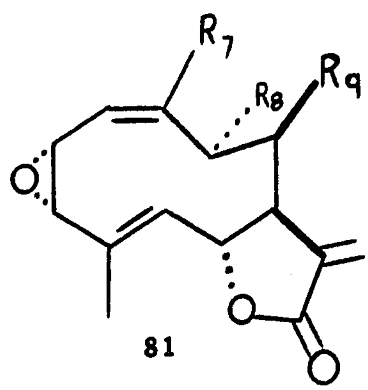

81

$R_1 = R_4 = R_7 = CO_2CH_3$ $\quad$ $R_2 = R_5 = OAc$

$R_3 = R_9 = -O-\overset{\overset{O}{\|}}{C}-\overset{\overset{CH_3}{|}}{\underset{\diagdown O \diagup}{C}-CHCH_3}$ $\quad$ $R_6 = -O\overset{\overset{O}{\|}}{C}-\overset{\overset{CH_3}{|}}{\underset{\underset{OH}{|}}{C}}-CH_3$

$R_8 = -OH$

SUMMARY

Consideration of the vinyl methyl pmr signals of some 80 natural products of the germacrene system reveals that a vinyl methyl absorption occurring at δ 1.55 or higher field (over 30 examples) is invariably associated with trans geometry for the double bond to which the methyl group is attached. This observation was discussed in terms of variations from the idealized crossed conformation commonly adopted by the trans, trans-1(10), 4-diene system. The utility of the correlation as a tool in structure determinations is indicated and exemplified.

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6. The value of δ 1.55 is selected even though δ 1.59 represents the highest field for a *cis* example in Table I. This allows for new compounds which might lower the value; *e.g.*, *cis*, *cis*-germacrone, a synthetic compound has been reported[7] to have vinyl methyl absorptions at δ 1.74 and δ 1.57.

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9. That the C-10 methyl is responsible for the high field signal follows from the thirteen samples (compounds 4, 5, 6, 9, 10, 11, 15, 16, 20, 22, 27, 28, and 31) which possess two endocyclic double bonds, but have a methyl group only at the C-10 carbon. Sathe, Kulkarni, and Kelkar's original observation was made from three examples of this type.

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29. A vinylic methyl signal is shifted to lower field by approximately 0.1 ppm on the introduction of a neighboring hydroxyl group (Cf. 23 and 24, and 35 and 37).

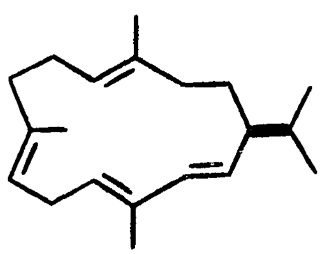
..."The majority of germacranolides contain a double bond conjugated with the bound carboxyl which makes them rather sensitive and unstable. When determining their structures by chemical methods we committed errors in some cases but we corrected them gradually by applying modern physical methods to their study."...

F. Sorm, Pure and Applied Chemistry, 21, 263 (1970).

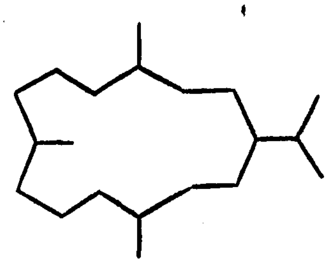
III. NEW MARINE DITERPENOIDS

INTRODUCTION

Naturally occurring diterpenoids containing a fourteen-membered carbocyclic ring have been recognized as such only relatively recently. Cembrene (1) also known as thunbergene, d-tumbelene and the Wienhaus hydrocarbon, was the first 14-carbon ring compound to be identified.[1-5] 1 occurs in the oleoresin of many pine trees of the subgenus Haploxylon of which Cembrae is a group. Thus, cembrane is the trivial name for the saturated cembrene derivative 2. The absolute configuration of the



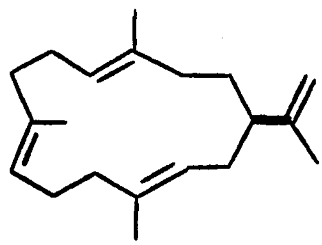
1



2

asymmetric carbon in cembrene is S, which follows from a degradation to the known (-)-S-2-isopropyl-5-oxohexanoic acid.[5,6] The all trans stereochemistry of the trisubstituted double bonds is known from an x-ray study of cembrene.[2] (Reference 2 shows R chirality for cembrene; i.e., the enantiomer of the natural form is depicted.)

Three hydrocarbons (3, 4 and 5) have been isolated which are isomeric with cembrene (Table I). Cembrene-A (3) isolated from a tree in India[7,8] possesses the identical gross structure found for compounds isolated about the same time from a Siberian spruce[9,10] in Russia, from termites in Australia,[11] and from a Pacific soft coral.[12] The compound isolated in Russia was called neocembrene and the Australian compound was named neocembrene-A.



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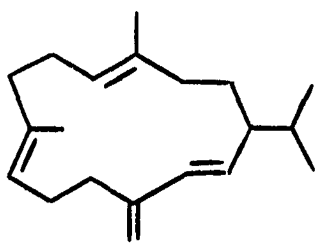
The other two hydrocarbons, isocembrene (4) and casbene (5), were isolated from a Russian pine tree[13] and castor beans,[14,15] respectively.



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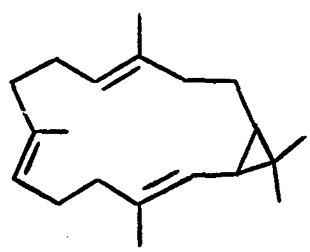

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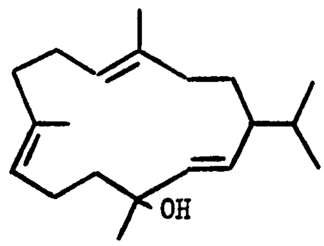
The stereochemistry has not been vigorously demonstrated for the trisubstituted double bonds in 3, 4 or 5.

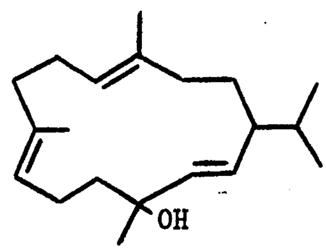
Table II summarizes the available data on oxygenated cembrane derivatives. (Cembranolides were discussed in Section I.) Five monohydric alcohols, thunbergol (6),[16,17] isocembrol (7),[13] mukulol (8),[8] cembrol (9),[18] and nepthenol (10)[12,19] have been reported (Chart I).

Chart I

Naturally Occurring Cembrols



6
Thunbergol



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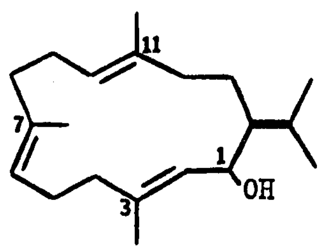
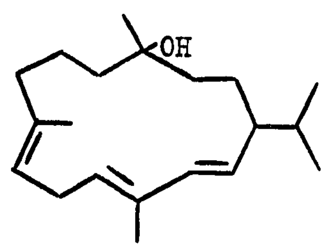
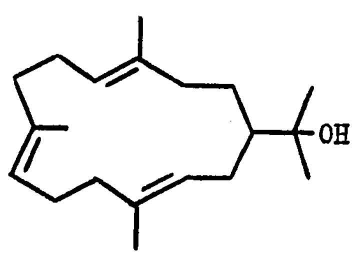
Isocembrol



8
Mukulol



9
Cembrol



10
Nepthenol

Table I

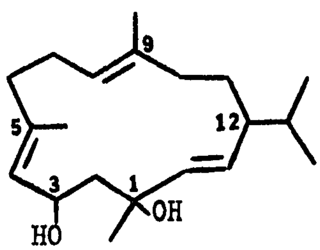
Cembrane Derived Hydrocarbons					
	Name	Formula	Mol Wt	Mp	α_D
(+)	Cembrene (1)	$C_{20}H_{32}$	272	59-60°	+238°
(-)	Cembrene-A (3)	$C_{20}H_{32}$	272	oil	-19.7°
(+)	Isocembrene (4)	$C_{20}H_{32}$	272	--	+60.3°
	Casbene (5)	$C_{20}H_{32}$	272	--	--

Compounds 6 and 7 differ only in configuration at the carbinol carbon atom. The configuration of the alcohol carbon has not been established for compounds 6, 7, 8 or 9. The chirality of the asymmetric carbon bearing the 3-carbon side chain has been firmly established only in 8, which was converted to (+)-cembrene. (The configuration was incorrectly assigned, however, due to a misinterpretation of the stereochemistry of cembrene.) The geometry of the double bonds in 6, 7 and 9 are all trans: assignment of the geometry of the double bonds in 10 has not been made. The 6,7 and 10,11 double bonds of 8 possess trans geometry, while Δ^2 remains unassigned.

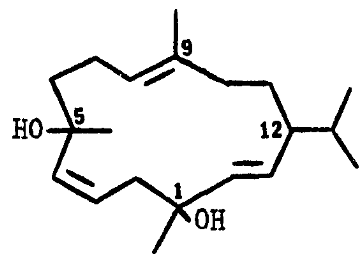
Seven oxygenated diterpenoids (Chart II) possessing the cembrane skeleton have been isolated from tobacco (Nicotiana tabacum) and characterized by the R. J. Reynolds group.[20-22] These authors assigned the name duvane (from duvan, Serbian for tobacco) to the structure 2, and named the macrocyclic diterpenoids from tobacco as derivatives of duvane, e.g., α-4,8,13-duvatriene-1,3-diol (11). Cembrane[23] appears to be the trivial name of choice in the literature, although the duvane nomenclature is commonly used when reference is made to the tobacco derived compounds.[24]

Chart II

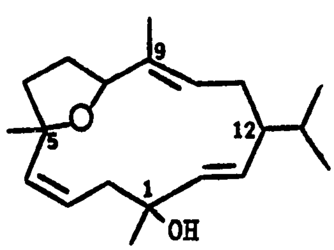
Oxygenated Diterpenoids From Tobacco[a]



11 and 12



13 and 14



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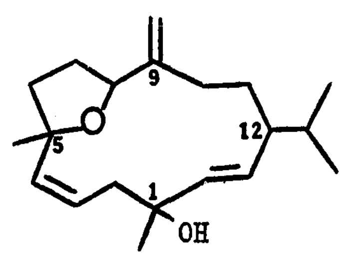


16 and 17

[a]See Table II for the names of the compounds shown above.

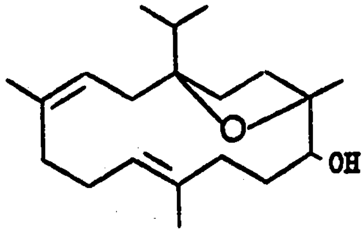
Table II

Oxygenated Cembrane Derivatives

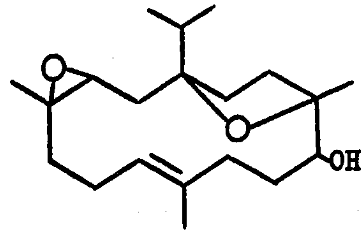
Name	Formula	Mol Wt	Mp	α_D
Thunbergol (6)	$C_{20}H_{34}O$	290	oil	+74.4°
Isocembrol (7)	$C_{20}H_{34}O$	290	--	+80.1°
Mukulol (8)	$C_{20}H_{34}O$	290	37-38°	+53°
Cembrol (9)	$C_{20}H_{34}O$	290	--	+59.6°
Nepthenol (10)	$C_{20}H_{34}O$	290	oil	--
α-4, 8, 13-Duvatriene-1, 3-diol (11)	$C_{20}H_{34}O_2$	306	65-66°	+281.6°
β-4, 8, 13-Duvatriene-1, 3-diol (12)	$C_{20}H_{34}O_2$	306	127-127.5°	+162°
α-3, 8, 13-Duvatriene-1, 5-diol (13)	$C_{20}H_{34}O_2$	306	118-120°	+100°
β-3, 8, 13-Duvatriene-1, 5-diol (14)	$C_{20}H_{34}O_2$	306	150-152°	+40°
α-5, 8-Oxido-3, 9, 13-duvatrien-1-ol (15)	$C_{20}H_{32}O_2$	304	95-96°	+86°
α-5, 8-Oxido-3, 9(17), 13-duvatrien-1-ol (16)	$C_{20}H_{32}O_2$	304	109-110°	+77.4°
β-5, 8-Oxido-3, 9(17), 13-duvatrien-1-ol (17)	$C_{20}H_{32}O_2$	304	108-109°	+72.5°
Incensole (18)	$C_{20}H_{34}O_2$	306	oil	-77.5°
Incensole oxide (19)	$C_{20}H_{34}O_3$	322	164-5°	-48°
Epoxynepthenol Acetate (20)	$C_{22}H_{36}O_3$	348	oil	-20.7°

The alpha and beta designations for the tobacco diterpenes (Table II) have no absolute stereochemical significance, as the chirality has not been firmly established for any of the asymmetric centers in the seven compounds. The alpha designation was given to the diol 11 isolated from tobacco in largest yield. The compounds 11, 13, 15 and 16 in the alpha series possess identical chirality at C-1, and the compounds 12, 14 and 17 of the beta series possess precisely the opposite configuration at this site. The configuration at C-12 is identical in all seven of the tobacco diterpenes (probably S, as in (+)-cembrene), but as yet not established as R or S. The geometry of the disubstituted double bond at C-13 is trans in all seven compounds. The trisubstituted double bonds in 11, 12 and 13 have been assigned all trans geometry.[20-22,24] Although the absolute configurations are unknown, the respective C-5 and C-8 configurations are identical in 15, 16 and 17. No other stereochemical assignments have been made for these interesting compounds.

The macrocyclic diterpenes incensole (18) and incensole oxide (19), which contain the cembrane skeleton were isolated by Italian chemists from frankincense.[25,26] Neither the geometry of the double bonds, nor the chirality of any of the asymmetric centers in 18 or 19 has been established.

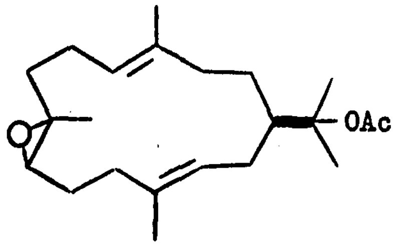


18



19

An acetylated cembrene derivative, epoxynepthenol acetate, 20, was isolated from a Pacific soft coral. The absolute stereochemistry shown below was established for 20.[12,19] The only stereochemical feature unassigned was the chirality of the transoid epoxide.



20

Thus, diterpenoids possessing the cembrane ring system have been found to occur around the globe in diverse natural sources. The isolation from a Caribbean gorgonian and preliminary characterization of three diterpenoids, which appear to be cembrane derivatives, is reported herein. Certain structural features of a fourth, non-cembrane derived diterpenoid isolated from a Pacific soft coral are also discussed.

RESULTS AND DISCUSSION

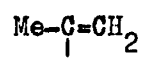
A. New Diterpenoids From A Caribbean Gorgonian

In the course of systematic investigations into the chemistry of marine invertebrates an unidentified gorgonian[27,28] taken at Bonaire, Netherlands Antilles, was examined. The previously unknown gorgonian was classified by Dr. L. S. Ciereszko of this department as a member of the Plexaura or Pseudoplexaura species. Three new diterpenoids were isolated from the hexane extract of the gorgonian. One of the compounds (B-1) proved to be identical to a compound already under investigation in this laboratory as part of a collaborative effort with Dr. R. E. Middlebrook, University of Puerto Rico, Mayaguez, Puerto Rico. Dr. Middlebrook had isolated the compound from the same unidentified gorgonian taken at Puerto Rico. Dr. Middlebrook has initiated efforts to have the gorgonian properly classified in the zoological sense. The thin layer chromatograms of the extracts of the Puerto Rican and Bonaire gorgonians were identical. The gorgonian was also identical by tlc to a specimen collected by Dr. Ciereszko at St. Thomas, Virgin Islands. The new compounds obtained from the gorgonian were prefixed with a B (Bonaire), and labeled B-1, B-2 and B-3 in the order in which they were rendered pure.

B-1 (21), $C_{20}H_{34}O_3$ (high resolution mass spectrum), was a non-conjugated, unsaturated ketone (ir bands at 1700 and 1640 cm^{-1}, no significant uv absorption). The ir spectrum also showed hydroxyl absorption

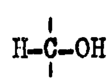
($3500\ cm^{-1}$). The pmr spectrum indicated the presence of the following structural features: three secondary methyl groups (doublets at 1.04, 1.00 and 0.97 ppm), a vinylic methyl (δ 1.69), a secondary alcohol (a one proton doublet of triplets at δ 3.36) and an exomethylene group (broad two proton signal at δ 4.71). The spectral data are shown in Figure 1.

By double irradiation[8] it was shown that the exomethylene signal (4.71 ppm) and the vinyl methyl signal (1.69 ppm) were mutually coupled (J $\sim$ 1 Hz), thus partial structure A was present.



A

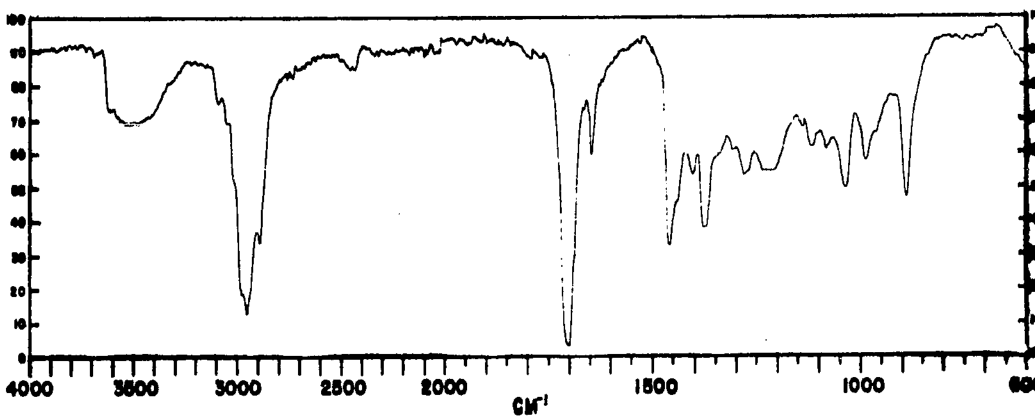
The secondary nature of the alcohol (partial structure B) was confirmed when the one proton signal at δ 3.36 in B-1 moved downfield (δ 4.6) in B-1 acetate (<u>22</u>). Spectral data for <u>22</u> are shown in Figure 2.



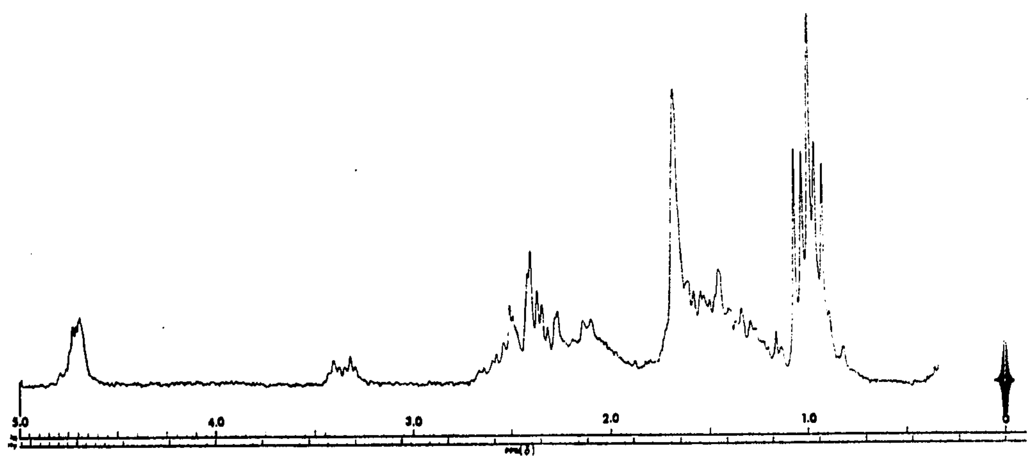
B

Carbon-13 magnetic resonance (cmr) spectroscopy[29] (Figure 3) proved very informative. The presence of A and B in B-1 were firmly established. Two olefinic carbon absorptions occurred at 148.2 and 109.6 ppm in the proton decoupled cmr spectrum. The former signal remained a singlet, while the latter was triplet in the off resonance decoupled cmr spectrum, showing that the single double bond consisted of a carbon atom bearing no hydrogens and one bearing two hydrogens, respectively. The singlet at 70.1 ppm in the proton decoupled cmr spectrum, attributed to the carbinol carbon atom, became a doublet in the off resonance decoupled spectrum, confirming the presence of a secondary

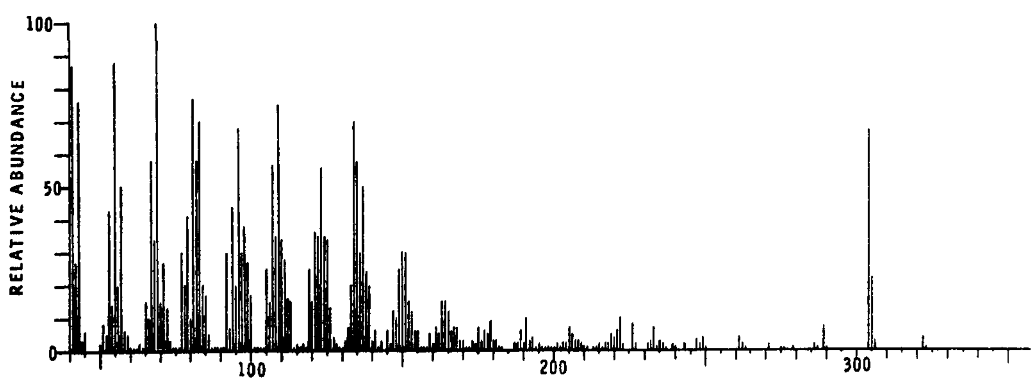
Figure 1



IR Spectrum ($CHCl_3$) of B-1 (21)

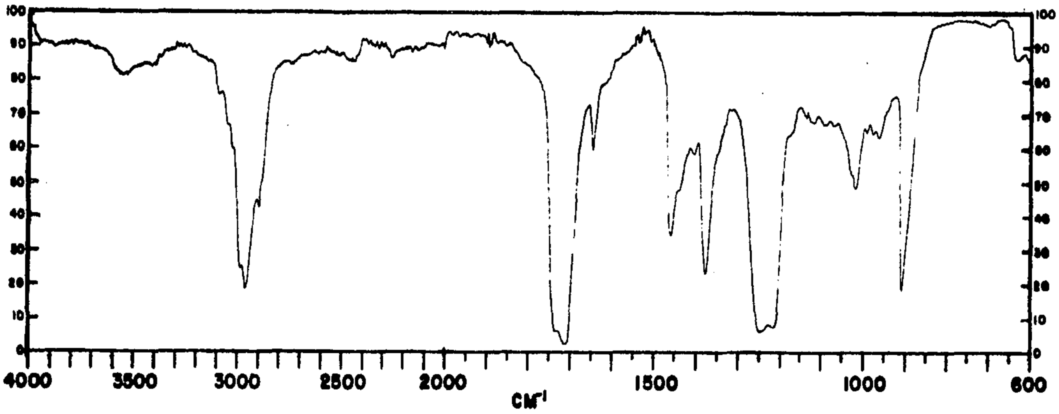


100 MHz PMR Spectrum ($CDCl_3$) of 21

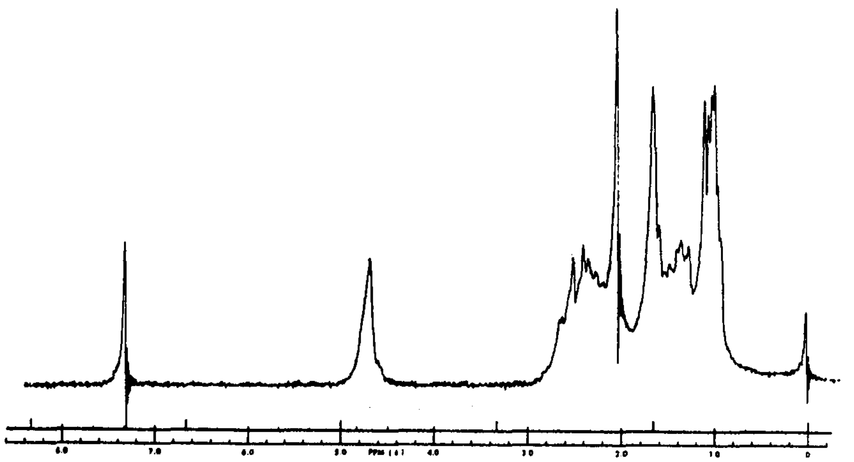


Mass Spectrum of 21

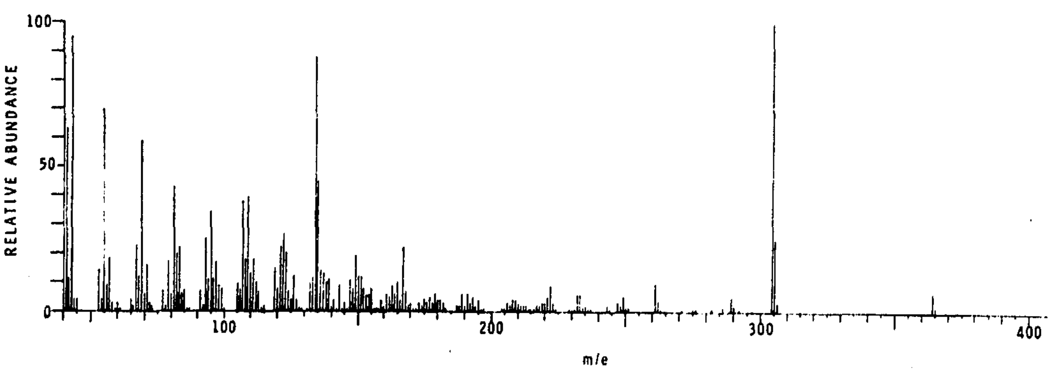
Figure 2



IR Spectrum ($CHCl_3$) of B-1 Acetate (22)

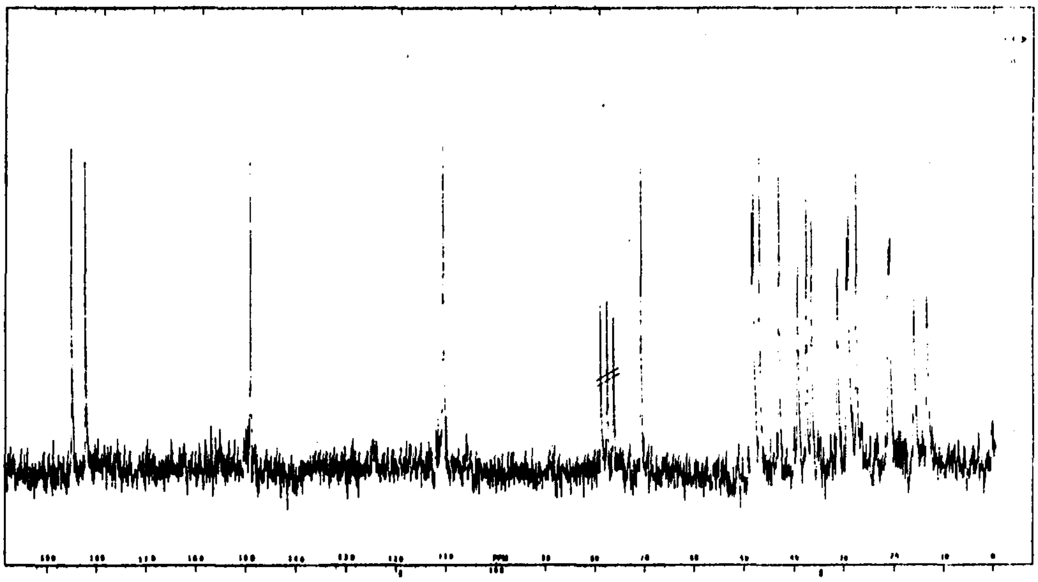


60 MHz PMR Spectrum ($CDCl_3$) of 22

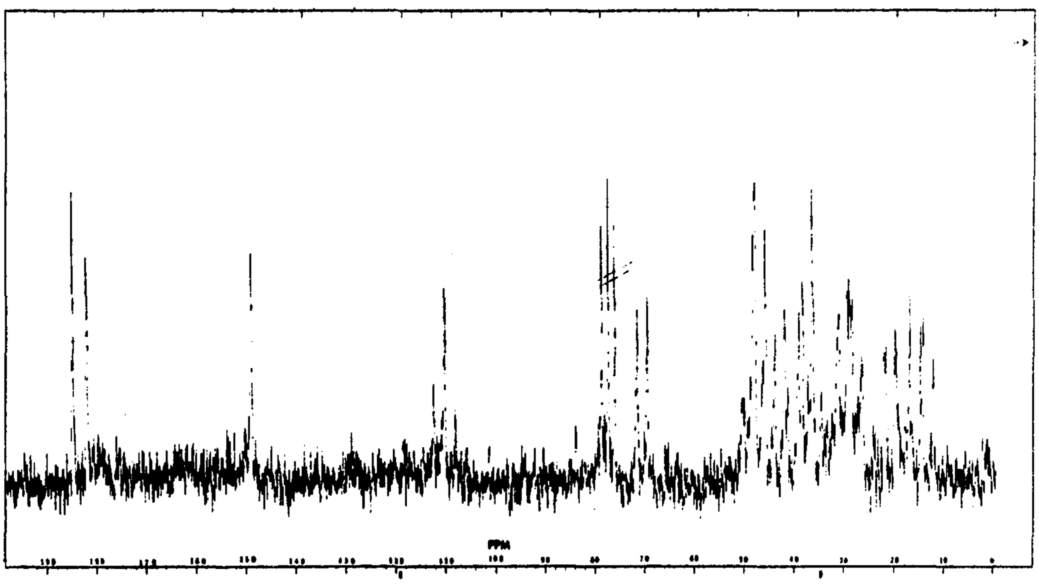


Mass Spectrum of 22

Figure 3



25.2 MHz Proton-Decoupled CMR Spectrum ($CDCl_3$) of B-1



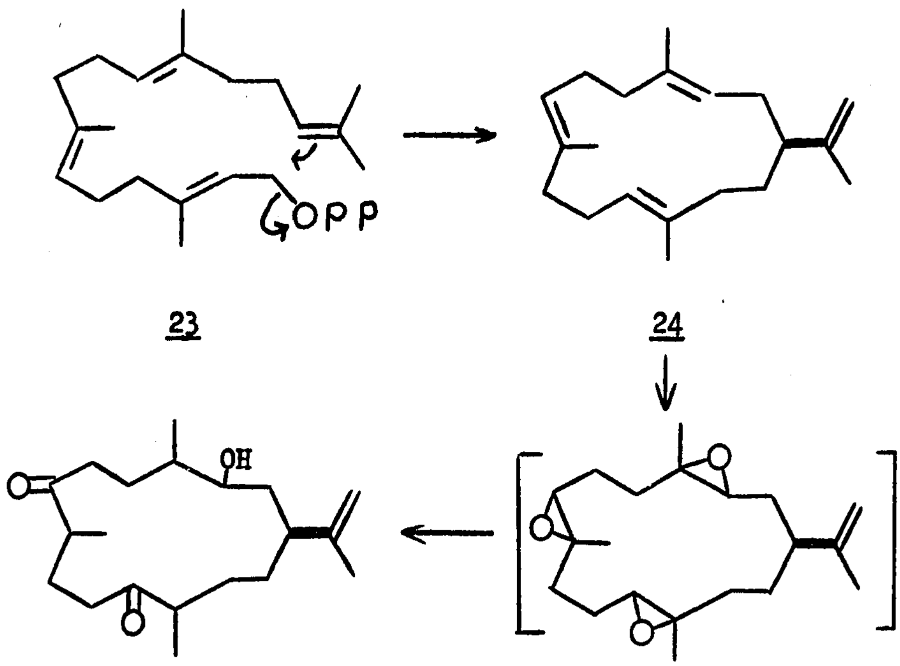
25.2 MHz Off-Resonance Decoupled CMR Spectrum ($CDCl_3$) of B-1 alcohol. The compound possessed two carbonyl carbon atoms as evidenced by the pair of singlets at δ 184.3 and δ 181.5 in both cmr spectra in Figure 3. The absence of absorption attributable to an aldehyde proton in the pmr spectrum of B-1 established the two carbonyl groups as ketones. It is noteworthy that only one ketone group was obvious from the other forms of spectroscopy available. Thus, the new compound, B-1, had a total of 3 unsaturations (2 ketones and one olefin) and being $C_{20}H_{34}O_3$, must be monocyclic and, from its structural features, was clearly a diterpene.

Making the reasonable assumption[8] that the compound arose in nature from geranylgeranyl pyrophosphate (23), the normal diterpenoid precursor,[14,15,30] by a single cyclization, then the cembrane skeleton (2), emerged as a ring system for B-1. If it be assumed that B-1 arose via (+)-cembrene-A (24) (Chart III), postulated in Section I as a precursor for other gorgonian derived cembrane derivatives, then the biosynthesis of B-1 required that the three endocyclic double bonds in 24 be saturated during the course of the biosynthesis. In addition, three oxygen atoms must be incorporated into the 14-membered ring. One possible sequence is proposed in Chart III, in which 21a represents one of the many possible structures for B-1.

Consideration of alternative ring systems led to either a 6 or 10-membered ring as the most logical ring size.[8] If the ring contained 6 carbon atoms, then the 1700 cm^{-1} absorption in the ir spectrum would be inexplicable. The standard value of 1715 cm^{-1} for a 6-membered ring ketone could be shifted lower by 15 cm^{-1} by intramolecular hydrogen bonding[31] between one of the ketone groups and the hydroxyl function,

Chart III

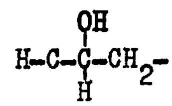
A Proposed Biosynthetic Sequence for B-1



23 24 21a

but the second ketone function should then possess a normal 1715 cm^{-1} absorption, which was not observed. A 10-membered ring cannot be ruled out, but the hitherto absence of 10-membered ring monocyclic diterpenoids in nature[32] and the fact that an isopropylidene rather than an isopropenyl group would be expected for this 20-carbon system on biogenetic grounds,[8] again favored the cembrane ring system for B-1.

The ir absorption at 1700 cm^{-1} was in accord with the assignment of a 14-membered carbocyclic ring to B-1. Table III shows three natural product derivatives (25, 26, and 27) all of which possess a 14-membered ring ketone and all of which have been reported to have carbonyl absorption at 1700 cm^{-1}. In addition, the doubled triplet pmr signal of the proton attached to the carbon atom bearing the hydroxyl group, indicated that the carbinol system was flanked by methylene and methinyl protons, as in partial structure C, and obviated the possibility of an α-ketol group.



C

The p-iodobenzoate derivative (28) was prepared from B-1 in order to obtain the structure by x-ray crystallography. Spectral data for 28 are in Figure 4. 28 was crystalline, but crystallized in dendritic needles from a variety of solvents. The crystals were quite

Table III

Cembrone derivatives

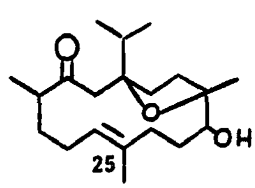
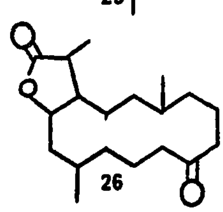
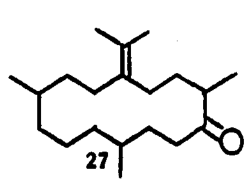
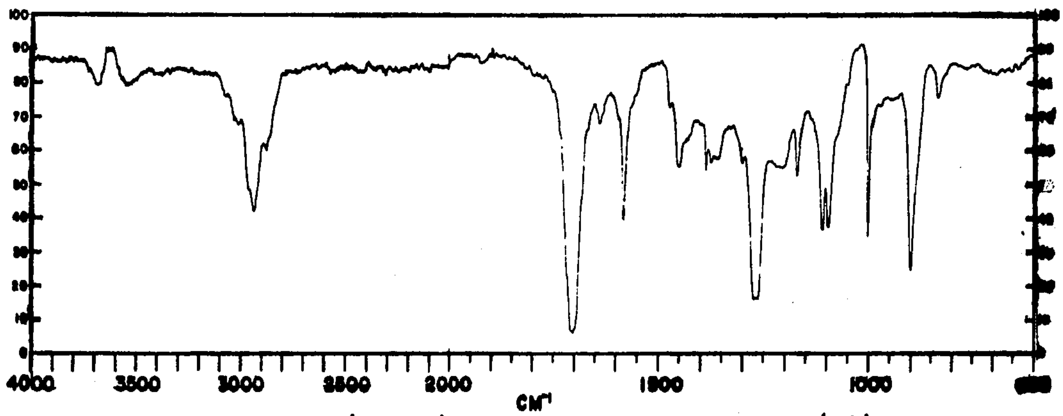
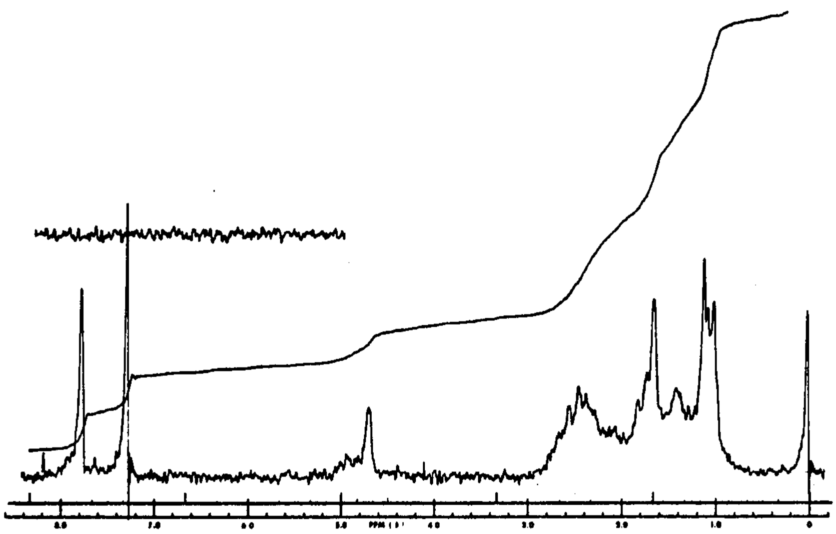
Compound	IR (C = 0) ν cm^{-1}	Ref.
 25	1700 (CCl_4)	26
 26	1700 ($CHCl_3$)	40
 27	1700 ($CHCl_3$)	25

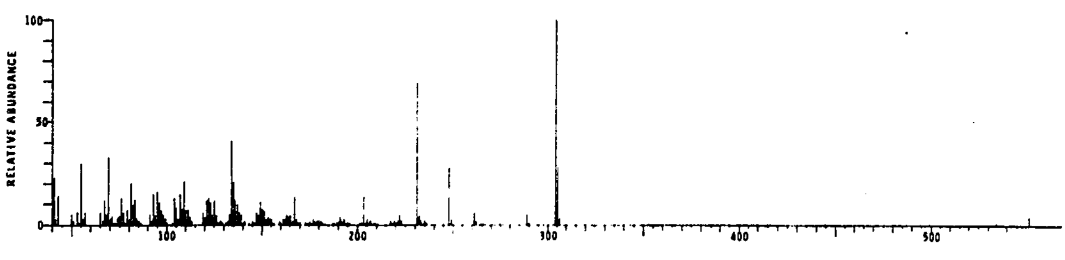
Figure 4



IR Spectrum ($CHCl_3$) of B-1 p-Iodobenzoate (28)



60 MHz PMR Spectrum ($CDCl_3$) of 28



Mass Spectrum of 28

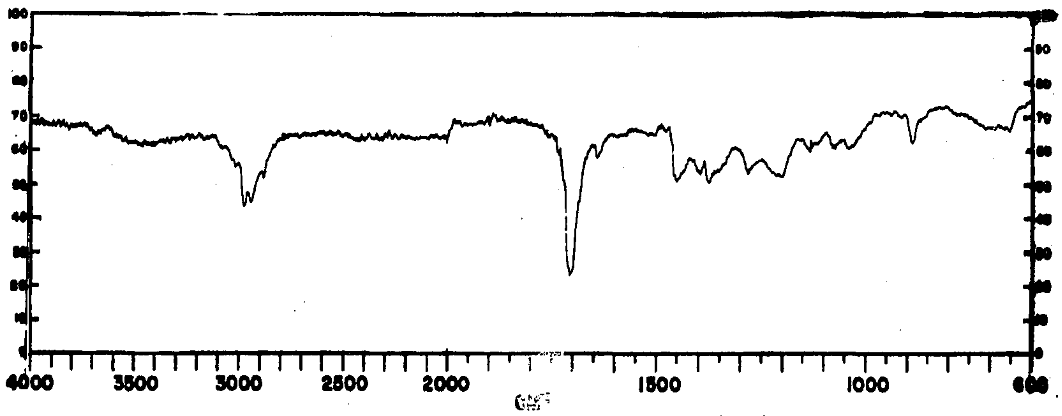
unsatisfactory for an x-ray study. The possibility of determining the structure of B-1 acetate (22) by direct method x-ray crystallographic techniques is currently being explored by Dr. D. van der Helm and Mr. S. Ealick of this department.

The second diterpene B-2 (29), $C_{20}H_{32}O_3$ (high resolution mass spectrum) was obtained only in very small yield. B-2 had no hydroxyl absoprtion in the ir spectrum, but did have an intense carbonyl absorption at 1700 cm^{-1}, indicating a cembrone (Table III). The absence of an alcohol group in B-2 was further indicated by its considerably greater mobility on tlc (R_f = 0.76, 3:1 benzene-ethyl acetate, silica gel H) than the monohydric B-1 (R_f = 0.51). Like B-1, B-2 possessed an isopropenyl group as shown by the following double irradiation experiment. Irradiation of the broad 2 proton singlet at 4.73 ppm sharpened the broad vinyl methyl signal at 1.70 ppm, and conversely irradiation at δ 1.70 caused the signal at δ 4.73 to sharpen. Figure 5 depicts the spectral data for B-2.

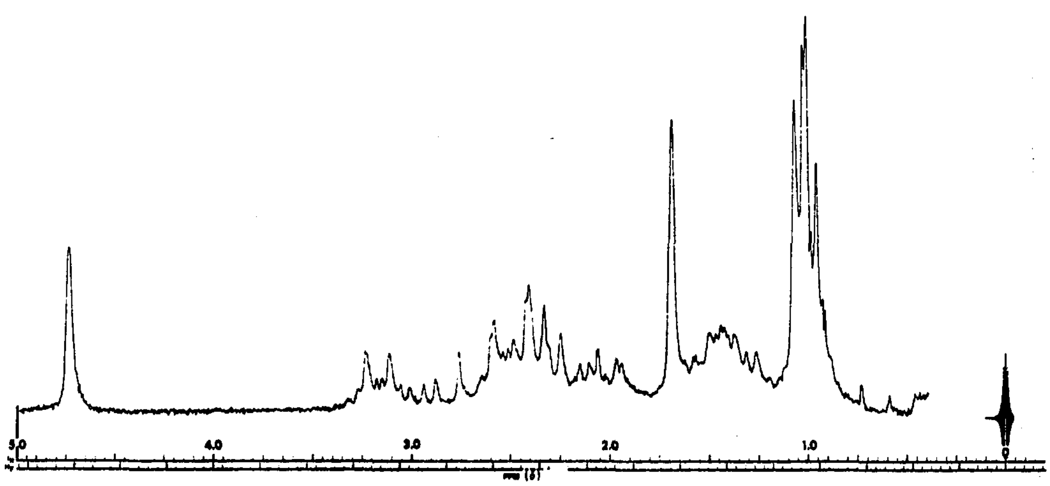
B-2 also contained three secondary methyl groups (δ 1.02, 9H, three overlapping doublets). The presence of an alpha proton of a secondary ether was suggested by the doublet of triplets at δ 3.17. There was no positive indicator for the third oxygen atom; however, the integrated intensity of the absorption in the pmr spectrum of B-2 between 2 and 3 ppm, suggested that B-2, like B-1, was a diketone, possessing a similar number of hydrogen atoms alpha to keto groups.

B-3 (30) $C_{20}H_{36}O_3$ (combustion analysis) had ir absorption at 3600 and 3450 (hydroxyl), 1700 (ketone), and 1640 cm^{-1} (double bond). Spectral data for B-3 is shown in Figure 6. The large OH band in the

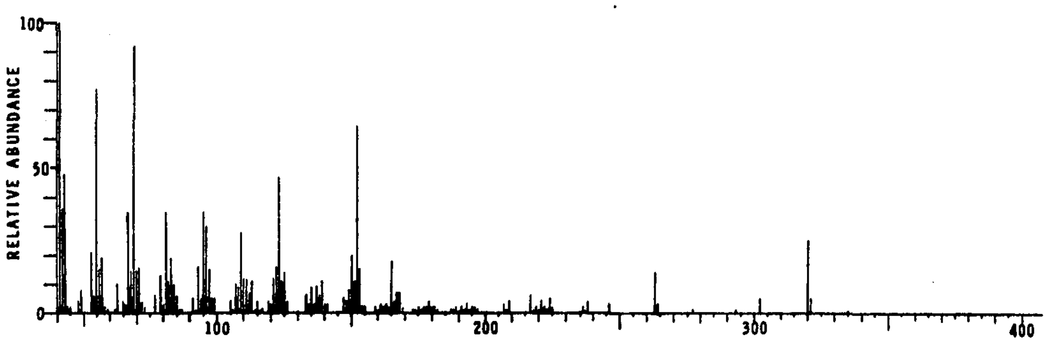
Figure 5



IR Spectrum ($CHCl_3$) of B-2 (<u>29</u>)

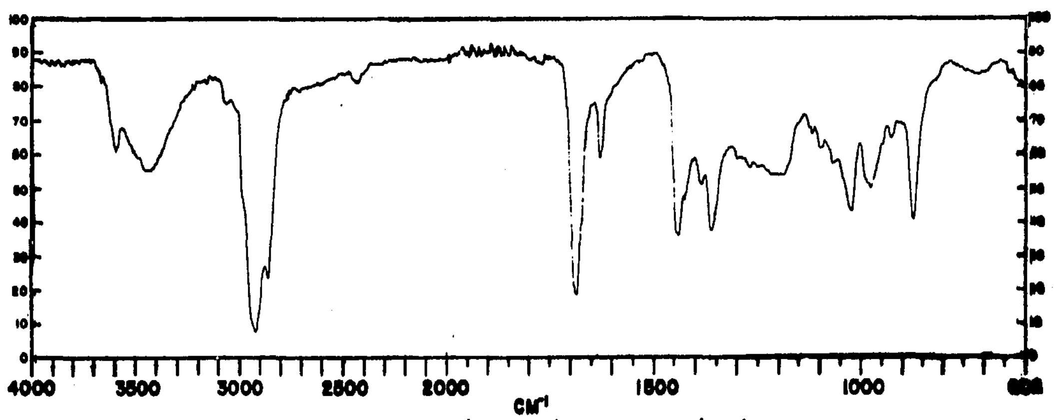


100 MHz PMR Spectrum of <u>29</u>

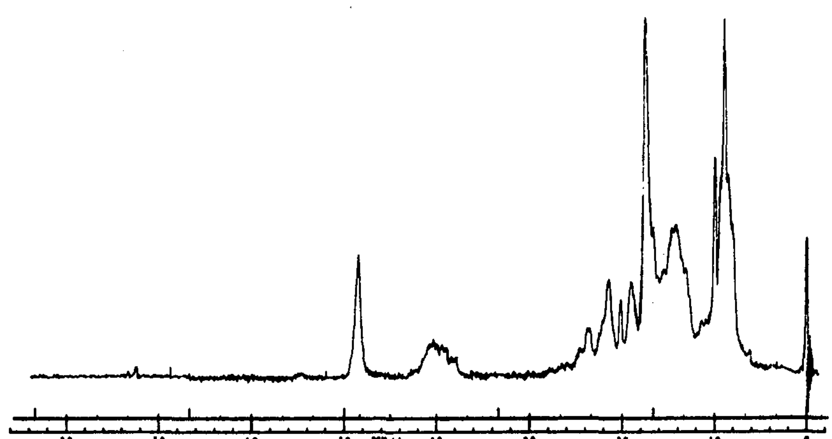


Mass Spectrum of <u>29</u>

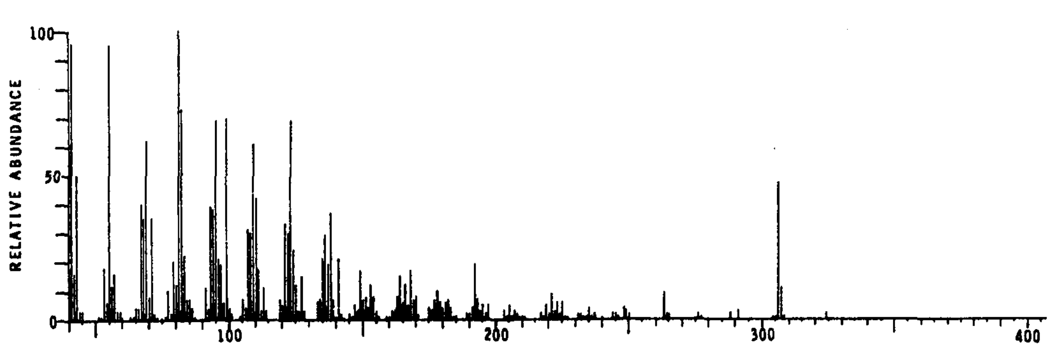
Figure 6



IR Spectrum ($CHCl_3$) of B-3 (30)



60 MHz PMR Spectrum ($CDCl_3$) of 30



Mass Spectrum of 30

ir spectrum coupled with its relatively slow mobility on tlc (R_f = 0.26, 3:1 benzene-ethyl acetate, silica gel H) and the 2 proton multiplet at 4.00 ppm, suggested that B-3 was a disecondary diol. This was confirmed when B-3 formed a diacetate (31); the pmr absorption arising from both protons attached to the secondary carbinol carbons moved downfield approximately 1 ppm. The spectral data for 31 is presented in Figure 7.

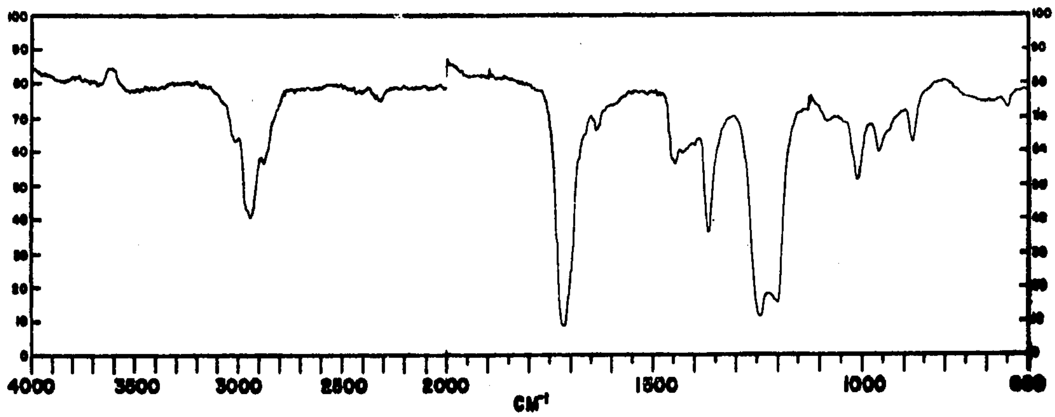
The pmr spectrum of 31 clearly revealed the presence of three secondary methyl doublets (δ 1.02, 0.92 and 0.82). An isopropenyl group was also shown to be present by double irradiation as before for B-1 and B-2.

B-1, B-2, and B-3 all possessed 20 carbon and 3 oxygen atoms; further they possessed the following common structural features: three secondary methyl groups, an isopropenyl group and at least one ketone. Thus, they were closely related. Specifically, B-1 was a monohydroxy-diketone and B-3 was a dihydroxy-ketone, suggesting that oxidation of one of the hydroxyl groups in B-3 would produce B-1.

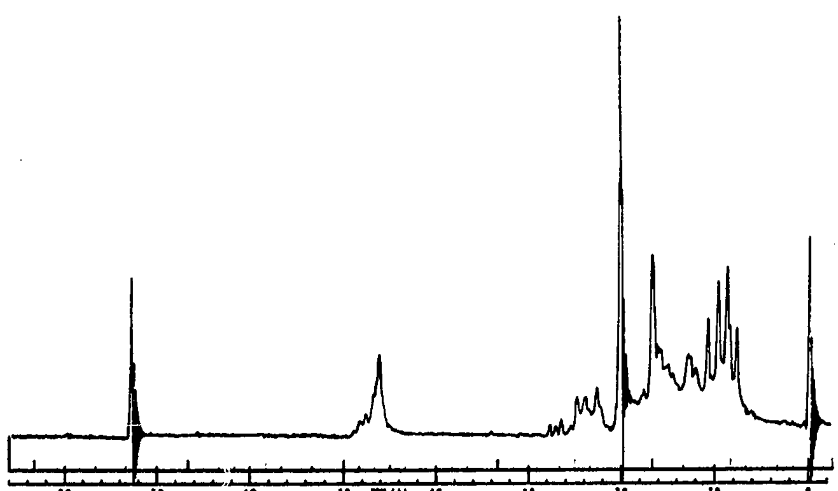
The observations made above represent an attempt to correlate the chemical evidence at hand with a logical biosynthetic sequence which would evolve the B-compounds. The large number of compounds possessing the 14-membered ring (cembrane) skeleton and the established monocyclic nature of B-1 and B-3 make the cembrane skeleton very attractive; however, it should be reiterated that many other structures satisfy the raw data presented above. Chemical studies to elucidate the unknown structures are continuing.

This marks the first report of naturally occurring monocyclic diterpenoids which possess ketone functionality. The number of nuclear

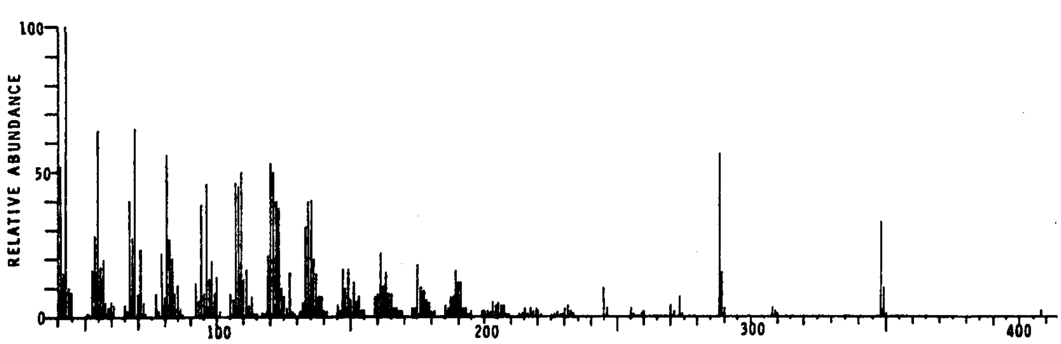
Figure 7



IR Spectrum ($CHCl_3$) of B-3 Diacetate (31)



60 MHz PMR Spectrum ($CDCl_3$) of 31



Mass Spectrum of 31

oxygen atoms in the three diterpenoids places them between nepthenol (soft coral) and the cembranolides (gorgonians) and may indicate the level of chemical sophistication of the new gorgonian in the overall classification scheme.

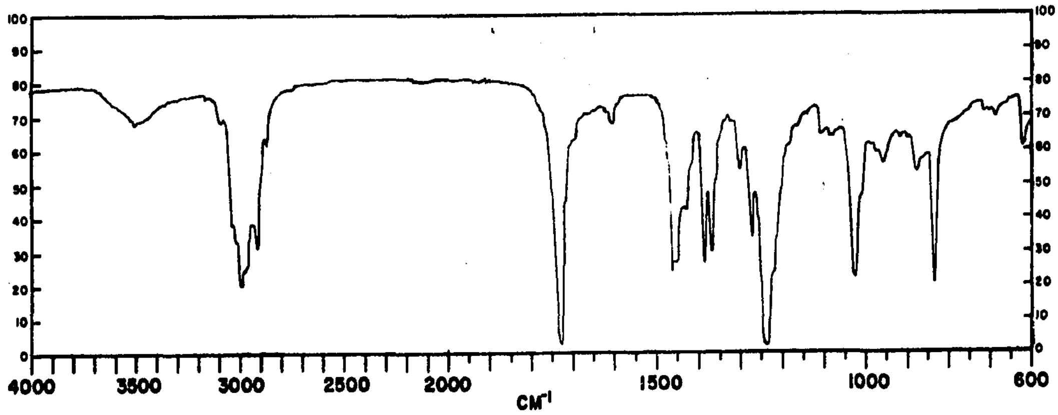
B. A Novel Diterpenoid From A Pacific Soft Coral

A preliminary report[33] has appeared which described the isolation of a diterpene acetate from Sclerophytum capitalis (formerly called Sclerophytum capitale). The new diterpenoid was designated SCC pending structural elucidation. The present effort constituted an extension of the previous work.

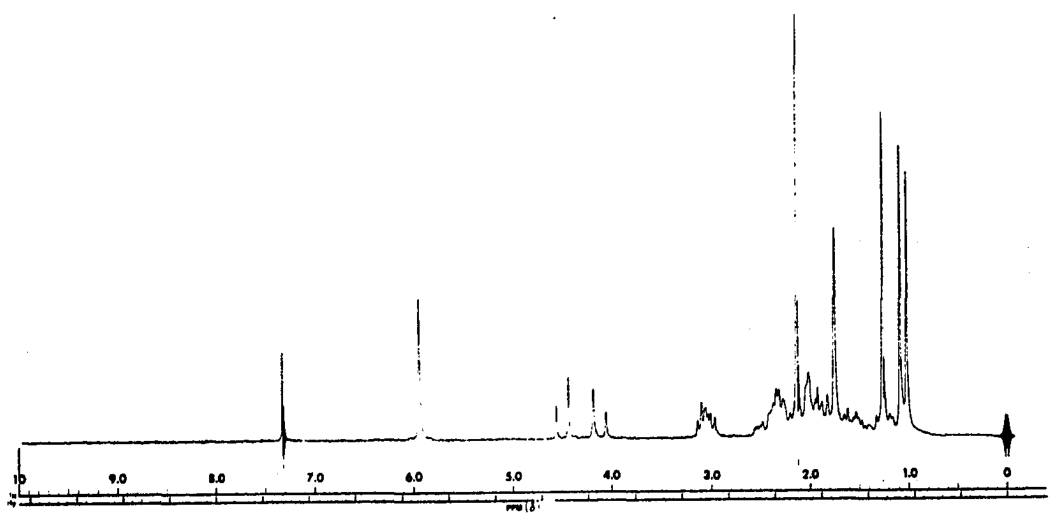
SCC (32), $C_{22}H_{34}O_4$ (high resolution mass spectrum), had ir absorption at 1730, 1240 (acetate) and 1610 cm^{-1} (double bond). The spectral data for SCC is displayed in Figure 8. The presence in SCC of partial structure A (isopropenyl group) was established when irradiation of the two proton signal at 5.94 ppm caused the vinylic methyl signal at 1.76 ppm to sharpen, conversely irradiation at 1.76 ppm caused the signal at 5.94 ppm to sharpen. The exomethylene absorption at δ 5.94 occurred at approximately 1 ppm lower field than a non-conjugated exomethylene signal normally occurs, indicating that the exomethylene was at the terminus of a conjugated system (D).[34] The strong uv absorption at 247 nm (ε = 17,000) supported the assignment of the diene D.

Me–C(–)=CH_2	–C=C–C(CH_3)=CH_2
A	D

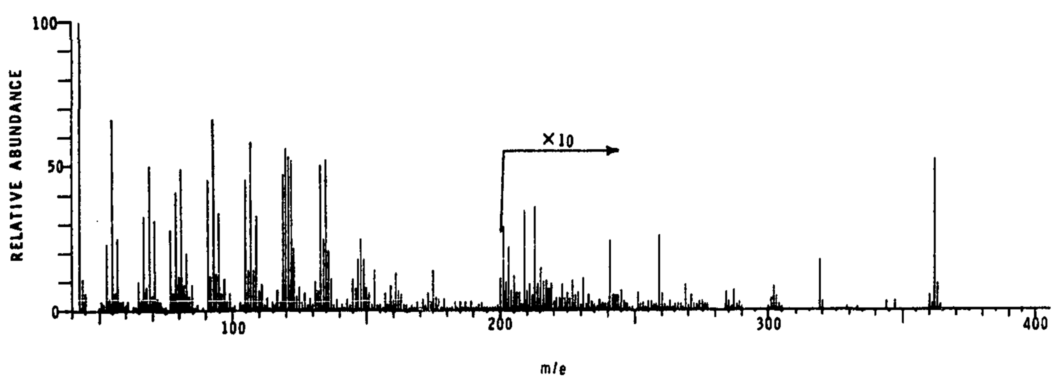
Figure 8



IR Spectrum (KBr) of SCC (32)



100 MHz PMR Spectrum ($CDCl_3$) of 32



Mass Spectrum of 32

The absence of further olefinic proton absorption demanded that the second double bond be tetrasubstituted.

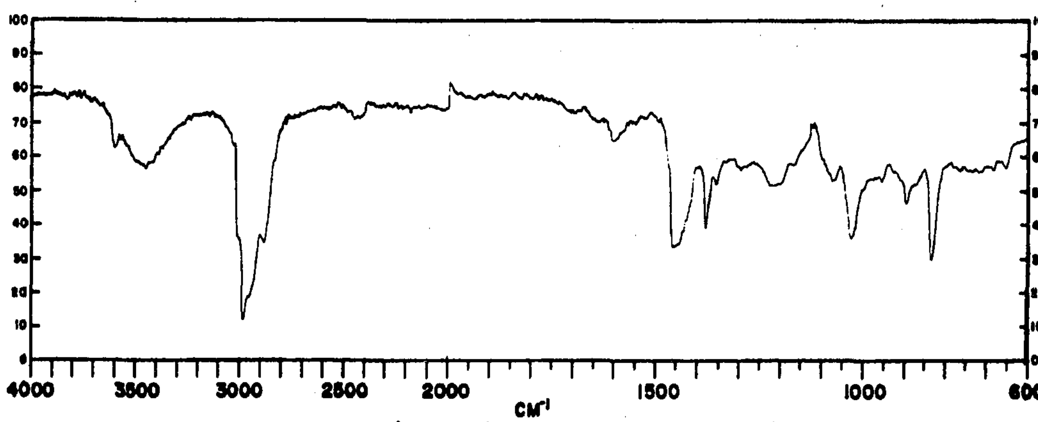
Treatment of SCC with a trace of sodium in methanol afforded deacetyl SCC (33); spectral data for 33 is presented in Figure 9. Partial structure E, previously postulated[33] to be present in SCC was established when the AB quartet (4.3 ppm) due to the methylene protons in E of the parent compound 32 changed to a pair of quartets at higher field in 33. That the multiplicity increase was due to coupling between the methylene protons in E and the hydroxyl proton of the newly formed primary alcohol was demonstrated by rerunning the pmr spectrum of 33 with a drop of D_2O added. Figure 10a shows the result; the AB quartet reappeared. The geminal coupling between the methylene protons of E was attributed to the presence of a fully substituted carbon atom alpha to the $-CH_2OAc$ group.[36] The observed geminal coupling constant of 11 Hz was in agreement with typical values.[36]

$$-\overset{|}{\underset{|}{C}}-CH_2OAc$$

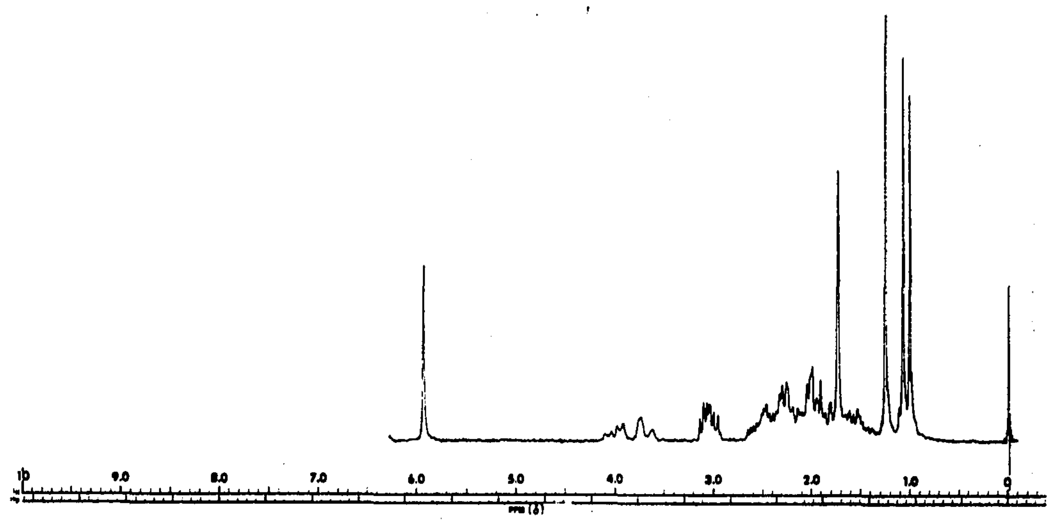
E

An isopropyl group was also present in SCC (ir doublet 1380 cm^{-1}, pmr 6H doublet at 1.06 ppm). Irradiation in the allylic region (δ 2.33) in 32 and (δ 2.33) in 33 caused the six proton doublet at δ 1.06 in 32 and δ 1.05 in 33 to collapse to a singlet, showing that the methinyl proton of the isopropyl group was allylic, and, therefore, that the isopropyl group was one of the substituents of the tetrasubstituted double bond as shown in partial formula F. (A non-allylic methinyl proton of an isopropyl group normally absorbs at ca. 1.60 ppm. See Sadtler Standard NMR Spectra Nos. 3416, 3432 and 3956.)

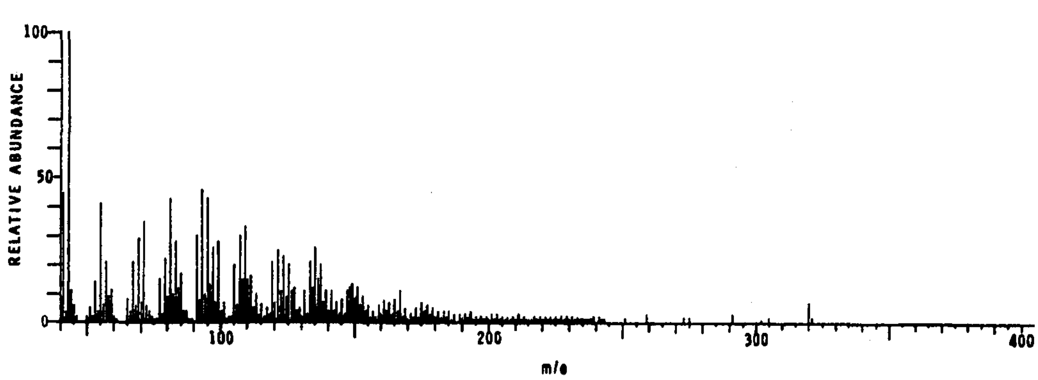
Figure 9



IR Spectrum ($CHCl_3$) of Deacetyl SCC (33)

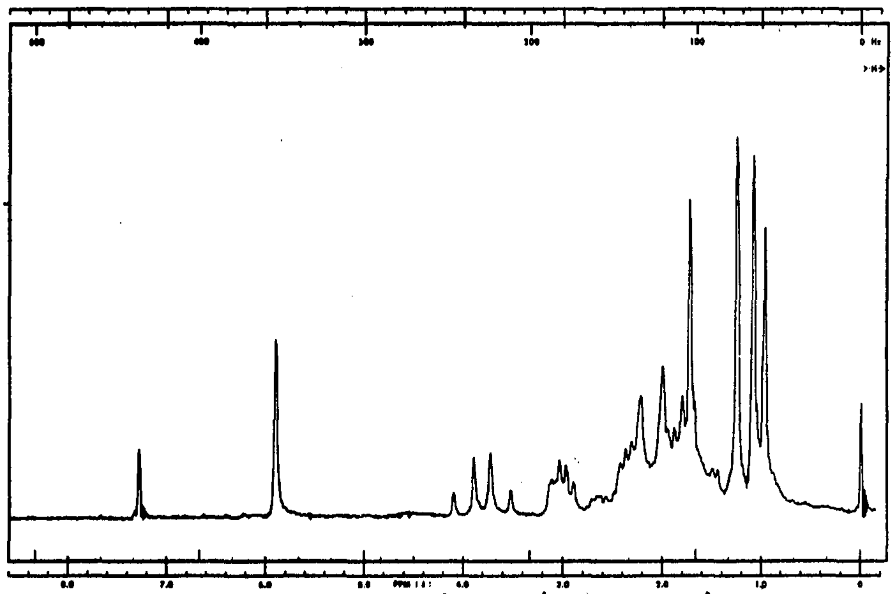


100 MHz PMR Spectrum ($CDCl_3$) of 33



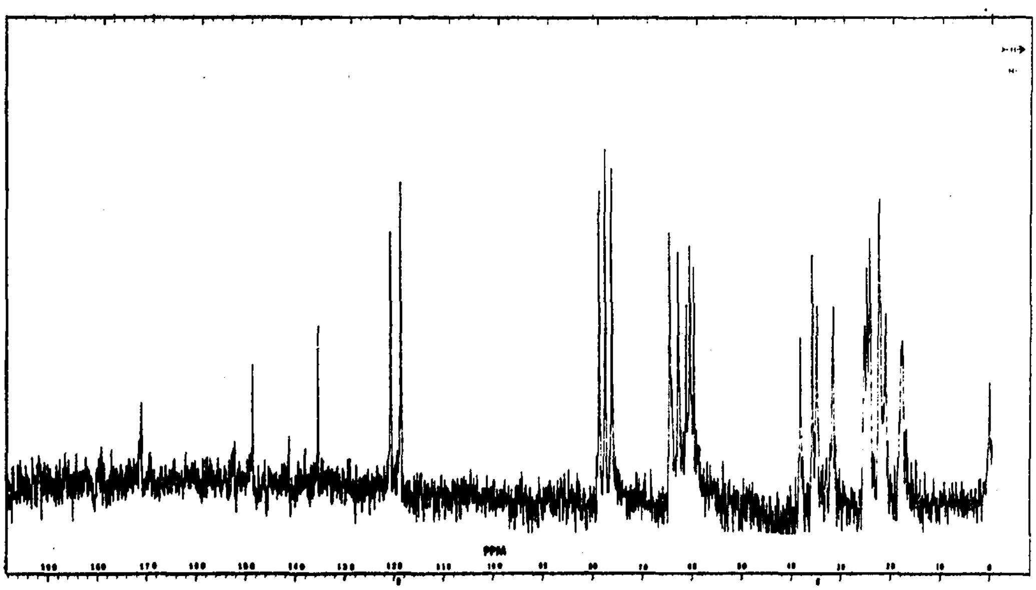
Mass Spectrum of 33

Figure 10a

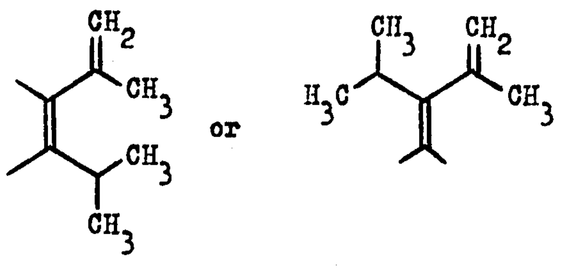


100 MHz PMR Spectrum ($CDCl_3$/1 drop D_2O) of
Deacetyl SCC (33)

Figure 10b

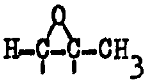


25.2 MHz Proton-Decoupled CMR Spectrum ($CDCl_3$)
of SCC (32)



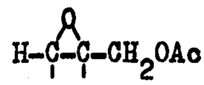
F

Two oxygen atoms in SCC were shown above to be present in an acetate function. The formula for SCC allowed for two more oxygen atoms. SCC did not exhibit hydroxyl absorption and deacetyl SCC did not show carbonyl absorption, therefore, the remaining two oxygen atoms were ethereal. Definitive evidence for the nature of the ether oxygens was not obtained; however, the pmr spectra of 32 and 33 displayed absorption at 3.0 ppm which integrated for 2 protons, indicating the presence of two epoxide hydrogens. One of the epoxide protons was judged to be part of partial structure G, the methyl signal of which occurred at 1.27 ppm in 32.



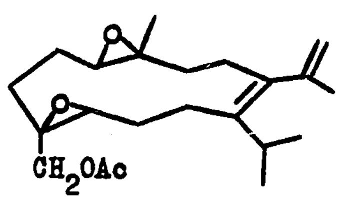
G

It was shown above that a $-CH_2OAc$ group was present and that the carbon to which the group was attached was fully substituted. The second epoxide would appear to be reasonably associated with the fully substituted center alpha to the $-CH_2OAc$ group, as in partial structure H. It is noteworthy that the chemical shift and geminal coupling of the methylene protons in H are quite in accord with this assignment.[38,39]

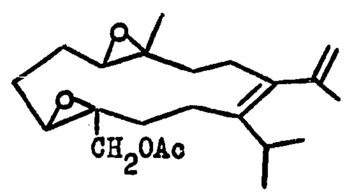


H

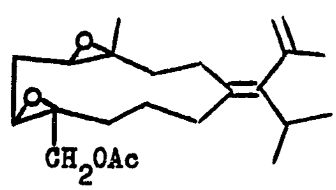
The partial structures F, G, and H together with one more ring accounted for all the rings and double bonds allowed by $C_{22}H_{34}O_4$. In the absence of further chemical evidence, the partial structures established above for SCC together with six methylene groups, required by the formula for SCC, were combined to form possible total structures. Three of the vast number of possible structures which incorporate the functionality deduced for SCC are represented by 32a, 32b, and 32c.



32a



32b



32c

The proton decoupled cmr spectrum of SCC (Figure 10b) confirmed the presence of one carbonyl (acetate) carbon (δ 170.4), four olefinic carbons (δ 148.0, 134.8, 120.0, and 118.0), five carbons bearing singly bound oxygen (δ 64.2, 62.4, 60.8, 60.0, and 59.3) and twelve other carbon atoms.[29]

The presence of partial structure F alone makes SCC unique,[32] but even more intriguing is the likely presence of an eleven or twelve membered ring. It is interesting that the 12-membered ring in 32a and 32b is isoprenoid while the 11-membered ring in 32c is nonisoprenoid.

Chemical studies leading to the structural elucidation of SCC have been slowed due to its relative inaccessability; Sclerophytum capitalis is collected in the Marshall Islands. Therefore, a sample of SCC has been provided to Dr. D. van der Helm for low temperature x-ray crystallography.

EXPERIMENTAL

Experimental conditions specified in Section I apply.

New Diterpenoids B-1, B-2 and B-3 - An unidentified gorgonian which exhibits taxonomic characteristics of both plexaura and pseudoplexaura species was collected by Dr. Leon S. Ciereszko on June 1-2, 1973 off the island of Bonaire in the Carribbean Sea. The unknown species, air dried, (432 g) was extracted with hexane.

The extract was concentrated and allowed to stand overnight in 100 ml of hexane. A solid crystallized and was collected. Tlc showed two major spots. The solid was chromatographed (400 g silic AR CC-7, 4:1 benzene-ethyl acetate, 50 ml/20 min). After 4 l of 4:1 benzene-ethyl acetate had been placed on the column, the polarity of the solvent was increased to 1:1 benzene-ethyl acetate; 1 l of this solvent was eluted. Fractions 23-29 showed a single spot by tlc and were combined and the solvents removed to yield a white crystalline solid. The solid was recrystallized several times from benzene-hexane affording 1.3868 g of pure B-1. Fractions 43-60 likewise displayed a single spot on tlc, and after combining the fractions, evaporating the solvents and recrystallizing several times from benzene-hexane, 1.5855 g of pure B-3 was obtained. B-1 and a third diterpenoid, B-2 had previously been isolated from this same unidentified gorgonian in small yield by Dr. Robert E. Middlebrook from a specimen collected at Puerto Rico. The mother liquor from which B-1 and B-3 coprecipitated was shown by tlc to contain B-2.

B-1 had: mp 111.5-112°; $[\alpha]_D^{24}$ - 7.8° (c, 0.902, $CHCl_3$); R_f = 0.51 (3:1 benzene-ethyl acetate, silica gel H); ir ($CHCl_3$) 3500 (broad, hydroxyl), 1700 (C=O), and 1640 cm^{-1} (C=C); 100 MHz pmr ($CDCl_3$) δ 4.71 (m, 2H, C=C$\underline{H}_2$), 3.36 (dt, 1H, J = 8.5 Hz, J = 2.5 Hz, -C$\underline{H}$OH), 1.69 (d, 3H, J = 1 Hz, C=C-$\underline{Me}$), 1.04 (d, 3H, J = 6.5 Hz, H-C-$\underline{Me}$), 1.00 (d, 3H, J = 6.5 Hz, H-C-$\underline{Me}$), and 0.97 ppm (d, 3H, J = 6.5 Hz, H-C-$\underline{Me}$); 25.2 MHz proton decoupled cmr ($CDCl_3$) δ 184.3 ($\underline{C}$=O), 181.5 ($\underline{C}$=O), 148.2 ($\underline{C}$=C), 109.6 (C=$\underline{C}H_2$), 70.1 (-$\underline{C}$HOH), 48.0, 47.6, 46.5, 42.6, 38.9, 37.1, 36.1, 30.9, 29.0, 28.7, 27.1, 20.5, 20.3, 15.6 and 13.0 ppm; mass spectrum (70 eV) m/e (rel intensity) M^+, 322 (4), 304 (67), 289 (7), 286 (2), 261 (4), 249 (4), 233 (7), 226 (8), 222 (10), 219 (5), 191 (10), 189 (6), 179 (9), 165 (12), 164 (15), 163 (15), 151 (30), 150 (30), 137 (50), 134 (70), 123 (56), 109 (75), 107 (57), 98 (38), 96 (68), 94 (44), 83 (70), 81 (67), 79 (41), 71 (27), base peak 69 (100), 67 (58), 57 (50), 55 (88), 53 (43), 43 (76), and 41 (87).

Anal. Calcd. for $C_{20}H_{34}O_3$: C, 74.48; H, 10.63; mol wt 322.25079. Found: C, 74.66; H, 10.39; mol wt (mass spectrum) 322.24770.

B-2 had: mp 86-87°; $[\alpha]_D^{24}$ +61° (c 0.115, $CHCl_3$); R_f = 0.76 (3:1 benzene-ethyl acetate, silica gel H), ir ($CHCl_3$) 1700 (C=O), and 1640 cm^{-1} (C=C); δ 4.73 (br, 2H, C=C$\underline{H}_2$), 3.17 (dt, 1H, J = 11.5 Hz, J = 6 Hz, -OC-$\underline{H}$), 1.70 (br, 3H, C=C-$\underline{Me}$), 1.02 (m, 9H, three H-C-$\underline{Me}$); mass spectrum (70 eV) m/e (rel intensity) M^+, 320 (25), 302 (5), 293 (1), 277 (1), 263 (14), 165 (18), 153 (15), 152 (64), 151 (11), 150 (20), 139 (11), 125 (14), 123 (47), 122 (16), 121 (12), 113 (11), 111 (12), 110 (12), 109 (28), 107 (10), 97 (15), 96 (30), 95 (35), 93 (16), 84 (10), 83 (19), 82 (11), 81 (35), 79 (13), 71 (15), 70 (14), 69 (92), 68 (15), 67 (35), 63 (10), 57 (19), 56 (15), 55 (77), 53 (21), 43 (48), 42 (36), and base peak 41 (100).

Anal. Calcd for $C_{20}H_{34}O_3$: mol wt 320.23514. Found: mol wt (mass spectrum) 320.23330.

B-3 had mp 119-121°; R_f = 0.26 (3:1 benzene-ethyl acetate, silica gel H); ir ($CHCl_3$) 3600, 3450 (hydroxyl), 1700 (C=O) and 1640 cm^{-1} (C=C); 60 MHz pmr ($CDCl_3$) δ 4.83 (s, 2H, C=$\underline{CH_2}$), 4.00 (m, 2H, two $\underline{C}$HOH), 1.78 (s, 3H, C=C-$\underline{Me}$), and 0.96 ppm (m, 9H, three H-C-$\underline{Me}$); mass spectrum (70eV) m/e (rel intensity) M^+, 324 (2), 306 (47), 291 (3), 288 (2), 276 (2), 263 (9), 248 (4), 235 (4), 221 (9), 205 (5), 192 (19), 168 (17), 164 (15), 153 (12), 149 (17), 141 (21), 138 (37), 136 (29), 127 (15), 123 (69), 121 (33), 109 (61), 99 (70), 95 (69), base peak 81 (100), 71 (35), 69 (62), 67 (40), 55 (95), 43 (50), and 41 (96).

Anal. Calcd for $C_{20}H_{34}O_3$: C, 74.02; H, 11.19. Found: C, 74.24; H, 11.05.

B-1 Acetate - A solution of B-1 (98.5 mg) in 2 ml of acetic anhydride and 2 ml of pyridine was stirred overnight at room temp. Tlc of the reaction mixture indicated complete conversion of B-1 to its acetate. The reaction mixture was diluted with chloroform (10 ml) and washed successively with 5% HCl (2x10 ml) and water 10 ml). The chloroform layer was dried ($MgSO_4$) and the solvent removed under reduced pressure on the rotary evaporator affording a white solid. Recrystallization from benzene-hexane gave 109.1 mg of B-1 acetate as white feathers: mp 95°; R_f = 0.70 (1:1 benzene-ethyl acetate, silica gel H), ir ($CHCl_3$) 1730, 1245 (acetate), 1700 (C=O), and 1640 cm^{-1} (C=C); 60 MHz pmr ($CHCl_3$) δ 4.70 (s, 2H, C=$\underline{CH_2}$), 2.04 (s, 3H, OAc), 1.70 (s, 3H, C=C-$\underline{Me}$), and

1.04 ppm (m, 9H, three H-C-<u>Me</u>); mass spectrum (70eV) *m/e* (rel intensity) M^+, 364 (7), base peak 304 (100), 289 (5), 286 (2), 261 (10), 222 (9), 191 (6), 189 (6), 179 (6), 167 (22), 165 (10), 151 (12), 149 (19), 135 (45), 134 (88), 126 (12), 123 (20), 122 (27), 121 (22), 119 (15), 112 (10), 111 (18), 110 (13), 109 (40), 108 (18), 107 (28), 105 (10), 97 (17), 95 (35), 93 (25), 83 (22), 82 (20), 81 (43), 79 (17), 71 (16), 69 (59), 68 (12), 67 (23), 57 (18), 55 (70), 53 (14), 43 (95), and 41 (63).

Anal. Calcd for $C_{22}H_{36}O_4$: C, 72.49; H, 9.96. Found: C, 72.85; H, 10.04.

B-1 - p-iodobenzoate - A solution of 0.9243 g of *p*-iodobenzoic acid in 10 ml of thionyl chloride was refluxed for 3.5 hr. After removing the excess thionyl chloride on the rotary evaporator, the last traces of gaseous byproducts were removed under vacuum, affording a white solid (*p*-iodobenzoyl chloride) which was not further purified. B-1 (136.5 mg) was dissolved in 7 ml benzene and 3 ml pyridine containing 0.483 g of the *p*-iodobenzoyl chloride prepared previously. After stirring for 2 days at room temp, tlc indicated essentially no reaction. The mixture was then refluxed for 2 days. Tlc showed the absence of starting material. The residue obtained after removing the solvents was chromatographed (100 g silic AR CC-7, 6:1 benzene-ethyl acetate, 50 ml/20 min). Fractions 7-9 showed a single spot by tlc, and proved to be the *p*-iodobenzoate derivative of B-1 (26 mg). A variety of solvents was employed in recrystallizing the solid, but suitable crystals for an x-ray study were not obtained; the crystals, although well formed, were either too small or dendritic. B-1 *p*-iodobenzoate had: mp 129-131°;

R_f = 0.76 (3:1 benzene-ethyl acetate); ir ($CHCl_3$) 1705 (broad, aromatic ester and ketone) and 1640 cm^{-1} (C=C); 60 MHz pmr ($CDCl_3$) δ 7.78 (s, 4H, aromatic), 4.90 (m, 1H, ArCOOC<u>H</u>), 4.70 (s, 2H, C=C$\underline{H}_2$), 1.68 (s, 3H, C=C-<u>Me</u>), and 1.08 ppm (m, 9H, three H-C-<u>Me</u>); mass spectrum (70 eV) <u>m/e</u> (rel intensity) M^+, 552 (4), 534 (1), base peak 304 (100), 289 (5), 261 (6), 248 (28), 231 (71), 203 (14), 167 (14), 149 (12), 137 (10), 136 (12), 135 (21), 134 (41), 125 (12), 123 (11), 122 (13), 121 (12), 109 (21), 107 (15), 104 (13), 96 (11), 95 (16), 93 (15), 83 (12), 82 (10), 81 (20), 76 (13), 69 (33), 67 (12), 55 (30), 43 (14), and 41 (23).

<u>Anal</u>. Calcd for $C_{27}H_{37}O_4I$: C, 58.68; H, 6.75. Found: C, 58.90; H, 6.79.

<u>B-3 diacetate</u> - A solution of 106 mg of B-3 in 2 ml of pyridine and 2 ml of acetic anhydride was refluxed for 30 min, after which time tlc showed the absence of B-3 and the appearance of a new spot. The mixture was diluted with chloroform (10 ml), washed with 5% HCl (3x10 ml) and water (10 ml), dried ($MgSO_4$) and the chloroform evaporated to give a yellowish solid, tlc of which showed a single spot. The solid was filtered through a short Florisil column (0.5x8 cm, 1:1 benzene-ethyl acetate) and recrystallized from benzene-hexane, affording 119 mg of white needles: mp 82-83°; R_f = 0.51 (3:1 benzene-ethyl acetate, silica gel G); ir ($CHCl_3$) 1720 (broad) and 1245 (acetate), 1700 (ketone), and 1240 cm^{-1} (C=C); 60 MHz pmr ($CDCl_3$) δ 4.75 (m, 2H, two <u>H</u>-C-OAc), 4.64 (s, 2H, C=C$\underline{H}_2$), 2.01 (s, 6H, two OAc), 1.68 (br, 3H, C=C-<u>Me</u>), 1.02 (d, 3H, J = 6.5 Hz, H-C-<u>Me</u>), 0.92 (d, 3H, H-C-<u>Me</u>), and 0.84 ppm (d, 3H, J = 6.5 Hz, H-C-<u>Me</u>); mass spectrum (70 eV) <u>m/e</u> (rel intensity) M^+, 408 (2), 348 (33), 308 (3), 288 (56), 237 (7), 270 (4), 255 (3), 245 (10),

231 (4), 217 (3), 203 (5), 189 (16), 175 (18), 161 (22), 149 (16), 147 (16), 135 (40), 134 (40), 121 (50), 120 (50), 109 (50), 95 (46), 81 (56), 69 (65), 67 (40), 55 (64), base peak 43 (100), and 41 (52).

Anal. Calcd for $C_{24}H_{40}O_5$: C, 70.55; H, 9.87. Found: C, 70.73; H, 9.67.

Isolation of SCC - Sclerophytum capitalis, air dried, wt 3.88 kg, collected by Dr. Robert E. Middlebrook and Ray Gross off the islet of Japtan in the Marshall Islands on August 7, 1973, was extracted with hexane. The concentrated hexane extract was placed in a refrigerator overnight. The insoluble portion was filtered and recrystallized several times from benzene-hexane to afford 1.5 g of SCC as white prisms: mp 111.5-112°; R_f = 0.71 (3:1 benzene-ethyl acetate, silica gel H); ir (KBr) 1730, 1240 (acetate), and 1610 (C=C); uv (95% ethanol) 247 nm, ε = 17,000; 100 MHz pmr ($CDCl_3$) δ 5.94 (s, 2H, C=C-C=C$\underline{H_2}$), 4.50 (d, 1H, J = 11 Hz, $\underline{H}$-CHOAc), 4.12 (d, 1H, J = 11 Hz, $\underline{H}$-CHOAc), 3.06 (m, 2H, two $\underline{H}$-C-O), 2.15 (s, 3H, OAc), 1.76 (s, 3H, C=C-$\underline{Me}$), 1.27 (s, 3H, $\underline{Me}$-C-O), and 1.06 ppm (d, 6H, J = 7 Hz, H-C-$\underline{Me_2}$); 25.2 MHz proton decoupled cmr ($CDCl_3$) δ 170.4 ($\underline{C}$=O), 148.0 ($\underline{C}$=C), 134.8 ($\underline{C}$=C), 120.0 ($\underline{C}$=C), 118.0 $\underline{C}$=C), 64.2 ($\underline{C}$-O), 62.4 ($\underline{C}$-O), 60.8 ($\underline{C}$-O), 60.0 ($\underline{C}$-O), 59.3 ($\underline{C}$-O), 37.9, 35.5, 34.6, 31.3, 25.0, 24.5, 23.8, 21.9, 21.9, 20.8, 17.4 and 17.4 ppm; mass spectrum (70 eV) m/e (rel intensity) M^+, 362 (5), 319 (2), 302 (1), 259 (3), 241 (2), 231 (1), 227 (1), 215 (2), 213 (4), 209 (4), 205 (1), 203 (2), 201 (3), 200 (1), 175 (14), 161 (13), 153 (14), 149 (18), 148 (25), 147 (18), 145 (11), 137 (11), 136 (21), 135 (52), 134 (25), 133 (50), 131 (10), 123 (22), 122 (52), 121 (53), 120 (56), 119 (47), 109 (33), 108 (13), 107 (58), 106 (14), 105 (45), 97 (11), 95 (34), 94 (13), 93 (66), 92 (12), 91 (45), 83 (20), 81 (49), 80 (12), 79 (41), 77 (28), 71 (31), 69 (50), 67 (33), 65 (10), 57 (25), 55 (66), 53 (23), 44 (11), and base peak 43 (100).

Anal. Calcd for $C_{22}H_{34}O_4$: C, 72.89; H, 9.45; mol wt 362.24571. Found: C, 72.84; H, 9.46, mol wt (mass spectrum) 362.24654.

Deacetyl SCC - SCC (152.2 mg) was dissolved in 20 ml of methanol and a catalytic amount (1 mg) of sodium was added. The mixture was allowed to stand overnight at which time tlc indicated the absence of SCC. Most of the methanol was removed on the rotary evaporator under reduced pressure without heating. Water (10 ml) was added and a white solid formed which was taken up in chloroform. The chloroform layer was washed (water) and dried ($MgSO_4$). After removal of the solvent, a white solid formed, which was recrystallized from hexane, affording 124.7 mg of white feathers: mp 119-121°; R_f = 0.11 (3:1 benzene-ethyl acetate, silica gel H); ir ($CHCl_3$) 3600, 3450 (hydroxyl) and 1600 cm^{-1} (C=C); 100 MHz pmr ($CDCl_3$) δ 5.92 (s, 2H, C=$\underline{H}_2$), 4.01 (dd, 1H, J = 6.5 Hz, J = 12 Hz, $\underline{H}$-CHOH), 3.67 (dd, 1H, J = 2 Hz, J = 12 Hz, $\underline{H}$-CHOH), 3.04 (m, 2H, two $\underline{H}$-C-O), 1.75 (s, 3H, C=C-$\underline{Me}$), 1.28 (s, 3H, $\underline{Me}$-C-O) and 1.05 ppm (d, 6H, J = 7 Hz, H-C-$\underline{Me}_2$); 60 MHz pmr ($CDCl_3$ + 1 drop D_2O) δ 5.92 (s, 2H, C=C$\underline{H}_2$), 4.00 (d, 1H, J = 12 Hz, $\underline{H}$-CHOD), 3.63 (d, 1H, J = 12 Hz, $\underline{H}$-CHOD), 3.04 (m, 2H, two $\underline{H}$-C-O), 1.75 (s, 3H, C=C-$\underline{Me}$), 1.28 (s, 3H, $\underline{Me}$-C-O), and 1.05 ppm (d, 6H, J = 7 Hz, HC$\underline{Me}_2$); mass spectrum (70 eV) m/e (rel intensity) M^+, 320 (7), 305 (2), 302 (1), 291 (3), 275 (2), 273 (2), 259 (3), 251 (2), 167 (11), 151 (12), 149 (13), 148 (12), 147 (11), 141 (11), 139 (11), 137 (20), 136 (15), 135 (26), 134 (12), 133 (21), 131 (11), 127 (12), 126 (11), 125 (20), 123 (23), 121 (25), 119 (21), 113 (10), 111 (16), 110 (15), 109 (33), 108 (15), 107 (30), 105 (20), 99 (28), 97 (24), 95 (43), 93 (46), 91 (30), 85 (17), 83 (28), 81 (43), 79 (22), 77 (15), 71 (35), 69 (29), 67 (21), 57 (21), 55 (41), 53 (14), 44 (11), base peak 43 (100), and 41 (45).

SUMMARY

Four novel diterpenoids were isolated from marine invertebrates and partially characterized. Three of the new compounds ($C_{20}H_{32}O_3$, $C_{20}H_{34}O_3$, $C_{20}H_{36}O_3$) appeared to possess the cembrane skeleton and ketone functionality; they were found in an unidentified Caribbean gorgonian. The fourth new marine diterpenoid ($C_{22}H_{34}O_4$) isolated from a pacific soft coral (S. capitalis) appeared to contain an unusual terminal conjugated diene system substituted by methyl and isopropyl groups.

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