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The Association of Cardiovascular Mortality Rates in Georgia with the Abundance and Distribution of Certain Elements in Rocks, Soils, and Plants.

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UNITED STATES DEPARTMENT OF THE INTERIOR

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The State of Georgia is a suitable region in which to relate cardiovascular mortality rates to the chemical nature of the environment because unusually-detailed epidemiological data are available for this State, and the varied geologic formations exposed give rise to distinct soil types and abundant vegetation that is available for sampling.

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The map of cardiovascular disease mortality in Georgia shows a distinct grouping of counties having low rates and high rates. When this map is superimposed on a geologic map the location of these counties suggests that there may be a relationship between disease mortality and the nature of the geologic formations. Furthermore, when the mortality rate map is superimposed on a soils map, a similar relationship is suggested. These correlations were of sufficient interest to the personnel of the U. S. Public Health Service, and of the Geochemical Census Branch, U. S. Geological Survey that a cooperative study of this problem was undertaken in 1963 by initiating a geochemical reconnaissance survey, covering counties that have substantial differences in cardiovascular death rates. The basic premise of this project is that if the geologic formations and soil types do actually influence the risk of dying from this disease, the influence may be through the chemical composition of the rocks, soils, and plants that occur in the different regions.

A limited sampling program including rocks, soils, and plants thought to be representative of these regions was completed during the past year, and the samples have been analyzed by chemical and spectrographic methods for 33 elements. Statistical evaluations of the data obtained have been made, and the results are presented in this paper.

CARDIOVASCULAR MORTALITY RATES

Death rates for the cardiovascular diseases are primarily for coronary heart disease, but include stroke, hypertensive disease, and other diseases of the heart and blood vessels. Rates have been computed for the State of Georgia by usual county of residence, utilizing all deaths for the period 1950-59 inclusive (1). Standard vital statistics techniques have been used in computing rates, along with several refinements to meet the specific needs of this type of ecological study. The group of greatest epidemiological concern is middle aged white males, which may be defined broadly as white males age 35 to 74. Rates have been computed for this age group, using the average of the 1950 and 1960 censuses as the population at risk, and adjusting rates by the direct method by 10-year groups to the total U. S. population of that age in 1950. Differences in rates are therefore not due to differences in the age, sex, or race of the population of the different counties.

The high rate counties have rates for the cardiovascular diseases roughly double, and in some instances more than double, the rates for the low rate counties. In this one State contrasts are found almost as great as for the entire United States (2). These contrasts are quite clearly not due to random error, and thus far show no evidence of being due to methods of data collection or classification--and we have made extensive search for such evidence. Thus, there is an incentive to search for and test hypotheses regarding factors which may be responsible for these differences.

These death rates tell us that the risk of dying in middle age is twice as great in the high-rate areas as in the low-rate areas. They do not tell us whether in the high-rate areas the attack rate is higher, these diseases more lethal, or both.

Figure 1 presents six counties in the northern part of the State with very low death rates. They are part of a group of contiguous low-rate counties in the Highlands of the Southern Blue Ridge and Upper Piedmont. Six counties with very high death rates are likewise part of a group of contiguous high-rate counties in the east-central part of the State, in the vicinity of Augusta and to the south. Savannah and Chatham County also have very high rates, as do some other counties in less clearly defined geographic areas. There are also individual sparsely settled counties with low rates scattered about the map of the State, but further study is required before one may have reasonable assurance about the risk of mortality in these areas. The counties that were chosen do give substantial evidence that they are properly classified. For example, there are 159 counties in Georgia, and the low-rate counties are all among the 20 lowest for all causes of death as well as among the very lowest for the cardiovascular diseases generally, and coronary heart disease specifically. Similarly, the high-rate counties are all among the 20 highest for all causes of death as well as being highest for the cardiovascular diseases.

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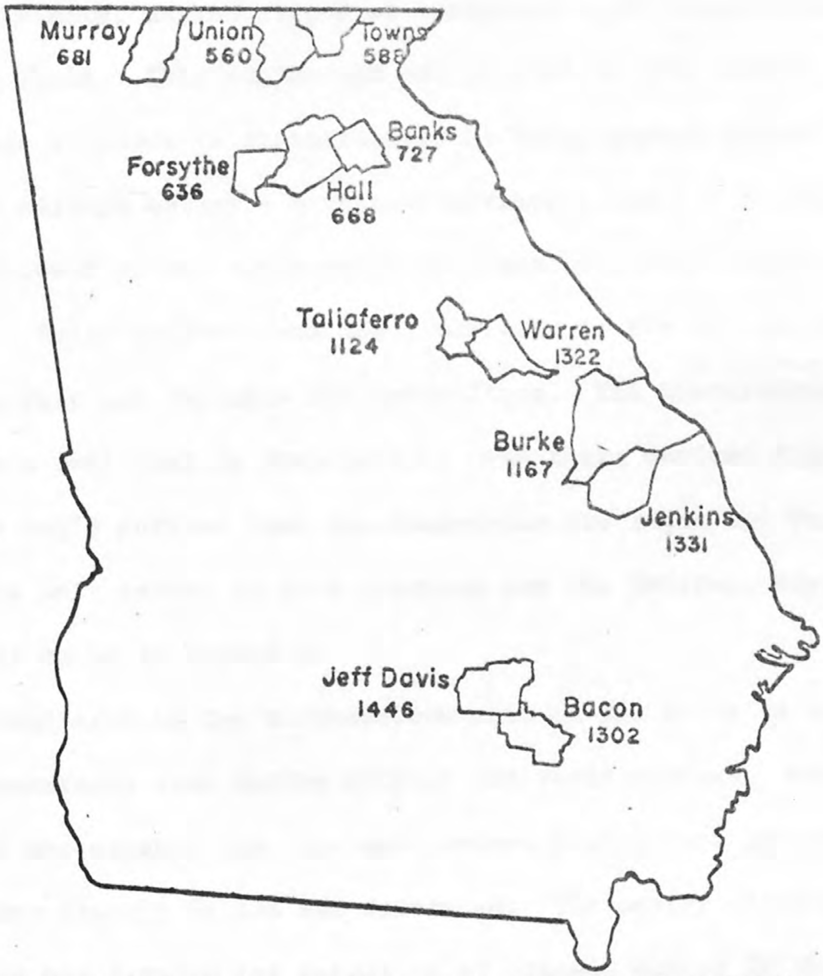

Figure 1. Selected Georgia counties with high and low death rates per 100,000 population for cardiovascular diseases, white males age 35-74, 1950-59.

GEOLOGY AND SOILS OF GEORGIA

In Figure 2 the State is divided into 5 physiographic regions (3), each characterized by features of relief and geologic formations (4) that have been largely responsible for the different soils that occur. The Cumberland Plateau barely extends into the extreme northwestern part of the State, where high, narrow ridges of sandstone occur interbedded with layers of shale. This region was not sampled in this study. The Valley and Ridge province is characterized by long, narrow ridges that parallel broad valleys having a northeast-southwest trend. The ridges are largely composed of the resistant sandstones and sandy shales of Paleozoic age. Soils derived from the limestones in the valleys generally are rich loams that are suitable for agriculture. The noncalcareous shales produce a soil that is less fertile than those derived from limestone, and the soils derived from the sandstones are light and relatively infertile. The Soil Series in this province are the Decatur, Dewey, and Clarksville, as shown in Figure 3.

The Highland Area in the northeastern part of the State is characterized by high mountains with narrow valleys and rapid streams. Most of the rocks here are crystalline, the most common kinds being gneisses and schists that are greatly folded and fractured. The cooler climate of the high elevations has favored the retention of organic matter in the generally acid soils, but the great relief of the area does not promote large-scale agriculture, and subsistance farms are prevalent. The Soil Series occurring here are the Porters and the Ashe.

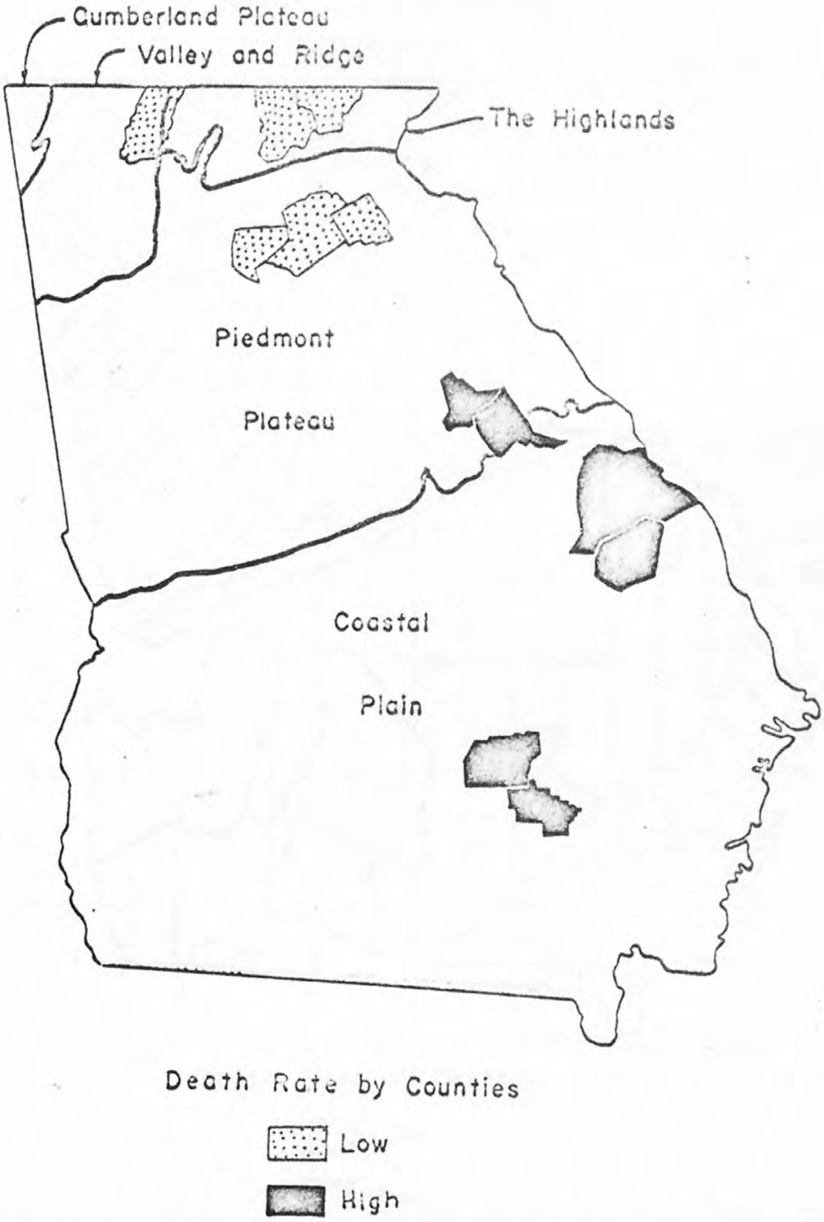

Figure 2. Physiographic Regions of Georgia, and location of counties that were sampled having high and low cardiovascular mortality rates.

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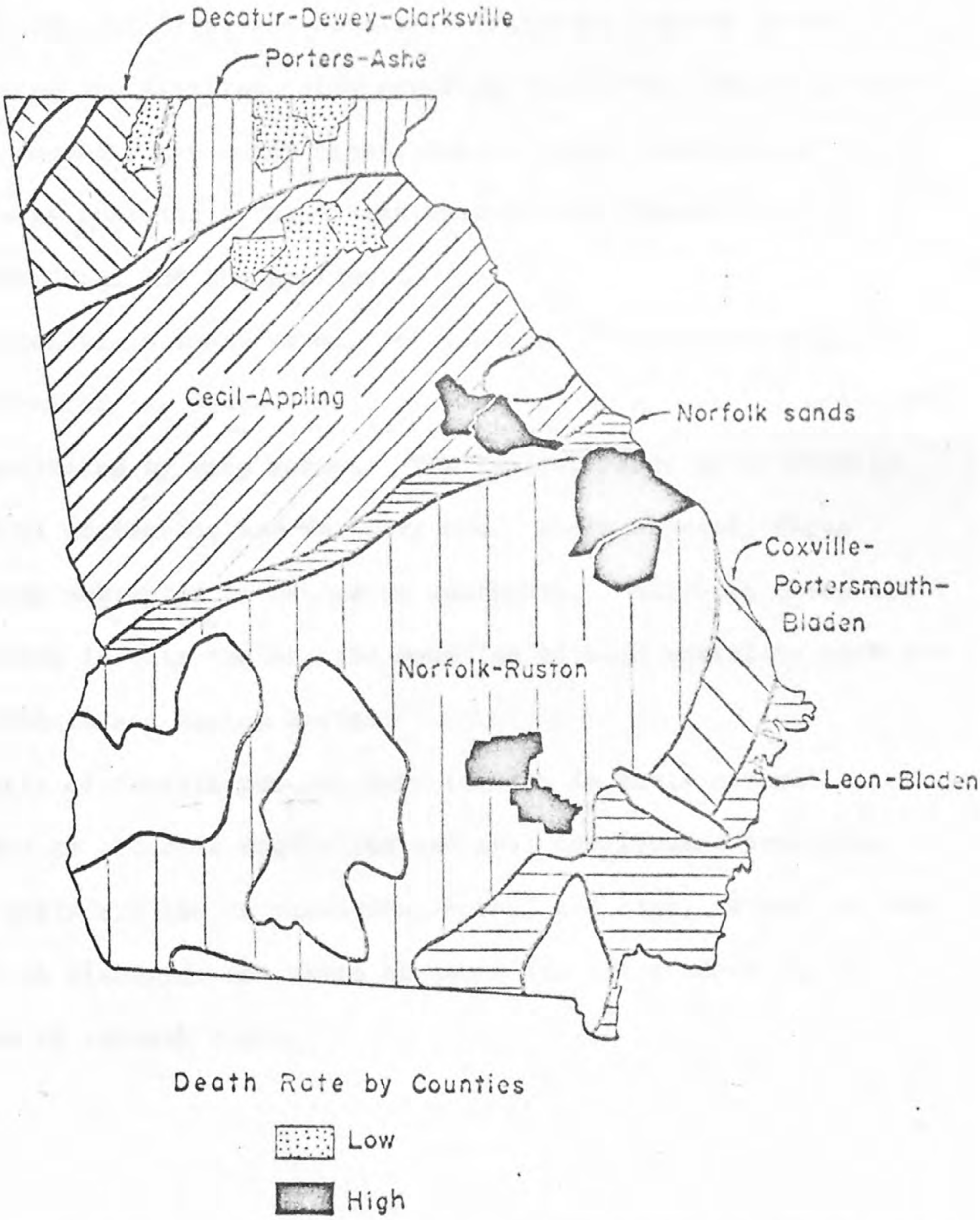

Figure 3. Soil Associations of Georgia, and location of counties that were sampled having high and low cardiovascular mortality rates.

The Piedmont Plateau stretches from the foot of the Appalachian Mountains to the Fall line at the Coastal Plain, and comprises about one-third of the State. The predominant rocks are granites, gneisses, schists, diorites, gabbros, and basalts. Intrusive igneous rocks, such as granites and diorites, also occur in this area. The soils of the Piedmont commonly are sandy loams, but in places erosion has exposed the clay subsoils. The characteristic Soil Series in this region are the Cecil and the Appling.

The Coastal Plain includes most of southern Georgia and comprises about 60 percent of the State. This area is low-lying for the most part and is characterized by many swamps. The typical sandy soils overlie marine rocks of Cretaceous and Tertiary age. Where exposed, these rocks have been subjected to extensive weathering. Although there are many Soil Series in this region, the counties of high mortality here are all in the Norfolk and Ruston Series.

Most soils of Georgia are not very fertile in their natural condition, due to climatic conditions and soil development processes (5). These soils are low in magnesium, boron, and zinc, as well as the major essential elements, and trace elements are often added in the fertilization of certain crops.

SAMPLING AND ANALYTICAL PROCEDURES

In our reconnaissance sampling program we attempted to broadly characterize the geochemical regimen of the areas of Georgia having different cardiovascular mortality rates. The evaluations that we first sought were fundamental chemical features of the lithosphere and biosphere, as expressed by the element content of rocks, unaltered soils, and native plants which, because of their spatial and temporal extent, we assume have been but slightly modified by man's occupancy. Man-made changes in the chemical nature of inhabited regions ordinarily are local, quite varied, of small scale, and of short duration as compared to the human life span. In particular, we are trying to determine if men, many of whom have lived 35 or more years in a certain county, have been subjected to definable chemical properties of their environment that could have influenced their chances of death from cardiovascular diseases. Therefore we cannot at this time consider the man-made changes in the chemical environment that fluctuate from field to field and from year to year. The complete evaluation of these changes would require the case-history approach to the problem, which was not the intent of this study; however, the effects of cultivation and fertilization of the soil, the introduction of cultivated plants, and other biotic changes resulting from the use of land for agriculture and industry <u>are</u> important in a study of man's relation to his environment and their consideration is a logical sequel to the present investigation.

We selected samples of rocks, soils, and plants that we thought were representative of two widely separated locations in each county that was investigated. Admittedly the selection of sample sites and the samples themselves was often largely subjective; however, the choices were based on previous field experiences and laboratory analyses. We selected sites located on the geologic formation or formations that could be reasonably assumed to have had the greatest influence on soil formation in the county. The soils that were sampled could be assigned to a named Soil Series that was typical of the region and were mature, undisturbed zonal soils of residual origin. The plants selected were native trees and shrubs growing on these soils (6). At some sites rock sampling was impractical because outcrops were lacking, or because weathering was so extreme that bedrock could not be distinguished from the C soil horizon. Soils were sampled to bedrock, where possible, and the identifiable horizons were analyzed separately. Tree and shrub samples consisted of the terminal 4- to 6-inch-long portions of branches, the leaves being removed and analyzed separately from the stems. The tree species sampled were mostly those of well-known genera, such as the oaks, hickories, maples, elms, pines, black gums, sweet gum, sassafras, and dogwood, whose element absorbing capabilities are at least partly known and whose extensive root systems provide a composite sampling of their substrates.

All samples were analyzed in the Denver laboratories of the U. S. Geological Survey, using the standard methods of sample preparation and analysis of these laboratories (7). The samples were analyzed for potassium, phosphorus, and calcium by "wet chemical" colorimetric methods, and for the remaining elements (except iodine) by semi-quantitative spectrographic methods. Iodine analysis of plants was accomplished by a new method that combines oxygen flask combustion and the ceric sulfate process.

RESULTS

In a reconnaissance survey of this type with a limited number of samples collected, there always exists the possibility that the element content of the samples is not truly representative of the typical element distribution in the groups of counties that were sampled. Although this fact was kept in mind during the study and attempts were made to minimize this source of error, we have as yet no means of determining that our samples are actually representative. Similarly, the mortality rates cannot be guaranteed to be absolutely exact; therefore the summary of results presented in Table 1 should be viewed with caution.

The group of counties with low death rates generally have the higher content of elements that were determined. No chemical element was found to be clearly present in greater amounts in the high-death-rate counties. In soil samples, the calcium content is slightly greater for the high-death-rate counties than for the low-rate counties. While this difference is not great enough to be statistically significant, this relationship is in harmony with the findings for drinking water in Oklahoma by county (8). Opposite findings have been reported for Great Britain (9) and the United States (10), in both instances the areas with higher calcium content in the drinking water tending to have lower death rates.

Table 1. Area with greater content of specified chemical elements by type of specimen and level of statistical significance.
[Area: "Low" is the group of low-mortality Georgia counties sampled (Union, Towns, Banks, Hall, Murray, and Forsythe). "High" is the group of high-mortality Georgia counties sampled (Bacon, Burke, Jeff Davis, Jenkins, Taliaferro, and Warren).]

Chemical element	Soil samples		Rock samples		Plant samples, matched species in both areas		Pines, all species combined	
	Area with higher chemical content	Level of statistical significance	Area with higher chemical content	Level of statistical significance	Area with higher chemical content	Level of statistical significance	Area with higher chemical content	Level of statistical significance
Barium	Low	-	Low	*				
Calcium	High	-	Low					
Cobalt	Low		Low					
Chromium	Low	-	Low	*	Low	-	High	-
Copper	Low	**	Low	-	Low	-	Low	-
Gallium	Low	*	(equal)					
Iron	Low	*	Low	-			Low	*
Lanthanum	Low		Low					
Lead	(equal)	-	High					
Magnesium	Low	**	Low	**	Low	-	Low	-
Manganese	High		Low					
Neodymium	Low	-	Low					
Nickel	Low	**	Low	-			High	-
Niobium	High		Low					
Phosphorus	Low	*	Low	**			Low	*
Potassium	Low	-	Low	-				
Scandium	Low		Low					
Strontium	High		High	-	Low	-	Low	*
Titanium	High		Low	*			Low	*
Vanadium	Low	-	Low	-				
Yttrium	High		Low					
Zinc	Low	**	Low	**	Low	-	Low	-
Zirconium	High	-	High	-				

* Difference statistically significant at the .05 level
** Difference statistically significant at the .01 level
\- Difference not statistically significant at .05 level
(blank) Difference not tested for statistical significance

Of the 46 comparisons of soil and rock samples, in only ten instances were the high-death-rate counties found to have a higher content of the elements that were determined, and none of these differences was statistically significant. The greater abundance of magnesium, zinc, phosphorus, iron, chromium, copper, gallium, nickel, and titanium in the low-death-rate areas was found to be statistically significant, at the levels indicated in Table 1, either for soil or rock samples. Some of these differences are substantial; for example, there is approximately four times as much magnesium in the samples from the low-rate areas as from the high-rate areas. However, the difference in magnesium content of plants, matched as to species, is negligible.

Zinc is present in markedly greater quantity in soil and rock samples from the low-death-rate areas. It also tended to be present in slightly greater amounts in the plant samples; however, these differences are nominal, either for matched species of plants from the two areas, or for pine species alone.

Strontium is the only element that has a higher average content in both soil and rock samples from high-death-rate areas, but the differences are too small to be statistically significant; in fact, the difference for the soil samples is so small that it could be due to rounding error alone. The various plant samples, with species matched for high- and low-mortality-rate areas, show slightly more strontium in the low-death-rate area. This difference is not statistically significant, but the analyses of pines alone do show a significant difference at the .05 level.

Phosphorus is present in significantly greater amounts in both soil and rock samples in the low-death-rate area. The difference for plant samples is not quite statistically significant at the .05 level, but for pines alone, the higher content of phosphorus from the low-death-rate samples is barely statistically significant at the .05 level.

Analyses for ten additional elements were made, but the results are not presented because in general not enough of the elements was found in either death-rate area for quantitative evaluation. The elements in Table 1 for which tests of statistical significance are omitted generally have such little difference between high- and low-death-rate areas that the tests were not run.

DISCUSSION

Ecological research such as this study should be thought of as purely exploratory. The factors causing the high death rates in counties of east-central Georgia are not known, nor are the factors known which provide protection in the counties of northern Georgia. Thus, it is obvious that we do not know whether to search for these factors in the physical and biological environment, or in the social environment. Further, we do not know whether we are really dealing with one low-death-rate area, or whether we have several contiguous areas with different factors providing the protection in the different areas.

Substantial progress has been made in testing and improving vital statistics techniques for measuring the risk of mortality in specific geographic areas, but it is recognized that much work in this area still needs to be done. Much also needs doing in determining the plants to be sampled and the sampling design, and in measuring the amounts of the various chemical elements in soils, rocks, and plants. Just as proportionate mortality is often a rather weak tool in vital statistics, the use of plant ash analyses as the basis for comparison of the chemical environment of areas may be found to be inadequate. The inherent variability of plants, both within species and between species, in regard to their chemical element content is a factor that must be better understood before significant comparisons of plant analyses can be made. In a comparison of the samples of five species of plants from all twelve counties combined, examples of differences in plant ash are as follows: The leaf of black gum has more than five times the magnesium content of the stem of sweet gum. Pine stems and leaves have more than eight times the zinc content of the leaves of dogwood. The strontium content of stems of dogwood is seven times that of pine stems and leaves.

We cannot at the present time definitely associate the patterns of chemical-element abundance with specific geologic formations, soil associations, or physiographic provinces, although this study does indicate that at least approximate associations may be possible.

The low-death-rate areas generally had a level of content of various chemical elements in soil and rock samples and in plant ash about as high as, and in a number of instances higher, than the level in the high-death-rate areas. Thus there is no evidence that these elements as a group, in the levels found in northern Georgia, are "harmful"--using cardiovascular death rates as our measure of "harmful"; it seems appropriate to consider further study of the possibility that one or more of these elements, either singly or as a group, may provide some measure of protection against the cardiovascular diseases.

We are, therefore, recognizing some of the many technical problems of this study which deserve careful attention, and that work in this area has just barely begun. Even if no positive results are achieved, it seems to us worthwhile to demonstrate that various individual chemical factors give no specific evidence of contributing to cardiovascular mortality.

SUMMARY

1. A reconnaissance survey was made and samples collected of soils, rocks, and plants in six counties in northern Georgia with very low death rates for the cardiovascular diseases, and in six counties in east-central Georgia with very high death rates. These samples were analyzed for 33 chemical elements.

2. There was a marked and significantly higher content of zinc and magnesium in both soil and rock samples ($P = .01$) in the low-death-rate area than in the high-death-rate area. However, the zinc and magnesium content of plant ash was not appreciably higher in the low-death-rate area, either for a wide variety of plants, for matched species, or for pines alone.

3. A great variety of chemical elements was found to be as abundant or in some instances more abundant in the low-death-rate area than in the high-death-rate area. It therefore seems reasonable to submit the hypothesis that these elements as a group, in the levels found in northern Georgia, do not increase the risk of death from cardiovascular diseases.

4. Further study is needed before suggesting hypotheses as to specific elements which may be protective against cardiovascular diseases.

REFERENCES

1. Sauer, H. I.; Council, C. R.; Terrell, J. C.; and Payne, G. H. Cardiovascular Mortality Patterns in Georgia and North Carolina, Presented to the Statistics Section, APHA, October 7, 1964.
2. Sauer, H. I. Epidemiology of Cardiovascular Mortality--Geographic and Ethnic. A.J.P.H. 52:94-105 (Jan.) 1962.
3. McCallie, S. W. Physical Geography of Georgia. Geol. Survey of Georgia, Bull. 42, 1925.
4. Georgia Division of Mines, Mining and Geology. Geologic Map of Georgia. Atlanta, Georgia: Georgia Division of Mines, Mining and Geology, 1939.
5. Carter, R. L.; and Giddens, Joel. Soils of Georgia, their Formation, Classification and Management. Univ. of Georgia College of Agric. Exp. Station Bull. 2, 1954.
6. Small, John K. Manual of the Southeastern Flora. Chapel Hill, N. C.: Univ. of North Carolina Press, 1933.
7. Ward, F. N.; Lakin, H. W.; Canney, F. C.; and Others. Analytical Methods Used in Geochemical Exploration by the U.S. Geological Survey. U.S. Geol. Survey Bull. 1152, 1963.
8. Lindeman, R. D.; and Assenzo, J. R. Correlation Between Water Hardness and Cardiovascular Deaths in Oklahoma Counties. A.J.P.H. 54:1071-1077 (July), 1964.

REFERENCES (continued)

9. Schroeder, Henry A. Relations Between Mortality from Cardiovascular Diseases in the United States and Some Constituents of Treated Water Supplies. J.A.M.A. 172:1902 (Apr. 23), 1960.

10. Morris, J. N.; Crawford, M. D.; and Heady, J. A. Hardness of Local Water Supplies and Mortality from Cardiovascular Disease in the County Borroughs of England and Wales. Lancet 1961, 1:860-862 (Apr. 22), 1961.

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1. The association of cardiovascular mortality rates in Georgia with the abundance and distribution of certain elements in rocks, soils, and plants, by H. T. Shacklette and Herbert I. Sauer. 21 p., 1 figure, 1 table.