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CONTENTS

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URBANIZATION AND REGIONAL DEVELOPMENT IN THE UNITED STATES

BRIAN J. L. BERRY

INTRODUCTION

The interrelations between urbanization and regional development in the United States may be studied on at least two planes:

(a) That of the long-term associations between regional growth and urban development as the nation expanded and its space-economy was successively transformed by a seriesof major innovations.

(b) The present cross-sectional relationships between the degree to which different regions are urbanized and their level of welfare.

In this paper we examine the former topic in sufficient detail to develop an understanding of the processes operating, specify the more important dimensions of the cross-sectional relationships that exist today, and suggest some of the implications for regional policy in the present American societal and institutional context.

REGIONAL GROWTH THE PRIME FACTOR IN DEVELOPMENT OF THE AMERICAN URBAN SYSTEM [1]

MERCANTILE BEGINNINGS

America's oldest cities were mercantile outposts of a resource area whose exploitation was organized by the developing metropolitan system of Western Europe. The initial impulses for independent urban growth came at the end of the eighteenth century, when towns were becoming the outlets for capital accumulated in commercial agriculture and the centres of colonial development of the continental interior.

[1] This section drawn from B. J. L. Berry and E. Neils, Location, size and shape of cities as influenced by environmental factors: the urban environment writ large. Paper presented at *Resources for the Future Conference on New Resources in an Urban Age*, 1967, and submitted to Geographia Polonica in 1968 to aid access by non-American scholars.

Arable land was the resource that counted in regional growth. Regional economies developed a certain archetype: a good deepwater port as the nucleus of an agricultural hinterland well-adapted for the production of a staple commodity in demand on the world market[2]. Growth potentials of regions depended on the extent and richness of the hinterlands accessible to the ports (Fig. 1), and the dis-

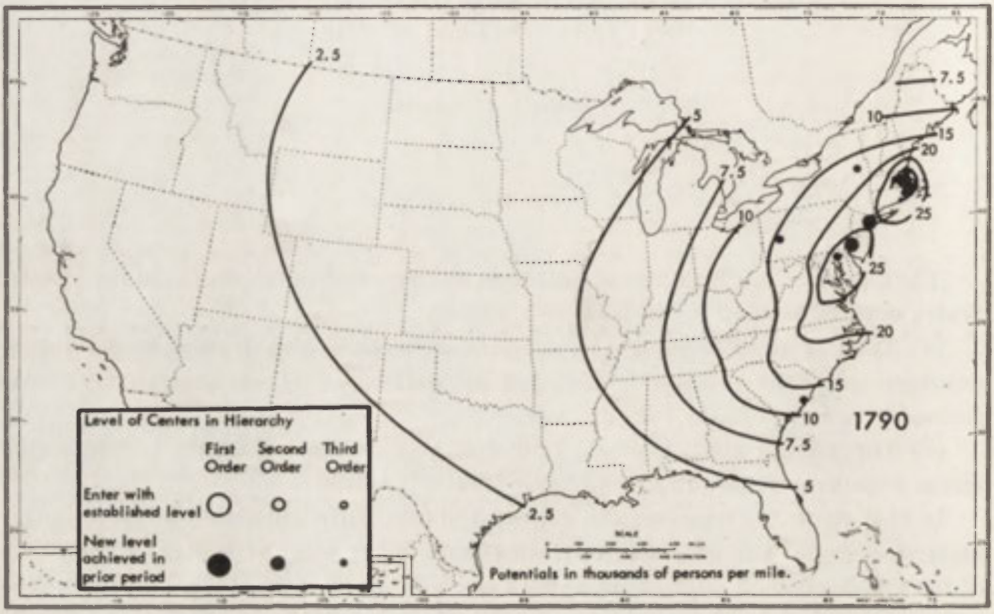

Fig. 1. Status of urban centres in 1970 related to population potentials in that year. Potentials at any point i were calculated by William Warntz in thousands of persons per mile as $p_i = {}_j p_j/d_{ij}$. Level of centres in the urban hierarchy estimated by John Borchert. See references in footnotes 4 and 5

tribution of economic activity before 1840 was a function of the expansion of nucleated agricultural regions into the vacuum of the unsettled continent (Figs. 2-4).

It was during this expansion phase that New York established itself as the national metropolis (Figs. 3-4), a position it was never to lose, by setting the terms under which exportable surpluses were marketed, imports obtained, and by which interior industries could secure credit. New York was the one colonial centre which had the advantages of good interior connections for both exports and imports. Boston and Charleston were prevented from exploiting the interior by physical barriers. Baltimore and Philadelphia were able to import with ease, but trans-Appalachian movement of exports to them was too costly. New Orleans was well-suited

[2] H. S. Perloff and L. Wingo, Natural resource endowment and regional economic growth, in J. J. Spengler, ed., *Natural resources and economic growth.*

to control the riverine internal trade, but was far distant from the growing supply areas of domestic manufactures and the heart of the domestic consumer market.[3] The prototypic American metropolis thus was a port at a strategic location on long-distance oceanic or riverine trade routes, providing a range of mercantile services, and determining the terms of trade.

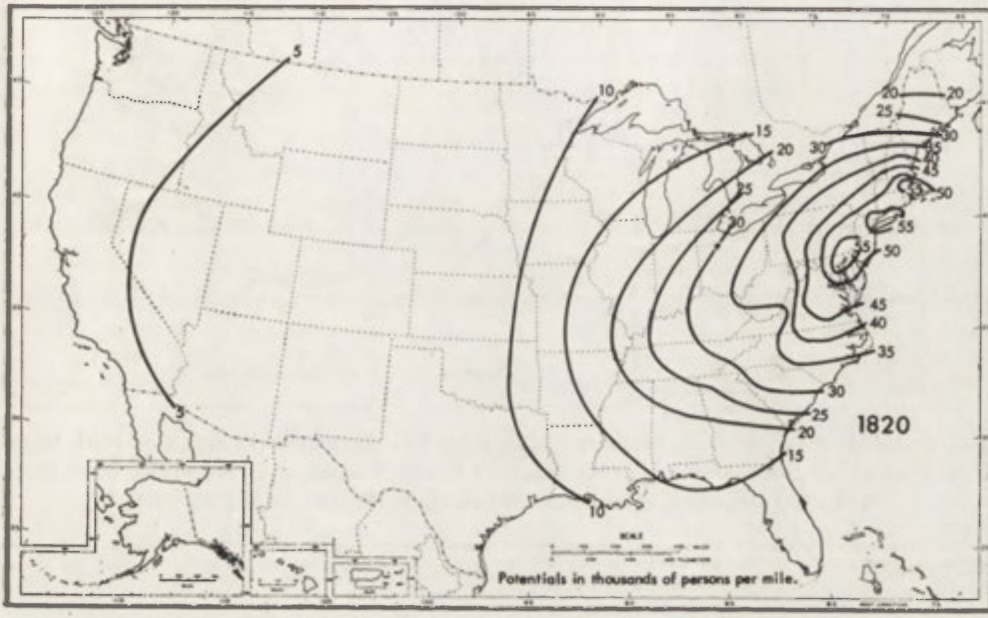

Fig. 2. Population potentials, 1820. Note the increasing densities along the east coast and the westward spread. Whereas Boston had the peak potentials in 1790, three east coast metropoli now share that role

This agricultural resource-dominated (but city-centred) expansion of the economy set the stage for subsequent developments by establishing a geography of markets, transport routes and labour force that conditioned the nature of succeeding growth.[4] The process of population increase and spread continued, and with rapid construction of the railroads and expansion of processing industries, new rail transportation-manufacturing centres such as Cincinnati, Chicago and St. Louis grew up at "gateways" from which the agricultural regions of the midwest could be or-

[3] B. Duncan and S. Lieberson, *Metropolis and region in transition*, Resources for the Future, Inc., 1967. J. R. Borchert, American metropolitan evolution, *Geographical Review*, 57 (1967), 3, 301—332.

[4] W. Warntz, *Macrogeography and income fronts*, Regional Science Research Institute, 1965. Also: Macroscopic analysis and some patterns of the geographical distribution of population in the United States, 1790—1950, in *Quantitative geography*, Northwestern Studies in Geography, 1967.

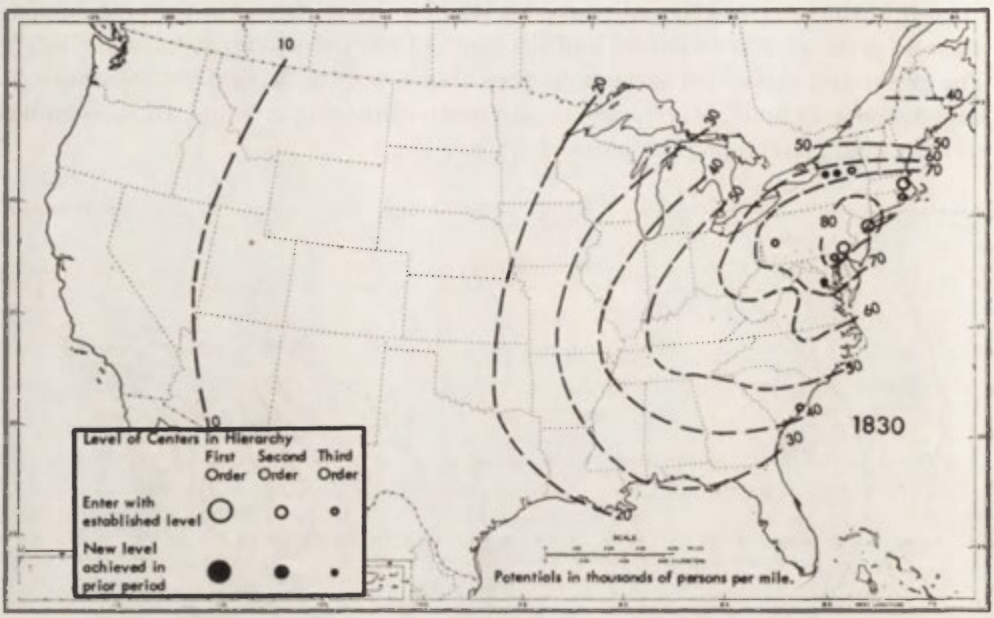

Fig. 3. Status of centres in the hierarchy, 1830, related to population potentials of 1840. Open circles indicate centres whose level in the hierarchy remained unchanged 1790—1830. Black symbols show centres rising to new status (along the Hudson—Mohawk route)

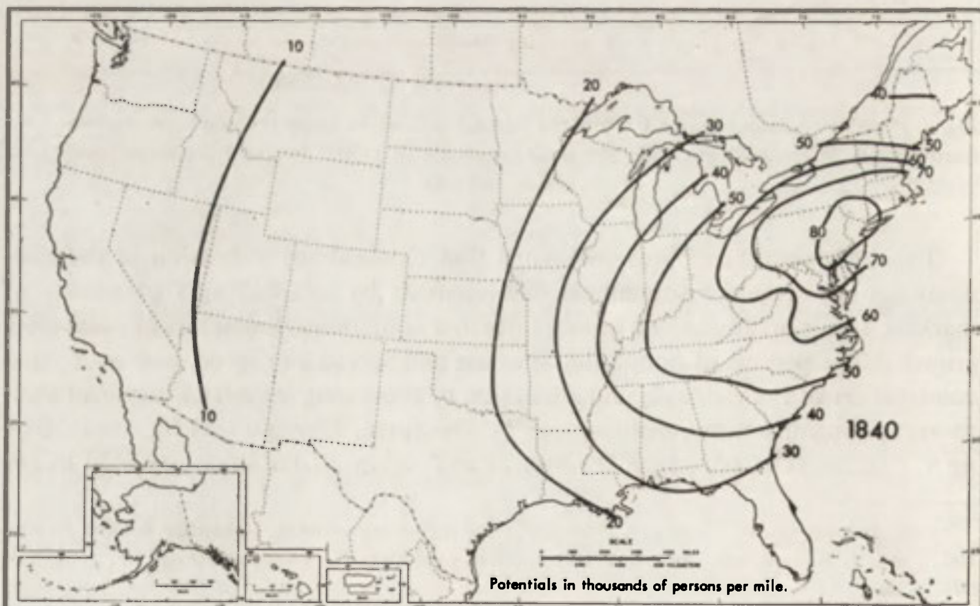

Fig. 4. Population potentials in 1840. Already, the peak potential has centred in New York, and the trans-appalachian spread of population continues

ganized. As in the east shipments of goods demanded by the agriculturalists and the assembly of agricultural products for regional, national and international markets took place to and from the national and regional metropoli through the organizational medium of a central-place hierarchy comprising regional capitals, smaller cities, towns, villages and hamlets.[5]

INDUSTRIAL TRANSFORMATION

But new resources became important from 1840-1850 onwards, and new locational forces came into play. Foremost was a growing demand for iron, and later steel, and along with it rapid elaboration of productive technologies. Juxtaposition of coal, iron ore and markets afforded the impetus for manufacturing growth in the northeastern United States localized by both factors in the physical environment (minerals) and system-related environmental components (linkages to succeeding stages of production). Manufacturing cities such as Buffalo, Cleveland, Detroit and Pittsburgh grew on bases that were spatially distinct from the earlier centres that

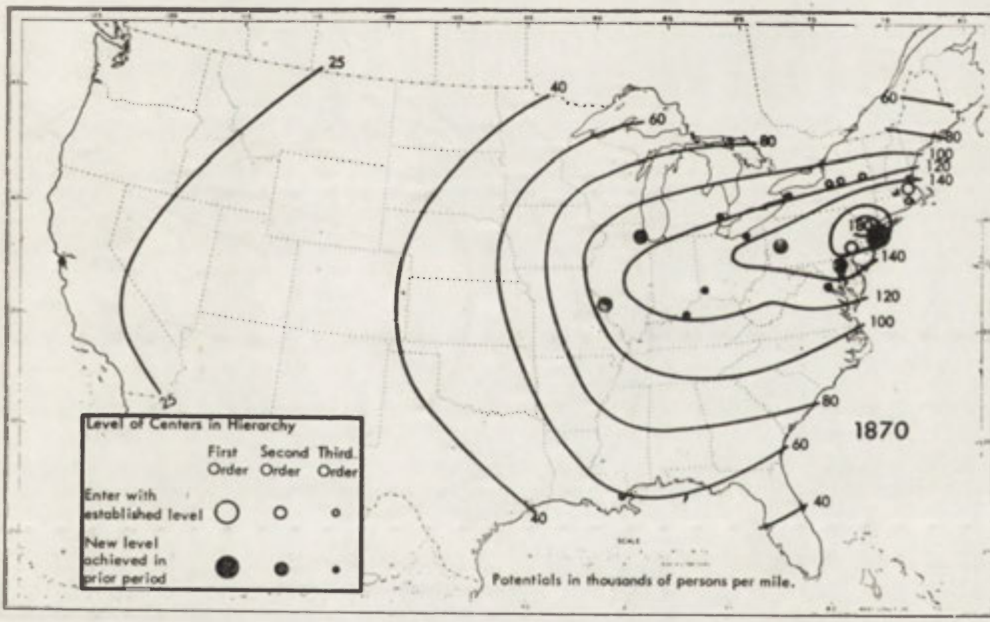

Fig. 5. Many urban centres achieved new status in the 1830—1870 period. The manufacturing belt and agricultural midwest stand out clearly in this growth. New York has moved ahead to first order status, and population potentials outline the northeastern heartland

[5] B. J. L. Berry, *Geography of market centers and retail distribution*, Prentice-Hall, Inc., 1967.

dominated long-distance trade, although some of the commercial metropoli were able to capture a share of the new manufacturing base. The "heartland" of the American manufacturing belt developed westwards from New York in the area bounded by Lake Superior iron ores, the Pennsylvania coalfields, and the capital, entrepreneurial experience, and engineering trades of the north-east, while at the same time New York cemented its dominance by accentuation of its financial, entrepreneurial, and specialized manufacturing roles. This heartland became not only the heavy industrial centre of the country, but has remained the centre of national demand, determining patterns of market accessibility since (Figs. 5-6).[6]

CUMULATIVE HEARTLAND-HINTERLAND RELATIONSHIPS

The heartland had advantages of both excellent agricultural resources and a key location in the minerals economy. With development, it grew into the urbanized centre of the national market (Figs. 10 and 11). Subsequent metropolitan growth has been in a pattern organized around this national core region. Since 1869 there

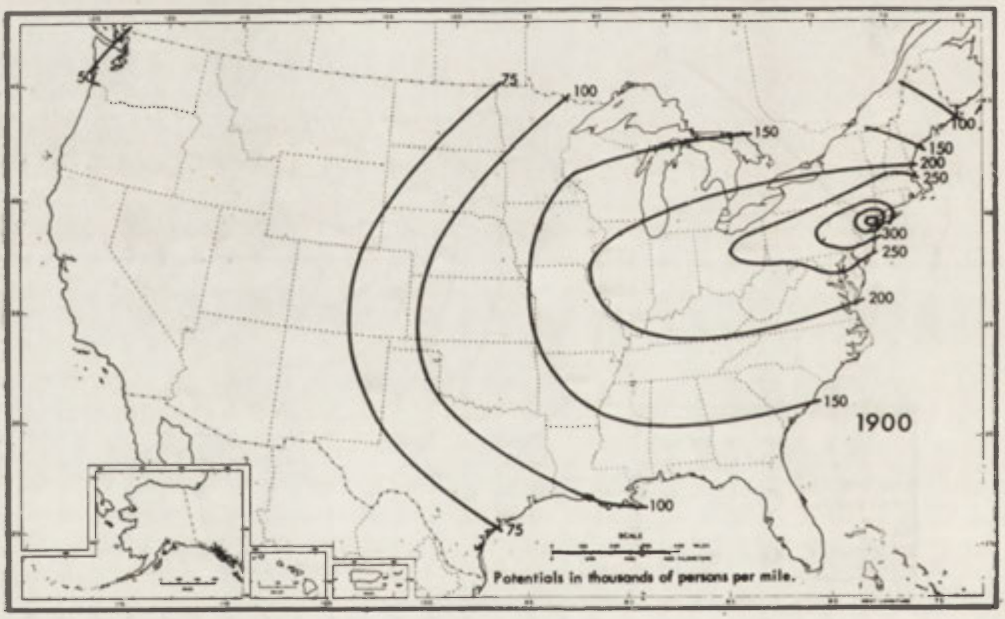

Fig. 6. Population potentials in 1900. The northeastern heartland and the New York peak are again emphasized

[6] Ch. D. Harris, The market as a factor in the localization of industry in the United States, *Annals, Association of American Geographers*, 44 (1954). E. L. Ullman, Regional development and the geography of concentration, *Papers, Regional Science Association*, 5 (1959).

has been a stable pattern of growth in manufacturing employment among the states.[7] Continued spread of population and agriculture over the continent pulled processing and servicing activities and new urban growth with them (Fig. 7). Howe-

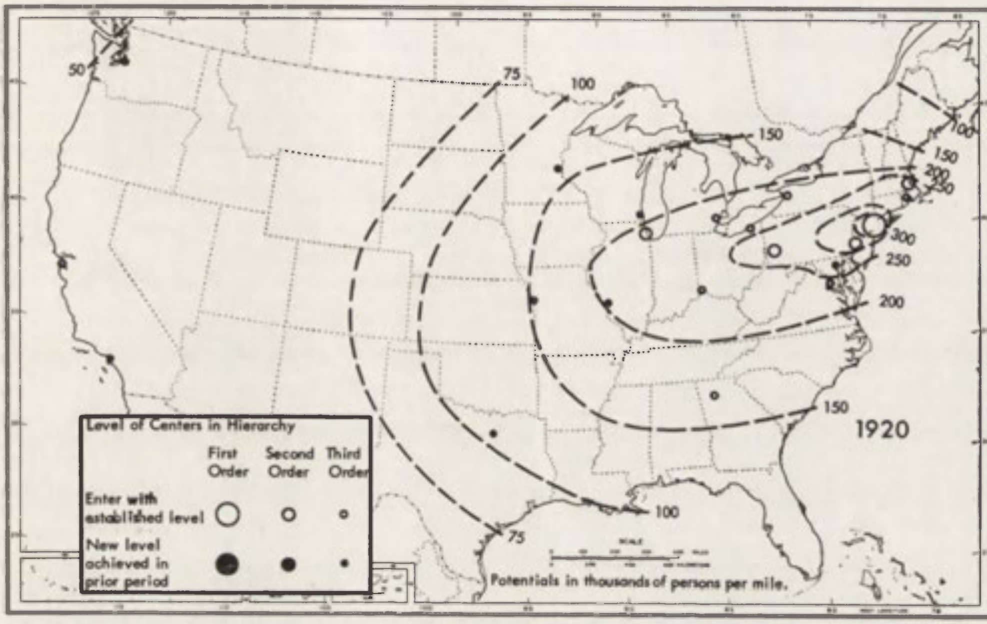

Fig. 7. New urban growth in the 1870—1920 period. Note emergence of the commercial metropoli of the plains and the west coast

ver, the developmentally-dominant effects still came from growth of the minerals economy until well into the twentieth century, so that a process of "circular and cumulative causation"[8] strengthened and maintained the relations of the national heartland and hinterlands — of core and periphery — and the new metropolitan centres that did emerge did so in sequence with the overall growth of the economy.

Before 1900, New Orleans, San Francisco, and Minneapolis grew as commercial "gateways" for the Gulf and Mississippi basin, the central valley of California, and the mid-continent plains, respectively. Between 1900 and 1940, Los Angeles grew as the trade and service centre for southern California, and Kansas City emerged in the central plains. Since 1940, Seattle has grown in the Pacific Northwest and

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7 G. H. Borts, *Patterns of regional economic development in the United States, and their relation to rural poverty*. Report to the National Advisory Commission on Rural Poverty, U.S. Department of Agriculture, 1967.

8 A. Pred, *The spatial dynamics of U.S. urban-industrial growth, 1800—1914*, The M.I.T. Press, Cambridge 1966.

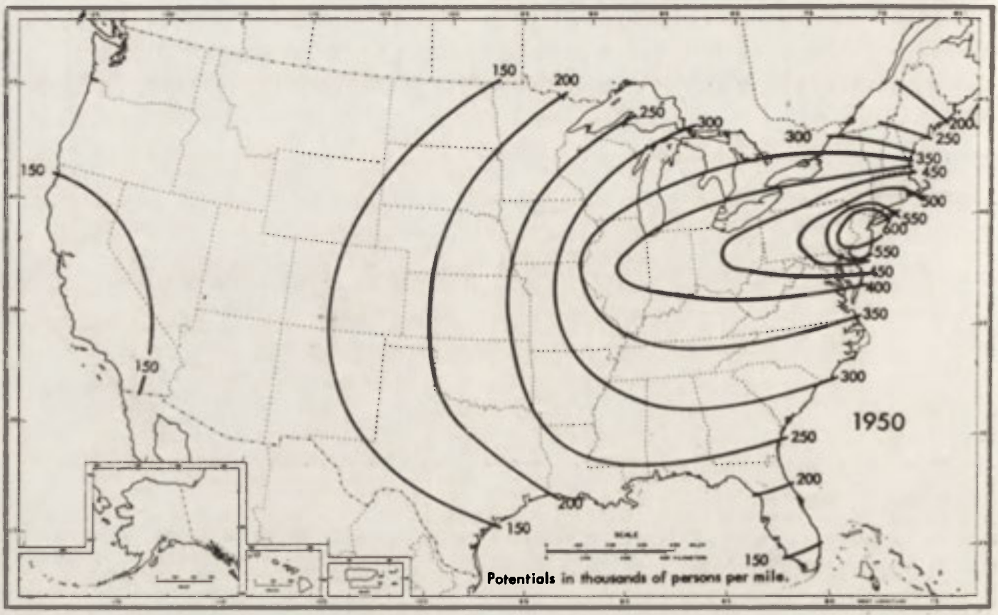

Fig. 8. Population potentials in 1950. Emergence of a Californian "rise" is a new feature of the pattern

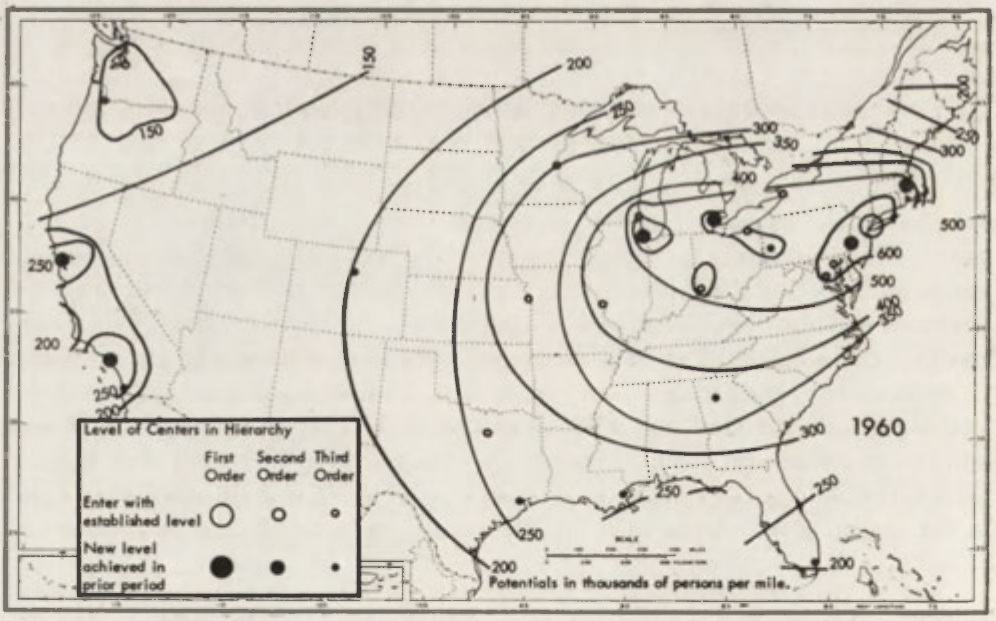

Fig. 9. In the 1920—1960 period the manufacturing belt metropoli, and cities in the Far West, Gulf Coast and Florida rose to new status. Population potentials reveal western peaks and greater local differentiation within the northeastern manufacturing belt heartland

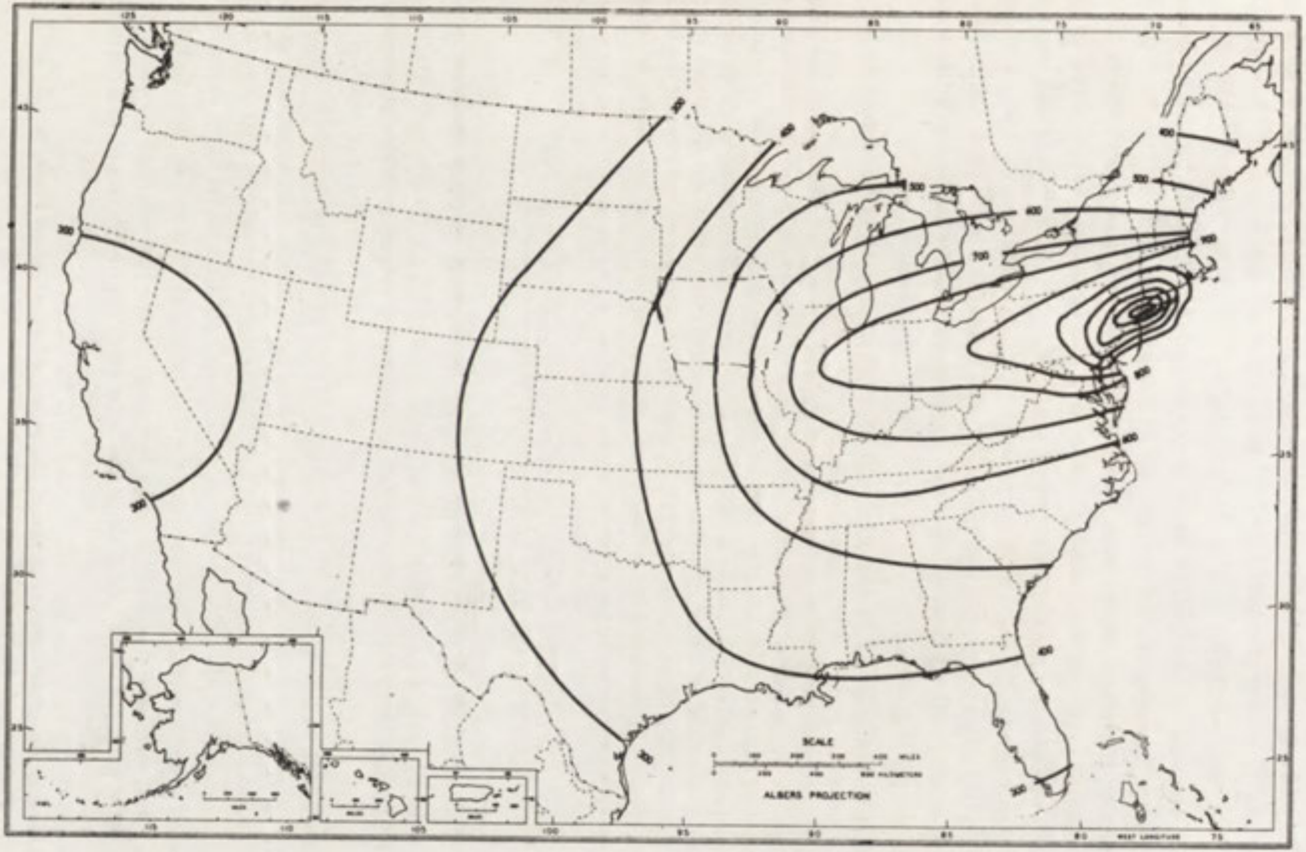

Fig. 10. U.S. Income potentials, 1956. Note that this measure of access to the national market is patterned in the same way as population potentials

Dallas, Houston and Phoenix in Texas and the southwest. These represent elaboration and deepening of subnational economies, building upon the geographic pattern of activity brought about by interregional resource shifts after 1850, although also reflecting the relative decline of mineral resource activities in the national economy and the increasing significance of the service sector (Figs. 7-8).

In each case, the basic conditions of regional growth were set by the heartland It was the lever for successive development of newer peripheral regions by reaching out to them as its input requirements expanded, and it thereby fostered specialization of regional roles in the national economy. The heartland experienced cumulative urban-industrial specialization, while each of the hinterlands found its comparative advantage based on narrow and intensive specialization in a few resource subsectors, only diversifying if the extent of specialization permitted achievement of some threshold scale. Flows of raw materials inward and finished products outward articulated the whole[9].

The spatial dimensions of the national economy have thus become

> "a great heartland nucleation of industry and the national market, the focus of large-scale national-serving industry, the seedbed of new industry responding to the dynamic structure of national final demand, and the center of high levels of per capita income . . . radiating out across the national land-scape are the resource-dominant regional hinterlands specializing in the production of resource and intermediate outputs for which the heartland reaches out to satisfy the input requirements of its great manufacturing plants. Here in the hinterlands, resource-endowment is a critical determinant of the particular cumulative advantage of the region and hence its growth potential[10]".

AMENITY RESOURCES AND THE SERVICE SECTOR

This is illustrated by post-1950 growth of the service sector; increase in the number of footloose industries including final processing, aircraft, aerospace and defense industries, and the "quaternary" activities of research and development; expansion and interregional migration of the non-job oriented population; and overall rising real incomes to such an extent that new amenity resources have moved to the forefront of the national economy. New advantages for economic growth have been found around the "outer rim" of the country, in regions and places relatively well-endowed with such amenities[11]. The advantages have been cumulative, for regional growth within the context of the national pattern of heartland and hinterland had brought these regions to threshold sizes for internal production of a wide variety of goods and services at the very time that changes in the definition

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[9] E. Ullman, *American commodity flows*, University of Washington Press, Seattle 1957.

[10] H. S. Perloff and L. Wingo, *op. cit.*

[11] E. L. Ullman, Amenities as a factor in regional growth, *Geographical Review*, 44 (1954) 119—132.

of urban resources made rapid advance possible. Hence the explosive metropolitan growth of the south, south-west and west (Fig. 9).

Two similar factor analytic studies of employment shifts in the national economy in the 1950—1960 decade provide graphic evidence of the bases of this growth, within the context of continuing heartland dominance, but with the added dimension of relative center-periphery shifts *within* the largest central cities. Factor analysis is an appropriate exploratory method of data analysis in this context because we are interested in "factors . . . the elements that cooperate to make a given situation" (Robert E. Park).

Both analyses are based upon industry-mix and competitive-shift coefficients for 32 two-digit industries. One analyzed changes over the 3000 + counties of the country; the second dealt simply with the S.M.S.A.s, as defined in 1960[12].

Both analyses produced the same eight-factor structure[13], with the first two components of greatest interest, and six industry-specific effects. The first factor in both cases recorded *relative change aue to industry mix in* a wide variety of sectors covering market-oriented manufacturing, wholesaling, retailing and services; the dominant element in changing employment patterns of the U. S. 1950—1960 was clearly whether or not an area was fortunate enough in 1950 to possess 1950—1960 growth sectors[14]. This change has resulted in continuing *centralization* of growth in the larger urban centres of the manufacturing belt, but also development of the southern and western rims because of their specialization in newer growth industries (compare Fig. 12 with Fig. 9), so that based on industry mix alone continued centralization has been accompanied by deconcentration of activity from the national heartland to the outer rim of the continent.

The second factor isolated complementary *competitive shifts in the light manufacturing and service sectors*. What is most important about this factor is that the county-level analysis revealed competitive shifts in favor of the outer rim of Florida, the southwest and west, as did the metro-level study, but it *also* showed the same shifts in favor of the suburbs of older metropolitan areas of the northeast. Relative losses were registered by the largest older central cities (Fig. 13). Thus additional

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[12] I performed these analyses for E. S. Dunn, Jr. As yet, his complete study is not available, and I am grateful to him for letting me make use of them. A preliminary report on the county analysis is in my *Strategies, models and economic theories of development in rural regions*, Agriculture Economic Report No. 127, U.S. Department of Agriculture, 1967.

[13] In the county analysis, a ninth factor characterized agricultural change.

[14] It is thus no accident that Wilbur Thompson gets excellent results using industry mix as his principal independent variable in predicting income levels, distribution and stability and city growth behavior. See: *Internal and external factors in the development of urban economies*, Paper presented at the 1967 Washington Conference of the Committee on Urban Economics, Resources for the Future, Inc.

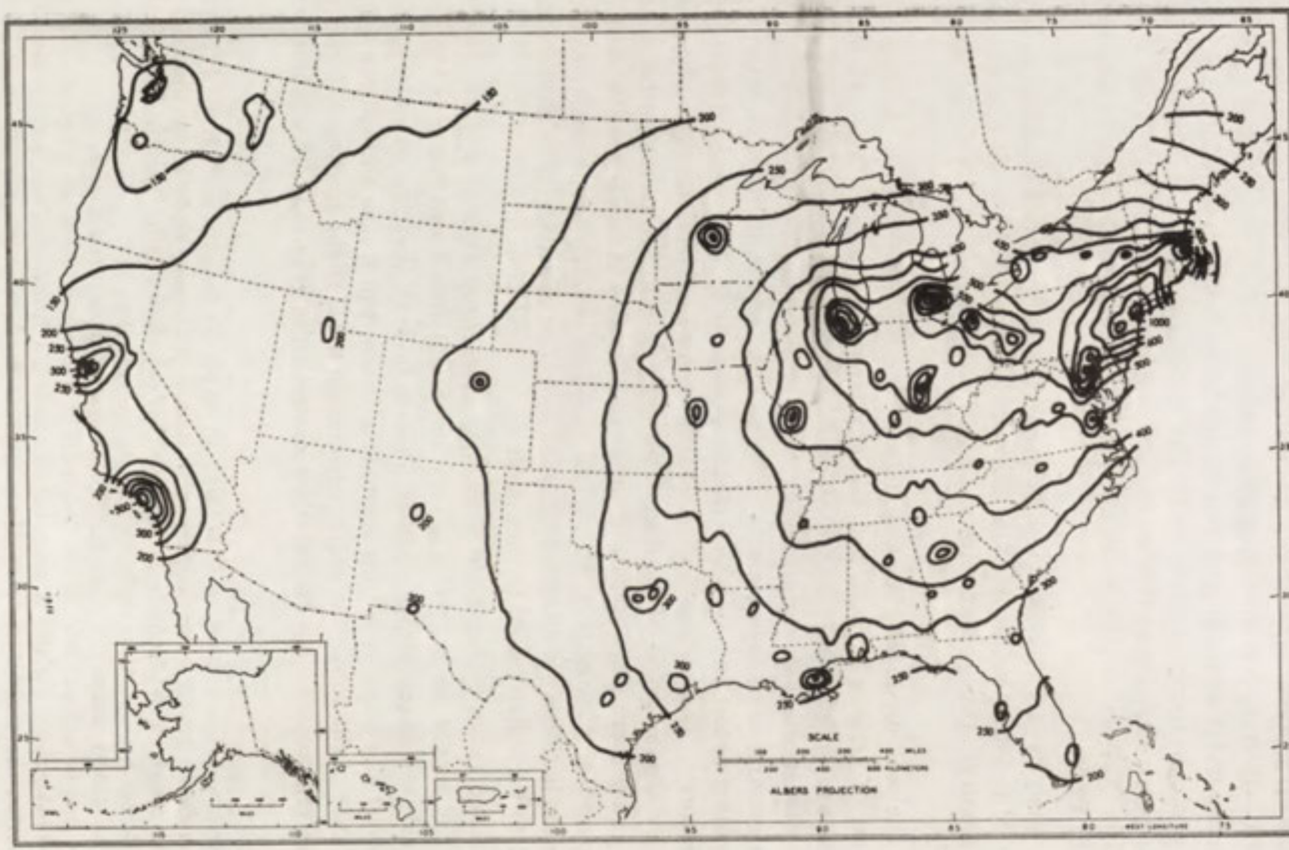

Fig. 11. Details of U.S. population potentials, 1960. County data were used by William Warntz to generate this surface, to show local metropolitan peaks on the overall configuration

Fig. 12. Growth due to industry mix, 1950—1960. Intensities based upon factor analysis of shift-share data

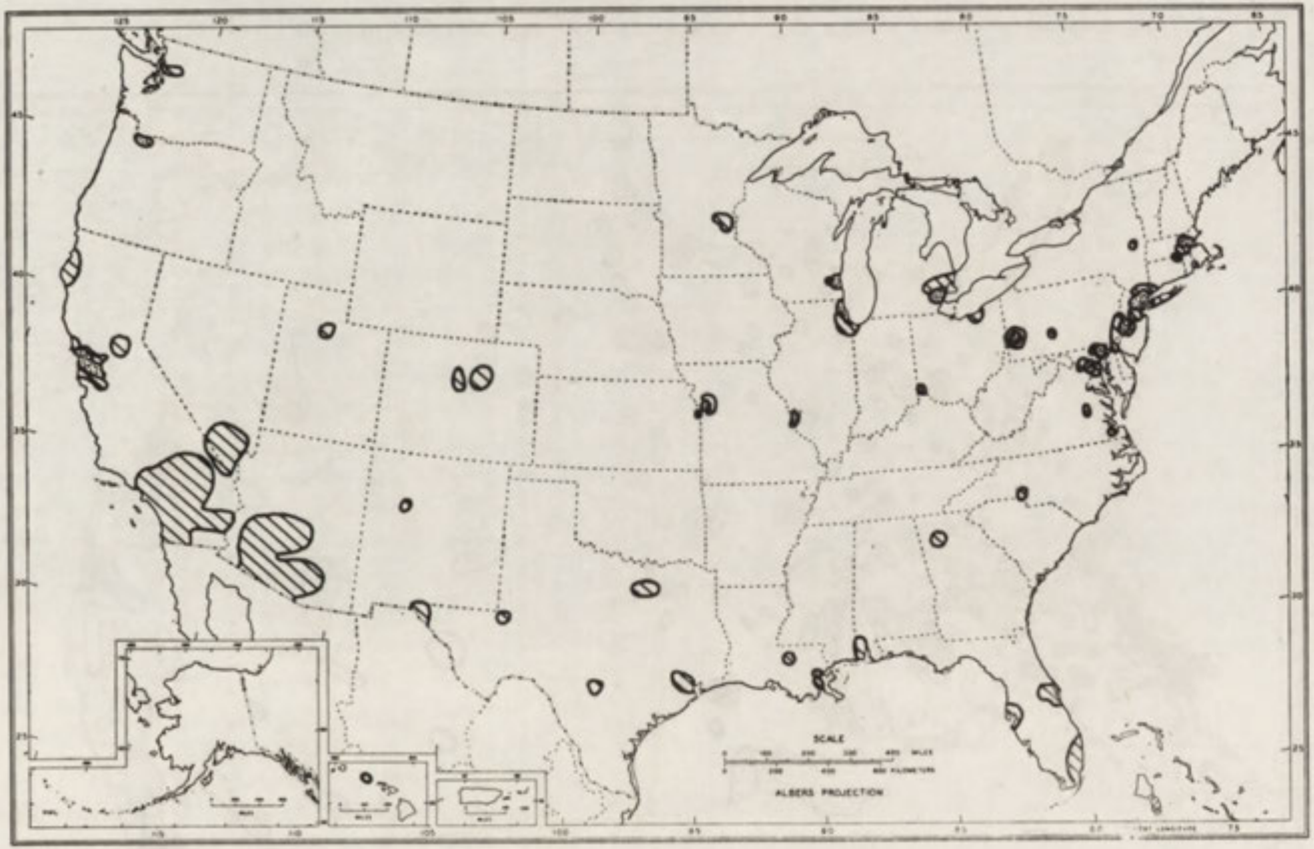

Fig. 13. Change due to competitive shifts, 1950—1960. Dotted areas experienced relative losses; cross-hatched areas in metropolitan suburbs, the southwest and south were the ones that gained

deconcentration at the scale of the nation and *decentralization* at the scale of the city have the same competitive bases.

By far the majority of U.S. cities changed much like the nation in the 1950—1960 decade — simply on the basis of the relative growth of the industries already there[15]. However, there were a few groups of SMSAs showing substantially different trends. The largest group was of cities in Florida, Arizona, Texas and California, plus Denver, Las Vegas and Reno. These have been the main beneficiaries of the competitive shifts. Most of the other changes are industry-specific, for example, in the textile towns of Fall River-New Bedford, Paterson-Clifton-Passaic, Pawtucket--Providence, in the mining towns of Wilkes-Barre, Johnstown and Scranton, or spectacular military-related shifts in San Diego, Seattle, Norfolk, and Washington, D.C. Finally, the nation's principal metropoli — New York, Chicago, Los Angeles, Detroit, Philadelphia, Boston, San Francisco — experienced continued growth due to industry mix, but were characterized by competitive declines at the centre and growth at the periphery.

URBANIZATION AND LEVELS OF WELFARE IN THE UNITED STATES, 1960[16]

By the 1960s these processes had completely metropolitanized the United States. Only a relatively limited part of the nation's area was characterized as "metropolitan" by the Bureau of the Budget (Fig. 15), but in fact the residents of most of the populated parts of the country journeyed to metropolitan employment opportunities on a daily basis (Fig. 16). Many segments of the country lay simultaneously within more than one of these commuting areas (Fig. 17), although of course the degree of local labour market participation dropped off in each case with distance (Fig. 18).

These maps are of interest for the picture of the United States that they provide — all but five per cent of the country's population resides within the daily commuting fields of its metropolitan centres, and these fields spread over the entire land area of the United States except where population densities are less than two persons per square mile and/or where there are national parks and forests, and Indian reservations. More importantly, though, the map of commuting fields shows a very fundamental property of the country's residential areas — *degree of participation*

[15] This is consistent with the systems notion of growth based on a "law of proportionate effect", as inferred from existence of parallel rank-size regularities in 1950 and 1960. See my: Cities as system within systems of cities, *Papers, Regional Science Association*, 13, 1964, pp. 147—163.

[16] This section drawn from B. J. L. Berry, *Spatial organization and levels of welfare: degree of metropolitan labor market participation as a variable in economic development*, Paper presented at the Economic Development Administration Research Conference, February, 1968.

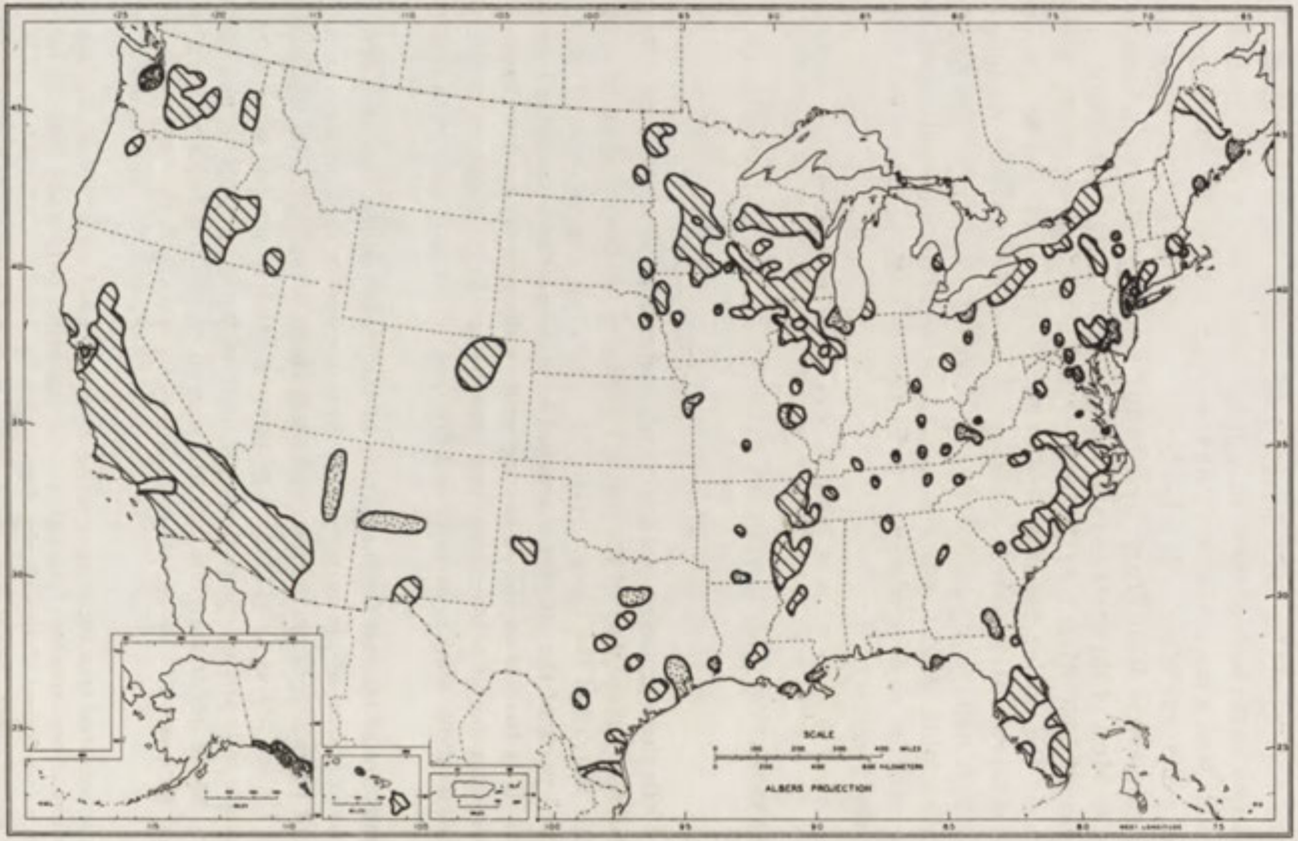

Fig. 14. Relative change in agriculture, 1950—1960. Lines indicate areas of relative competitive losses (both within the framework of overall decreased dependence on agriculture as a source of employment)

in metropolitan labour markets, the key variable in what we will term the "regional welfare syndrome", indexing the gradient of urban influence on surrounding areas.

The nature of this syndrome was revealed on an array of graphs which depicted the gradients of labour market participation and eleven other variables along six 200—300 mile-long traverses radiating from Atlanta[17]. Each graph showed that as the degree of labour market participation (i.e. daily commuting to employment in the central city) declines with increasing distance from the city, population densities and the proportion of the population classified as urban decline, together with the average value of farm land buildings, median family income, median school years completed, rate of population increase (which becomes negative in the peripheries) and per cent gain in the population through migration (which becomes negative). On the other hand, the percentage of the population classified as rural non-farm rises and then falls, and both the percentage of families with incomes less than $3,000.00 and the unemployment rate increase.

The changes are like a musical score. They are rhythmic — they rise and fall in concert. They symbolize, I argue, "regional welfare syndrome" based upon extent of participation of residential groups in principal urban or metropolitan employment opportunities, and the lowest levels of welfare are at the peripheries of metropolitan labour markets and especially in the interstices between them.

That the population is responding to these systematic variations in welfare is also implied, for population is generally increasing in the cores of the labour markets (there are central city versus suburban differences also to be seen in the traverses) and decreasing in the outer edges of the commuting fields, along the peripheries, and in the interstices. Some, but not all, of the labour market centres are gaining population due to net migration; however, much more extensive outer commuting zones, plus the peripheries and the interstices, are losing population due to out--migration.

EFFECT OF THE URBAN HIERARCHY

Amplitude in the syndrome appears related to rank of centres in the urban hierarchy. Generally, the smaller the centre the lower the population densities, median income levels and median school years completed at the core, and the lower the value of adjacent farm land and buildings (one must standarize here for larger

[17] These graphs, as well as a number of others (for St. Paul — Billings, Duluth — Minneapolis — Fairmont, St. Louis — Little Rock, Chicago — St. Louis, Dallas — Galveston, Dallas — — Odessa, San Francisco — San Diego, San Francisco — Medford, New York — Boston, New York — Burlington, Detroit — Sault Ste. Marie, Detroit — Dayton traverses, and for transects of Megalopolis at Boston, Philadelphia, and Washington), illustrating the occurences which are identified in the several paragraphs that follow, had been included in the original version of the paper, prepared early in 1968.

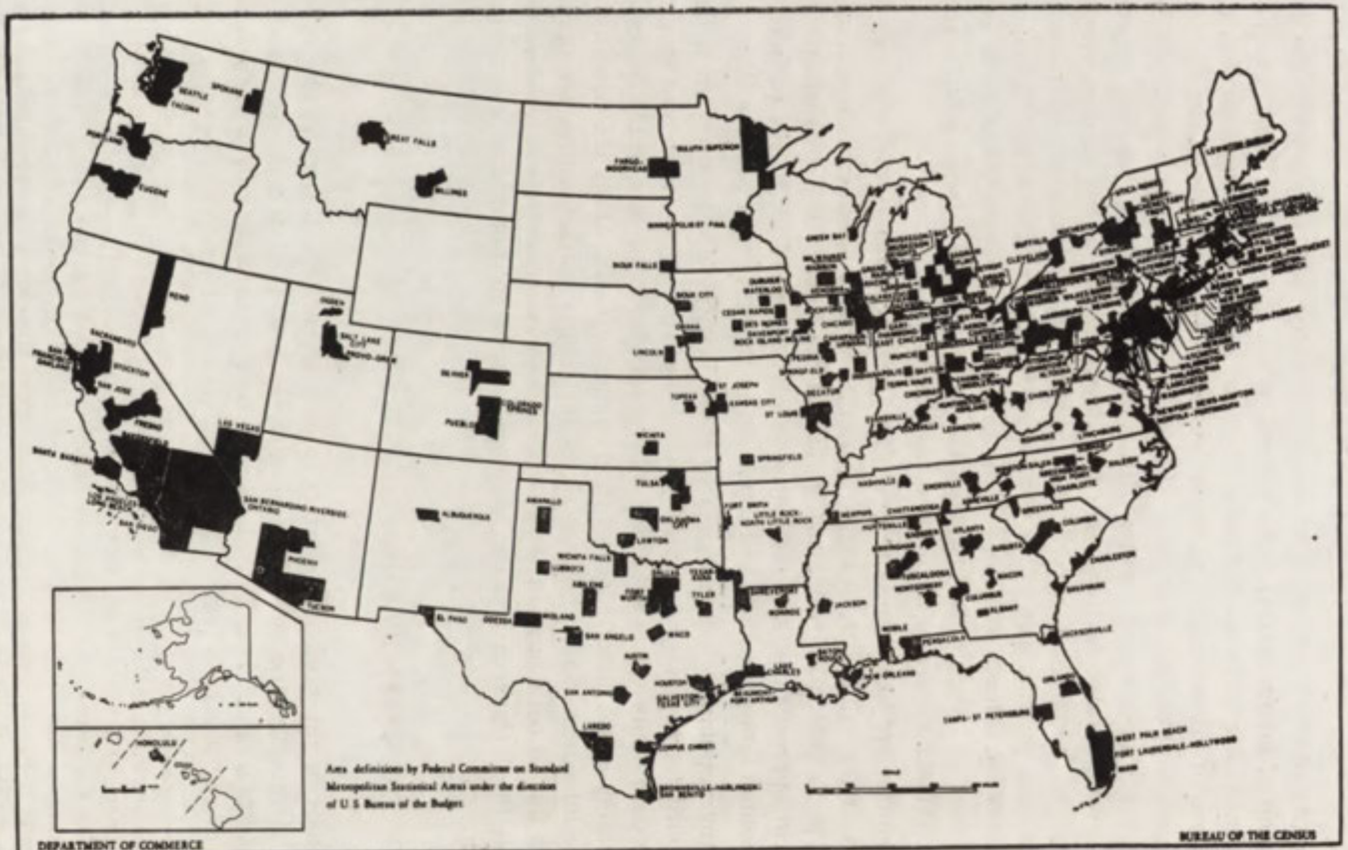

Fig. 15. Standard metropolitan statistical areas, 1960. The zones shaded black covered the counties designated as "metropolitan" in 1960 by the U.S. Bureau of the Budget

regional variations in agricultural productivity), the rate of population increase (the smallest cities will be declining) and the rate of growth due to net migration (in fact only the largest cities will be growing due to migration). Hence, all other things being equal, the lower the rank of the centre, the lower the point to which the gradients decline at the periphery.

EFFECT OF SPACING OF CENTRES

Where employment centres are closely spaced and their labour markets overlap, so that residential groups can take advantage of employment opportunities in more than one centre, declines with distance are reduced or eliminated. Conversely, the wider the spacing, the lower the point to which the gradients fall.

THE LARGEST CITIES

In the central parts of the largest cities the regional welfare pattern, while still working from the suburbs outwards to the inter-urban periphery, is reversed from these suburbs inwards — in the central city, incomes are lower and poverty and unemployment greater than in the suburban ring. Also, population growth and migration are slow or negative.

NATIONAL CORE-PERIPHERY VARIATIONS

Interaction of the city-size and spacing effects leads to complete reversal of the rhythms within many highly urbanized parts of the northeastern manufacturing belt. Cores of labour markets in this area have the lowest levels of welfare and are declining, and the limited peripheral zones, simultaneously the suburbs of two or more metropoli, are the areas of high income and growth.

BASIC DIFFUSION MECHANISMS

Clearly, the regional pattern of rural poverty in the United States parallels the rhythms of the nation's commuting fields. Degree of metropolitan labour market patricipation is a key variable.

Levels of welfare are distributed geographically in a regional syndrome of accessibility to and participation in employment opportunities provided by the nation's metropolitan centres. Additional orders of variation result from rank of these centres in the urban hierarchy, and the principal patterning of American economic space into a core manufacturing region and resource-exploiting peripheries.

Thus, the spacing of urban places is least and the degree of labour market overlap (providing alternative employment opportunities) is greatest in the manufacturing belt, where rural poverty is the least (Fig. 19). Spacing of centers increases, overlap decreases, and poverty increases at the inter-urban peripheries as potentials drop

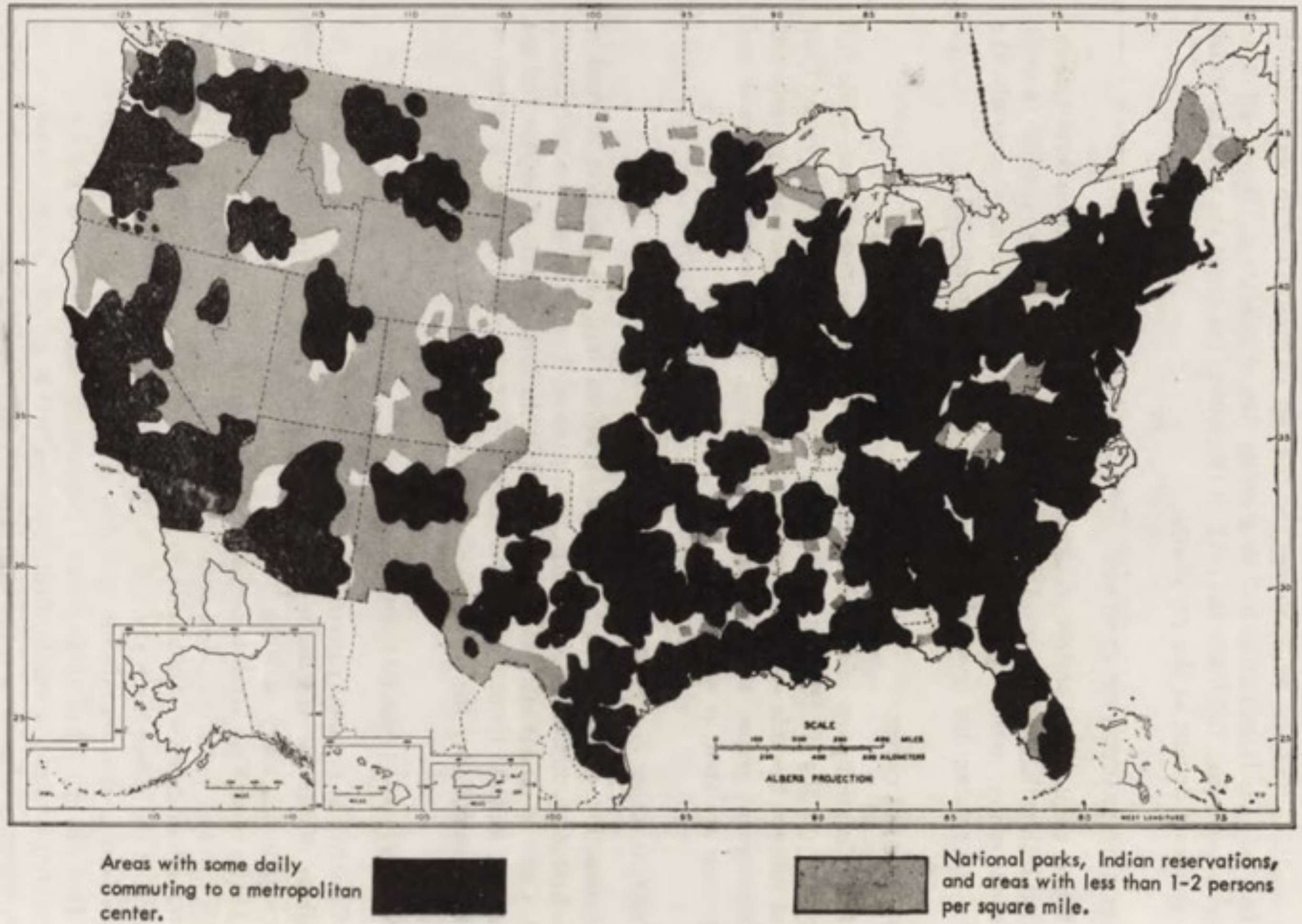

Fig. 16. Areas with daily commuting to a metropolitan centre in 1960. Studies at the University of Chicago indicate that most of the populated parts of the country lay within metropolitan fields of daily contact in that year

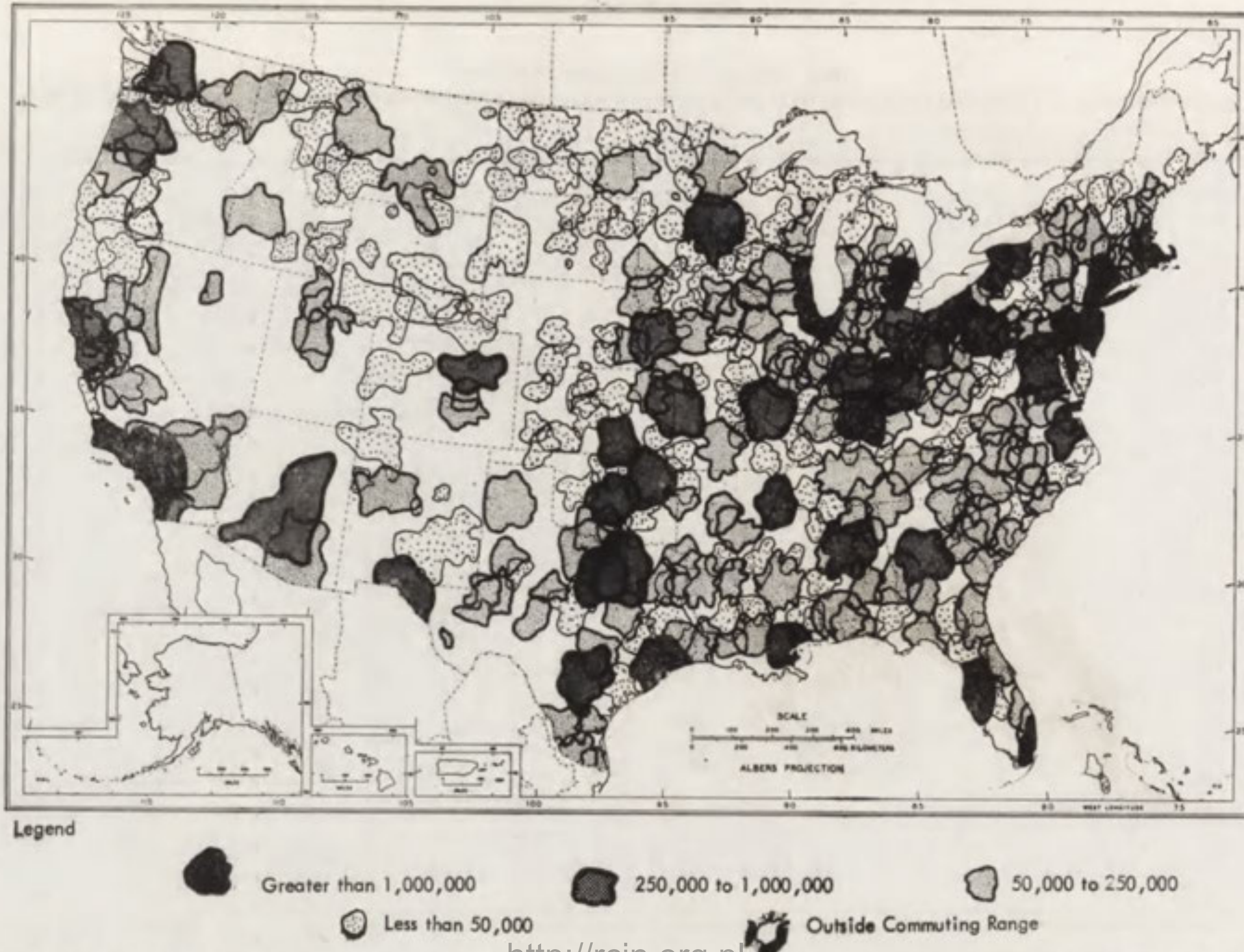

Fig. 17. Extent of individual commuting fields in 1960. Areas in daily contact with metropolitan and smaller urban centres are indicated, by size of centre. Note the extensive areas with commuting to more than one metropolis, revealing the complexity of urbanization

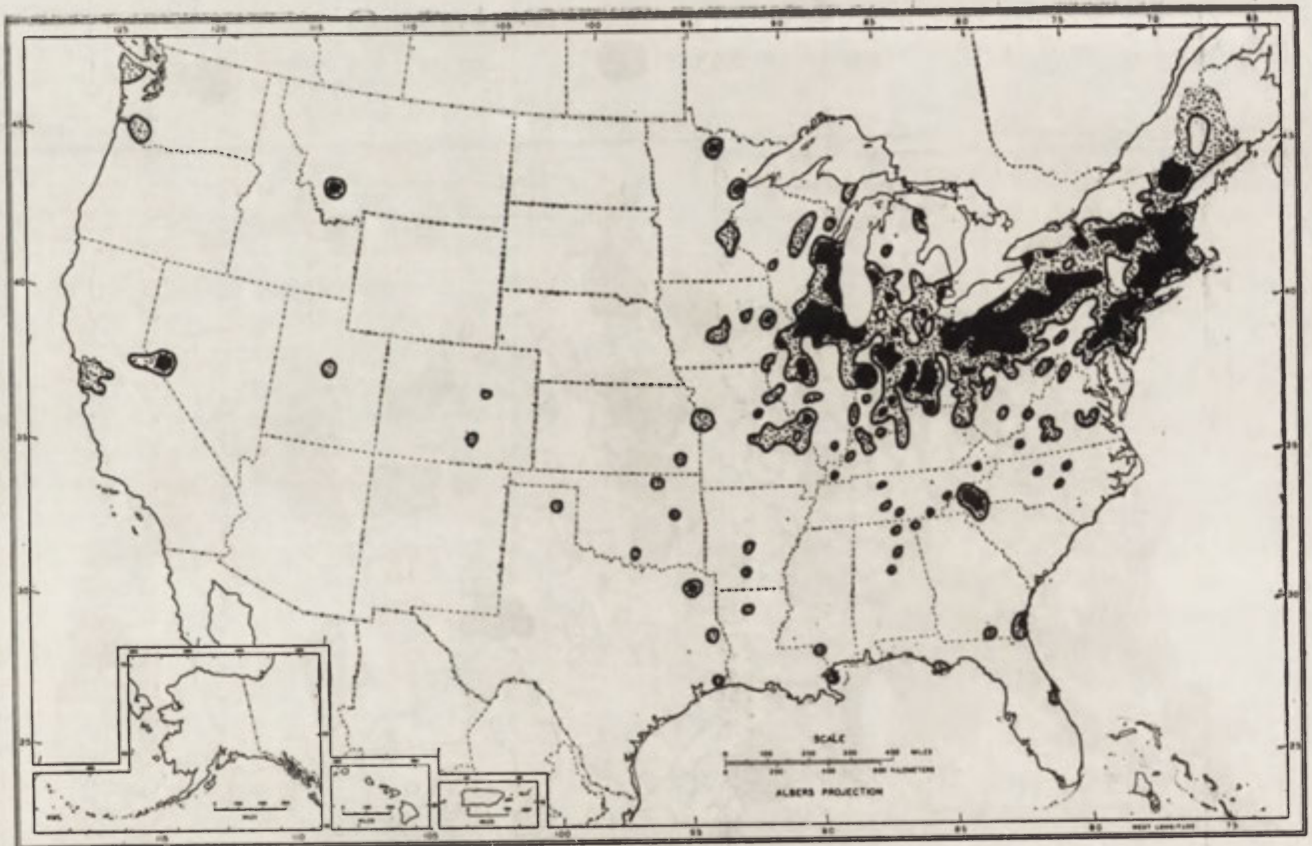

Fig. 19. Areas with least dependence on agriculture, 1960. The intensities are based upon factor scores created in a principal axis factor analysis of county employment data, 1960

GEOGRAPHIA POLONICA 20, 1972
Brian J. L. Berry — *Urbanization and regional development in the United States*, pp. 26—27

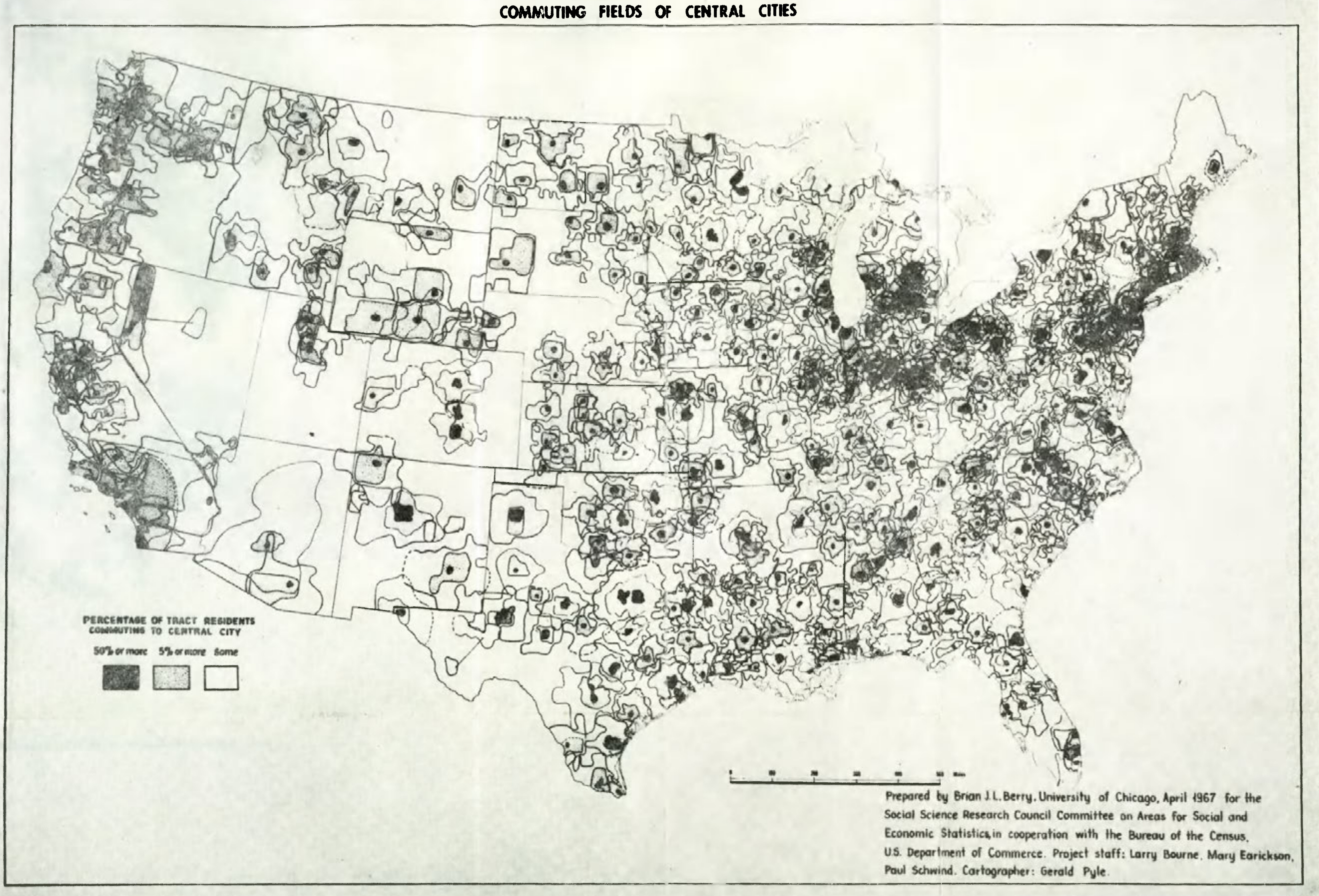

Fig. 18. Intensity of individual commuting fields in 1960. Variations in the proportion of tract or minor civil division residents commuting to urban centres are indicated

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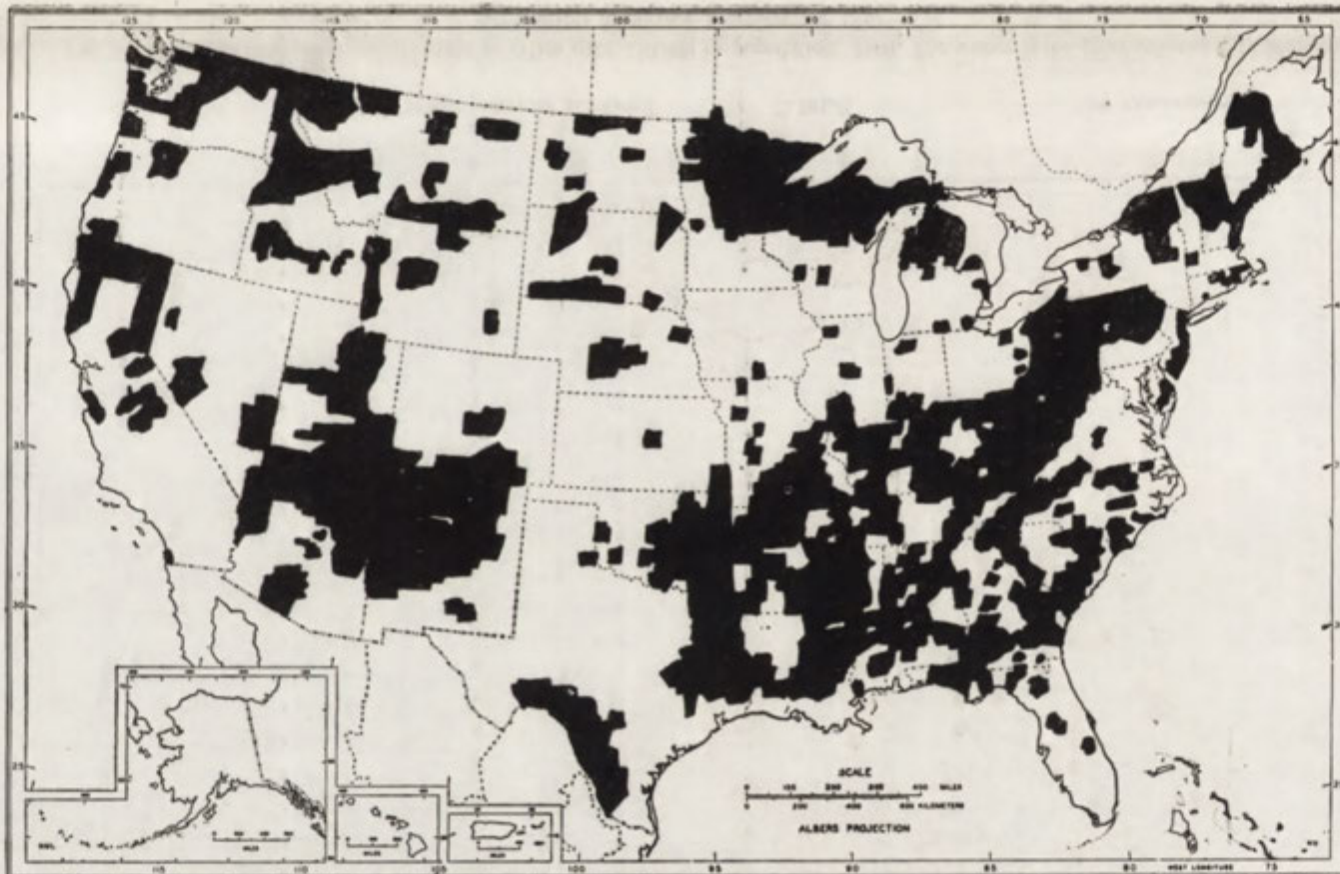

These 1,225 counties -- containing 49 million people -- qualify for federal public works grants and regional development aid, by reason of high unemployment and low average income.

Fig. 20. Counties in economic distress in 1964. Note the inverse relationship in low income and high degrees of participation in metropolitan labour markets

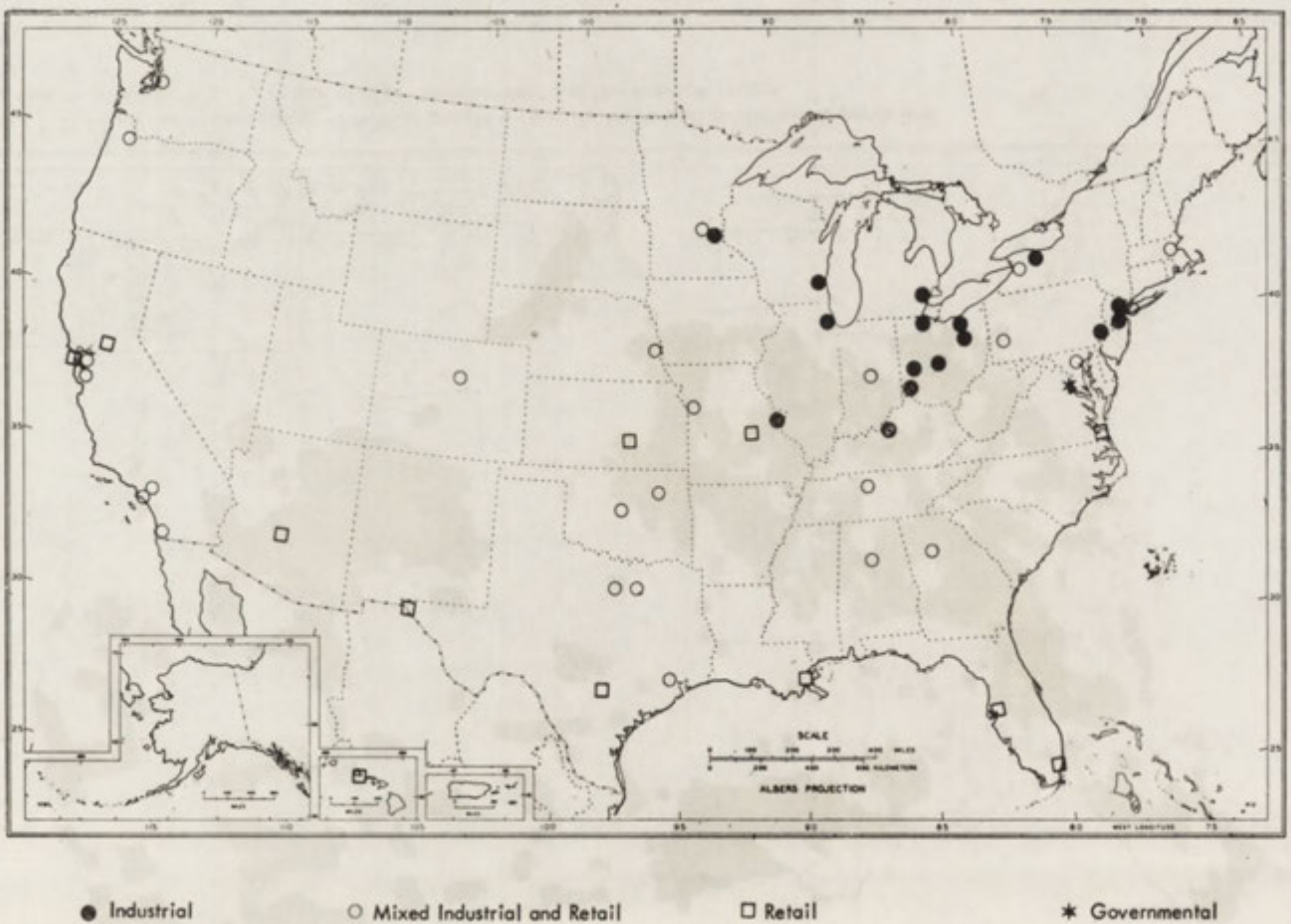

Fig. 21. Principal functional classification of cities over 250,000 in population, 1960. The source is the International City Managers' Association *Municipal Yearbook* for 1967

(Fig. 20). Likewise, manufacturing supports many large industrial cities in the northeast, and the amplitudes of the gradients of urban influence are greater, but as potentials drop commercial and service functions become relatively more important and the regularities of the central-place hierarchy appear (Fig. 21). Amplitudes are less for lower-level centres, and peripheral zones of poverty accordingly are greater. The smaller the centre, the less likely it is to have an effect upon the gradients of influence spreading from neighbouring larger centres.

Generally, labour markets appear to need to be of greater than 250,000 population to be viable parts of the urban system (Fig. 22). This is interesting in that this is the *maximum* permitted size for a growth centre under the terms of the legislation establishing the Economic Development Administration, the agency charged with the job of eliminating remaining pockets of rural poverty.

The patterns are so pervasive that it is a relatively simple next step to the inference that the structure arises from a set of diffusion processes that operate simultaneously — outwards from core to periphery in the network of metropolitan centres, down the urban hierarchy from the metropolis in each metropolitan region, and outwards from city to inter-urban periphery in the labour market. F. Boon has already developed an energetic model of these processes, and two empirical studies (of the diffusion of streetcar railroads — the first mass urban transportation — in the latter half of the nineteenth century and of urban renewal projects since 1949 begin to confirm the inference[18].

REGIONAL DEVELOPMENT ALTERNATIVES

Borts has recently provided an excellent review of the alternative policies proposed to alleviate rural poverty in the Unites States: relocation of industry to rural areas; industrial and residential location in growth centres; and subsidized migration to presently-established metropolitan areas[19]. In reverse order, they represent proposals to support and speed present long-run readjustment mechanisms, to stimulate development in the peripheries through "trickle-down" mechanisms by affecting the status of the centres, and to "de-tail" the poverty distribution by injections of capital into the poorest areas.

There have been many evaluations of these alternatives, including that of Borts himself. But whereas Borts considers the alternatives from a structural viewpoint, the regional perspective assumed here suggests that greater clarity in evaluation will by produced by considering several distinct cases:

[18] Françoise Boon, A simple model for the diffusion of an innovation in an urban system. Center for Urban Studies, University of Chicago, Chicago 1967. See also B. J. L. Berry and E. Neils, *op. cit.*

[19] G. H. Borts, *op. cit.*

(a) The outer peripheries within labour markets exceeding 250,000 population.
(b) Labour markets with less than 250,000 population.
(c) Areas outside the daily influence of urban centres of any appreciable size.

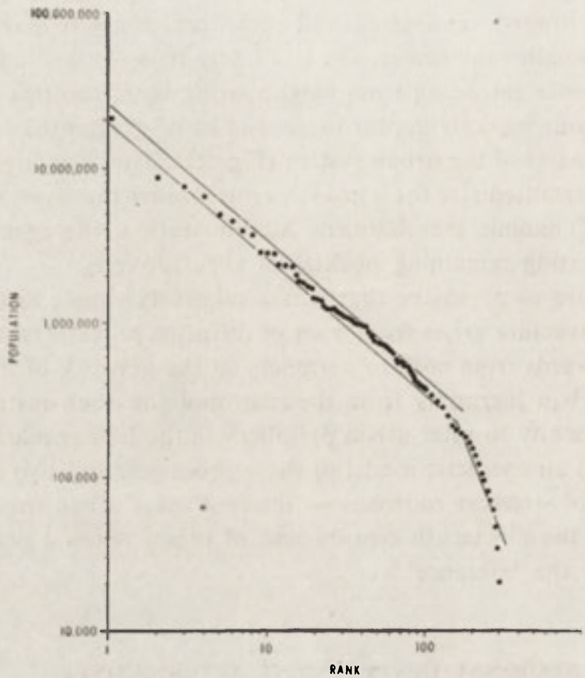

Fig. 22. Rank-size distribution of labour markets in 1960. Labour markets defined by relative closure as either consolidated urban regions or functional economic areas. See Berry, *Metropolitan area definition. A re-evaluation of concept and statistical practice*, U. S. Bureau of the Census, 1968

The readjustment processes already described — patterns of population change and migration — would indicate persistent pressures to allocate resources more efficiently over time within and between labour markets. The readjustments, moreover, are all in the direction of greater size and greater concentration up to labour markets exceeding several millions in population and focussing on central cities exceeding 2—3 millions. Then there is a reversal of trends, an involution of the welfare syndrome presumably because significant *diseconomies* of density and congestion have been reached. Clearly, then, readjustments directed to equalizing returns at the margin are being accomplished by shifts of labour from low-paying agricultural and agriculturalist-serving to higher-paying urban occupations, and also by the narrowing of earnings differentials between rural and urban occupations.

Why, then, the continuing rhythmic patterns of welfare differentials within labour markets? Fundamentally, today's rural poverty represents one of the lingering effects of the oversupply of labour in agriculture precisely because of the effects of distance which limit the opportunity to participate in the employment opportunities of major metropolitan areas.

The increased costs of travel with increasing distance limit longdistance commuting flows and the ability to participate in this employment on a daily basis. But why not then migrate? The rate of migration varies according to city size (generally, the larger the city, the higher the income level), distance, and unemployment in the prospective city of destination. Migration is age-specific. It leaves behind proportionately larger numbers of the aged who no longer have marketable skills, and for whom the only cure for poverty is an adequate system of income transfers. It is also education -and skill-specific, leaving behind the least educated and skilled. In short, migration compounds the differentials that it might be expected to correct.

Economic development for those who choose to stay rather than migrate therefore still takes place in an industrial-urban location matrix. Agricultural areas with more favorable locations in relation to industrial-urban centers enjoy more efficient factor and product markets than those located at the periphery. As a result many of the rural poor are engaged in small-scale subsistence farming, or in low--paying local, small-town service trades, at the periphery. There, birth rates are higher and the pressure upon children to leave school earlier is greater. Obviously, programs are needed to reduce this pressure to leave school, because greater levels of education imply more marketable skills and a greater propensity to migrate. Equally, rural school districts need resources to be transferred to them to insure equal educational experiences with urban schools. By extension, young and mature adults need job retraining to provide marketable skills.

But there are further constraints. For example, over one-quarter of the rural poor are Negro, and for them there is a dilemma, because the big-city alternatives are still the nation's seething segregated ghettos. Are there solutions in regional policy?

Because the underlying factor is distance and isolation, so that there is the opportunity to participate in metropolitan labour markets neither by commuting nor migration, the regional policies proposed to date all involve bringing jobs and people closer together — industry to rural areas; employment and people to "growth centre"; and people to the city (not forgetting the Appalachian program's emphasis on roads).

The constraints upon rural industrialization are evident. Rural areas offer few opportunities for scale and concentration and no external economies. Although rural wages may be lower, so are rural skills, and in any case this differential will be true only in the short-run. Most fundamentally, very few industries find profit--maximizing locations in rural settings, and so long as they must compete in a free market they will feel no compulsion to locate at the periphery. Every experiment of this kind has resulted in similar reports: higher costs in Britain's distressed areas.

and empty factory buildings subsidized by the Area Redevelopment Administration in the United States are but two examples.

Emphasis has thus switched to stimulating development in growth centres, to generate higher incomes and lower unemployment, and thus more in-migration, and better job opportunities, implying greater propensities to commute. The legislation establishing the Economic Development Administration set 250,000 as a maximum size for the central cities of development districts, which is entirely reasonable since above that size the necessary conditions for self-sustaining growth seem satisfied. Perhaps the greatest payoff in terms of both employment and unemployment seems to lie not in putting resources into centres very much smaller than this maximum, however, but in using the public treasury to enable centres close to the point to achieve self-sustaining growth. This is particularly true where has been a local record of unemployment, because for every increase in employment, unemployment is reduced by half the amount of the employment increase.

Examination of the gradients of influence of smaller centres indicates clearly enough that there seems little sense in trying to use small urban places as growth centres — their regional influence is too limited. Indeed, very few cities of less than 50,000 population appear to have any impact on the regional welfare syndrome, although admittedly the few that do are located in the more peripheral areas. It follows that a "new towns" growth centre policy is foolhardy unless criteria of scale and location are considered with a care that has so far seemed lacking.

If trickle-down from sufficiently large growth centres offers one viable strategy, however, adequate education of the young, retraining of those without skills, and subsidies to migrate (including travel, relocation and income payments) appear to offer the only realistic alternative for those isolated in the peripheries of labour markets exceeding 250,000, or those of less than that size selected as growth centres. It is especially true for those residing in the interstices between the labour markets. In the latter case, the migration stream should clearly be directed at the growth centre. Yet in no case should it foster movements to the cores of the largest cities, where ghettoization produces a parallel and perhaps more debilitating form of isolation.

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AN ECONOMIC APPROACH TO SOME PROBLEMS IN USING GEOGRAPHICAL ENVIRONMENT

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I. INTRODUCTION

Among the approaches to understanding national planning the problem of the rational perspective use of the geographical environment should also be considered.

The problematics of using geographical environment should be examined in several levels of spatial planning: the local, the regional, and the national level, respectively. However, examination of these problems on the level of national planning is of particular importance. It is the perspective character of the national plan, being a spatial cross-section of evolution of the national economy, which enables a comprehensive consideration of the interdependences between the management of existing natural resources and the geographical environment. The interrelation between perspective planning and a rational use made of the geographical environment finds its expression in the necessity of taking into account in the planning process the long-term changes taking place in the geographical environment. This is in order to avoid and prevent any adverse processes which this activity might bring about, and is of particular importance in the process of an intelligent shaping of the basic socio-economic and cultural values represented by socialist planning.

It should be stressed that the time horizon of this perspective should be set further off than the actual time set for the perspective plan. This is so because in this context one has to realize (1) the principal evolutionary tendencies of science and technology and (2) the image of the future spatial socio-economic pattern of the country.

The methodological premises for defining these two elementary factors differ. In spite of the fact that no sound methodological basis exists which would warrant the scientific value of prognoses, there is a way of arriving at a variety of "anticipating" estimates of such socio-economic values as the future size of population and future technological trends — although they may involve different degrees of certainty.

On the other hand, any vision of the future socio-economic pattern must be based on an additional factor: on the system of social values and aims and the needs as they will develop in future. It must be emphasized, that a clear definition of social values and aims is one of the basic presuppositions for drawing up a perspective plan. This refers to matters like the national security, the size of the national income, the meeting of demand for material goods, the cultural level of the population, and the health services rendered. The ecological conditions in which man lives, the maintenance of the high quality of the geographical environment (its balance), and the protection of the natural landscape must also be assigned to this category of values. In order to prevent discord and misunderstanding in substantiating these purposes, a sharply defined hierarchy of the different social values involved is indispensable.

The possibilities of accomplishing these ends are limited by the productive capacities, human potential, the existing infrastructure, and by conditions and resources of the geographical environment. These factors represent a group of a priori restricting elements in view of the hierarchy of aims adopted. From the viewpoint of perspective spatial planning the locational constraints and transferability of the restricting elements are of great importance. The limitations imposed by conditions and resources of the geographical environment result directly from the degree of the dependence of the various spatial systems, (like settlement, industry, agriculture and transportation), on the environmental factors.

For all the directives, emphasizing the importance of considering the geographical environment in perspective spatial planning, J. Zaremba (1965, p. 606) is right in his assertion, that up to now theory and practical application have failed to create effective means for co-ordinating spatial investments so as to eliminate discrepancies between short-sighted departmental interests and universal social requirements, and for defining the principles and the trends involved in making rational use of the space and of the natural resources of the country.

Both the theoretical and the methodological problematics of a rational use of the geographic environment show a *deficiency* in the group of scientific branches which are dealing with the spatial aspect of economic development. This is most distinctly in evidence in Regional Science which in this group of branches is supposed to play a synthetic and integrating part and which claims to formulate the theoretical basis for spatial planning.

Regional Science has been very successful in the introduction of a new methodology based on mathematical models and statistical methods, which were applied for empirical specification, and use of concepts by which formal systems could be applied for analyses. In this manner it became possible in the framework of Regional Science to use operational methods in location analyses and thus to arrive at optimum locational patterns, in order to obtain a more effective system of spatial economy. However, in its aim at a comprehensive perception of the problem of reaching an optimum in spatial economic activity, Regional Science is burdened with imperfection: the problematics of making rational use of the geographic environment.

Despite the fact that much detailed research has been undertaken in order to gain knowledge about resources and environmental conditions from the viewpoints of technics and natural sciences, and many postulates aiming at protection of the natural resources and the environment have been put forward, there is still a lack of a sound theoretical basis for illuminating the interdependence between resources and environmental conditions on the one hand, and the effectiveness of the economic activity of the society on the other. The fundamental methodological difficulty to be overcome is seen in the inability to define in a measurable and comparable way the effect which particular elements and conditions of the geographical environment have upon economic activities (B. Winiarski 1966, p. 85).

In view of the great importance of this problem it seems imperative to ponder the possibility of establishing this sort of basic assumption.

II. PASSIVE AND ACTIVE POTENTIAL OF THE GEOGRAPHICAL ENVIRONMENT

From an economic point of view the environmental conditions constitute a set of constraints on economic activities. A geographical environment considered as a complex of conditions for action, consists of two groups of elements: 1) resources, 2) natural conditions.

Natural resources are those components of the geographical environment which can be used for creating some kind of energy (running water, fuel, wind force, tides, forests, solar energy), industrial raw materials (minerals, timber, water), substances for human consumption (plant and animal life) and, finally, the earth (its soil and physiographic complex). All of them are objects in processes of production. The limitations which they impose upon the economy are brought about by the scarcity of particular kinds of these resources and their accessibility both on the ground surface and in the Earth's crust. It should be kept in mind, that the concept of natural resources also comprises the element of work required for exploitation; for instance, soil fertility is also the result of tillage and labour inputs.

Natural conditions, on the other hand, are those components of the geographical environment, like relief and geological structure, soil properties, and hydrographic and climatic conditions, which cannot be expressed as mineral and land resources, although no production could be undertaken without their contribution. These are constraints upon the technology of convertion of the resources (in industry and agriculture) and in the means of overcoming and adapting distance (in communication and construction).

The limitations imposed by the geographical environment may be interpreted in physical and in socio-economic terms.

Physical constraints due to the geographical environment are complex of conditions which set limits to biological and productive processes by defining the amount of raw materials and land extent; thus they represent a *passive* potential of the geographical environment. These physical limitations, essential in character, depend on the degree to which the environment and the technology of a given production is fully comprehended. Comprehension of both conditions and resources has much advanced in recent times, as the result of extensive soil studies and physiographical, geological, hydrographical and climatic research.

The environmental constraints imposed in a *socio-economic* aspect are defined by those criteria of appraisal or utility, which express the relation of society to the geographical environment in the sphere of economic activity. The application of the principle of *economy* should be supplemented by two additional non-economic criteria: (1) the principle of keeping up ecological conditions suitable for man's life, and (2) the principle of safeguarding a high standard, i.e. a proper balance of the geographical environment, or of recovering this standard in case it had been impaired.

For these two principles it is necessary to draw up ceiling standards for the ecological conditions and the balance of the environment, in due consideration of the disturbances caused by an unsuitable exploitation of the environment. Standards of this type must be based on research in the field of ecology and protection of the natural environment. While little doubt can be raised regarding the principles put forward above, much more controversial is the problem of protecting the esthetic and recreational values of the natural landscape. However, the introduction of such a separate principle poses a variety of problems when it comes to establishing a definite standard; hence it seems that these values might be protected by applying the principle of economy.

In theory it seems possible to introduce into the economic calculation the values realized by these principles in the form of what is called non-economic goods, and their appraisal might be based on the concept of the utility function put forward by J. Neuman and O. Morgenstern (1944).

The realization in the form of an economic calculation of the principle of economy limited by extra-economic criteria defines the extent to which resources should be economically exploited, i.e. the *active* potential of the geographical environment.

The *passive* potential of the geographical environment undergoes changes as the result of a more thorough understanding of this environment, whereas the active potential develops in the process of technological change which makes possible new and more effective methods of using the environment.

In consequence there arise two groups of research problems, the solution of which is the presupposition for comprehending the active potential of the geographical environment:

(1) the research problems of ecological conditions in view of the changes occurring in the geographical environment — changes caused by man's economic activities,

(2) the problems of a balance in the geographical environment in view of disturbances and of the range of all destructive activities committed by man's economy.

III. A COMPREHENSIVE EVALUATION OF THE GEOGRAPHICAL ENVIRONMENT

In investigations involving local and regional planning there have been developed methods of appraising geographical environment from the point of view of its usefulness for urban development. According to W. Różycka (1966, p. 9) these methods appear in two different stages dependent upon how complicated the evaluation is: one stage is bonitation, the second is *qualification.*

The methods of bonitation, originally evolved in pedology for defining the utility rate of soils, embrace the evaluation of the features, or of groups of features, of particular elements of the geographical environment.

The methods of qualifications, on the other hand, involve comprehensive evaluation of the geographic environment with regard to suitability of individual areas for various types of use. This sort of evaluation is based on a pre-prepared analytical investigation (a survey), followed by bonitation studies of particular elements of the environment.

The wide scope of application of qualification methods, especially in local (urban) planning raises the question, how far this sort of procedure is suitable for evaluating the geographical environment from the viewpoint of the aims of regional planning.

Any qualification for perspective spatial planning on a national scale requires the precise definition of the following problems:

(1) the type of scale to be applied in bonitation or qualification,
(2) the range of purposes this evaluation is to serve,
(3) the basic spatial unit of reference.

The problematics involved in setting scales for evaluations constitutes a basic theoretical and methodical problem in procedures of bonitation and qualification. On the basis of physiographic research in town and country planning, two fundamental types of evaluation of the geographical environment or of some of its elements, have been developed: nominal and ordinal scales.

Type one, nominal scales, use categories like favourable or unfavourable conditions. The only definite relation between these categories is equivalence or difference; they do not imply that either of these categories contains more values, or less of them. This type of scaling, for all its marked suitability for clearly marked purposes, especially in bonitation of separate elements, limits feasible empiric operation to merely an indication of similarities or disparities.

Type two, ordinal scales, mark the relative value of particular elements of the environment from the viewpoint of definite ways of using them but without defining distances between these values. The original arrangement of these evaluations is accomplished by empiric operations in which assumptions concerning majority, equality, or minority are used, and by introduction of transition and asymmetric relations. It should be stressed here that according to principles of logic it is permissible for this type of scale to apply such statistical operations as median values and certain methods of rank correlation analysis. This is why certain operations like adding and multiplying used in scales of this type are bound to raise objections. Practical application of these operations, such as adding the values of particular elements of the geographical environment carried out from different viewpoints — such as building conditions, health conditions, food-raising facilities, in order to obtain combined qualifying value, fail to indicate the inaccuracies incurred by applying inadmissible mathematical operations. This calls in question the merit of this type of evaluation method.

A number of methodical concepts regarding the qualification of the geographical environment, based on ordinal scales of values, have been developed by T. Bartkowski (1963, 1964). As an example of this sort of concept may serve his attempt at apprasing the value of land for a section of the Great Poland Lowland, of some 8000 sq . km extent, in the suburban zone of Poznań. This metod lies in an appraisal in a conventional point scale, with a basic areal unit of one sq.km, of all particular features of the geographic environment, such as: land slopes in excess of 5%, high groundwater table, thermic inversion, groundwater pollution, high soil fertility. These characteristics are appraised in a four-degree scale with regard to conditions favourable for building construction, health conditions, nutrition facilities. As the standard of his scale T. Bartkowski chose, optimum conditions prevailing in some area of his model. The points, marking the value of the land considered from the viewpoint of the particular conditions mentioned, are added up, and in this manner a characteristic value for each type of the environment is obtained.

For technical reasons we shall omit discussing the abundant and very essential methodical problematics involved in collecting data and in the cartographical presentation of all particular elements of the geographical environment; however it should be emphasized, that every attempt at bonitation or qualification of the geographical environment is relative, and actually represents an interpretation of the basic investigations which were intended to throw light on existing conditions and on the tendencies towards changes in the environment.

A further essential element in the procedure of qualification is the definition of basic spatial units of evaluation pattern. Neither of the two possible approaches resulting from basic studies, i.e. the grid system and the system of physiographical units, warrant conformity to the basic pattern of the spatio-economic units. However, in view of the marked generalization applied in the national plan, one may consider satisfactory a pattern of units so arranged, that it would allow for transformation with regard to voivodeships division.

Closely linked with the question of what type of scale to apply, is the purpose of qualification. Evaluations based on nominal scales refer to qualifications for more restricted purposes, for which the values can be defined by the "usefulness" of a given element of the environment, for instance, for building purposes, or due to is soil values for agriculture, or on account of the beauty of the landscape for recreation. It is impossible to arrive at a general, multi-purpose qualification of a geographical environment when nominal scales are applied. The use of ordinal scales does not solve the problem of a synthetic evaluation of the geographical environment, because of the previously mentioned reservation in the matter of adding-up individual values.

One way of overcoming these difficulties by introducing synthetic evaluation might be the drawing-up of scales of evaluation based on J. Neuman and O. Morgenstern's theory of utility function. Their concept makes it possible to define values under equivocal conditions in the form of numerical indices which these authors call "utilities". Individual preferences might refer to divergent trends of utilizing an environment, but they would have to satisfy the conditions of transference. However, this problem would require a seperate and adequate treatment.

Without going here into the practical usefulness of these two types of scales for the necessarily highly generalized cartographical picture of evaluations or a geographical environment drawn in a national scale, an attempt should be made at compiling qualification maps for the basic elements of an environment, made in different types of scales for the specialized purposes of agriculture, of settlements, and of recreation.

It should also be stressed, that this kind of work might be treated as some sort of formulation of a direct economic calculation.

IV. REMARKS ON ECONOMIC CALCULATION OF EFFICIENT USE OF NATURAL RESOURCES

Concurring with W. Wilczynski's suggestion (1963, p. 506) the essence of an economic calculation should be defined as a method of measuring costs and benefits of economic activity a method warranting from a social point of view their proper appraisal, and facilitating rational decisions aiming at maximalization of benefits.

Up to now analyses of the problem of using a geographical environment have emphasized the *cognition* and the *evaluation* of existing natural resources and conditions with specific purposes in mind; however, they failed to develop the *principles* of a monetary (indirect) economic calculation of the resource use, a calculation which would serve as basis for executing the principle of economy in setting in motion this potentiality.

This must be mainly ascribed to the difficulties arising when an attempt is made at appraising in money the available natural resources as means of production, as well as to the difficulties involved in formulation and application of the principle of economic use of the natural resources by means of calculation of the indirect costs.

A. THE PROBLEMATICS OF LAND RENT AND NATURAL RESOURCES

A basic problem encountered in an indirect calculation of the exploitation of the resources of the geographical environment is their monetary assessment. The essential question is whether prices can differ from the value which define the socially indispensable outlays for labour and if so, by how much (B. Gruchman 1965, p. 17). Establishing a reasonable pattern for evaluations stipulates considering preferences of a comprehensively social character, which for the most part result from the ratio of available resources to demands, thus from the scarcity of certain resources.

From the viewpoint of a monetary calculation it is the prices obtained for resources available in limited quantities which would dictate action and alternative decisions.

So far no uniform definition exists for the evaluation of resources.

Most progress has been made in the evaluation of land, in connection with land rent — while less attention has been paid to appraising and Earth crust resources.

In the category of *land rent* in capitalist economy with private ownership of land, it is possible partly to solve the question how to appraise the value of some natural resources and, principally, of land. Disregarding the well-known critical comment on the limited usefulness of this category under conditions of a capitalist economy it should be emphasized, that in a socialist economy, as in Poland, the operation of land rent (in the form of a differential rent) is limited to agriculture. The demands for a restitution of the land rent is motivated not only by necessity of a rational management of land which by nature is a limited resource, but also by the economics of investments, in urban and industrial development. Among other factors this refers to the effect of wastefulness in land use has upon the investment costs. Detailed analysis of the problem is given by H. Cholaj (1966).

However, introduction of a land rent calls for a suitable method of how to establish the value of land. An essential difficulty here is, to define what is called by H. Fiszel (1964) the substitute value. He suggests that this value be considered as the income foregone when the given piece of land, previously used by agriculture, is to be occupied for building purposes. H. Fiszel also recommends taking into account as income only the net production value. In this way value looked for would be established as the equivalent of the income foregone or, more exactly, the equivalent of the discounted value of the expected annual income. This concept still requires indications as to the purpose for which the land is to be used. This can be accomplished by preparing an optimum programme of land development.

Restitution of a land rent would in turn create a basis for comparative evaluation of land use for agriculture, industry, urban development or recreation purposes and it would also lead to an intensification of the urban land use by introducing appropriate incentives based on an ecomonic calculation.

The most generalized concept, both in theory and in calculation, dealing with a rent under socialist economy has been put forward by L. Kantorowicz (1961). The differential rent as conceived by L. Kantorowicz refers to the solution of problems involved in the utilization of the most valuable, rare natural resources. The value of this rent is established from the saving in labour, gained due to the optimal use of these resources.

The advantage of taking into account a rent in appraisals of production is that it equalizes production conditions for different resources and warrants profitability where production is rationally based, and it yields a relatively higher appraisal for those types of products for which rare natural resources are used. This in turn is an inducement to apply production methods as effectively as possible.

A new attempt at developing economic evaluation in the form of a system of indices, by which costs would be replaced in an objective way by proportions between different economic values, is the concept of "objectively motivated appraisals" advanced by L. Kantorowicz. In a general way though not very accurately, appraisals objectively motivated may be defined as proportions used for defining the labour indispensable for given production to fulfil the optimum plan contrived in a rational programme of allocating production. However, a precise definition of objectively motivated appraisals would require discussing the fairly complicated mathematical procedure for formulating these proportions in terms of multipliers.

When it comes to a product in limited supply, the appraisal is not only based on all definite conditions of its production and use. A diminution in the supply of one factor, as well as an increase in production for which the given factor is highly important, — both may lead to an increment of the value of this factor. This refers to variable factors which are limited in quantity, and where consumption per unit of production depends on the method of production. Apart from labour and power, natural resources must also be assigned to this group of factors. In this concept the appraisal of rare natural resources of highest value is done by means of the differential rent. The magnitude of this rent is established on the basis of those savings in labour, which are gained from making use of these resources in the optimum plan; hence it has the same properties as an objectively motivated appraisal.

Here attention must be called to the fact, that in this concept both the natural resources and the equipment for their use are mere factors bringing savings in labour. Hence the consideration of outlays for this type of factors and their appraisal must be looked upon merely as a means for an optimal division of labour and for comparing costs incurred under various conditions.

Making use of the concept presented by L. Kantorowicz of taking into account objectively motivated appraisals may lead to a more effective utilization of the natural resources. This concept, however, has several drawbacks. This has been most convincingly indicated by W. Niemczynow (cf L. Kantorowicz 1961, p. 13) who asserts, that objectively motivated appraisals are merely criteria which make possible a quantitative appraisal of the limitations of production facilities and natural resources, the inadequacy of the rate at which plant equipment is operated, and the extent to which the programme of production is strained.

B. INTERPRETATION AND REALIZATION OF THE PRINCIPLE OF ECONOMY IN THE USE OF NATURAL RESOURCES

The interpretation of the principle of economy in relation to utilization of natural resources in a perspective scale implies, that all those kinds of resources which in production should be used economically, must be consumed in such manner as to make them last as long as possible, though within the limits set by actual needs of the population. Hence this rule does not apply to those natural resources which can be exploited in unlimited quantities, either because they occur in quantities practically inexhaustible or because they are automatically restored.

One can specify more accurately this rule by distinguishing the various kinds of natural resources and by taking into account their particular conditions of occurrence. For this purpose two basic categories of natural resources must be considered separately: renewable and non-renewable resources.

To *renewable* resources, i.e. those which under certain conditions may become exhausted belong water power, forest resources, and soil fertility. Here restoration is conditional upon social efforts, be it prior investments indispensable for utilizing the resources such as water power plants, or in the form of continuously effort like reforestation, or soil conservation.

Among the *non-renewable* resources, i.e. resources gradually decreasing in time, in the first place mineral raw materials should be mentioned. Ch. Bettelheim (1959) suggests, that to each of these two categories separate principles in economic calculations should be applied.

As regards *renewable* resources, for which restoration a certain amount of social labour is required, the rule should be that they ought to be exploited at such a rate that their preservation and even their enrichment should be possible, if this should seem indispensable for meeting future demands: while at the same time current needs are satisfied. The developing of this rule, considered from an economic point of view, may involve interpretation of the cost of renewing natural resources as a factor in the social costs of producing those commodities requiring these resources for their production. Therefore, this cost should be included in the price of the commodities. This approach will comply with the principle of economy by limiting the demand for the given resource. This results from the fact, that if the price of a commodity include the social cost of renewing the resources used for its production its competitiveness will be less than when the additional cost is not taken into account.

This interpretation gives as opportunity of realizing the principle of profitability in the use of resources of the renewable kind, as foreseen in the perspective plan of national economy. The principle can be put to use by fixing that rate of exploitation of renewable natural resources which ensures their preservation and, possibly, their expansion also.

As regards *non-renewable* resources a difference must be made between resources which will be exhausted in a distant future and those which will be depleted in a short time. The former may be treated as if they were renewable. Here the principle of economy can be upheld by including in the production cost of the commodities the cost of exploration of new deposits, the cost of investment on the exploitation of the given resources, and perhaps also increases in the cost of exploitation. On the other hand, for resources depleted in a short time there have to be taken into account the costs of discovering and producing some substitute products.

C. MODEL OF BALANCE OF ENVIRONMENTAL COSTS AND BENEFITS

Realization of the basic social aim, i.e. the highest possible fulfilment of social needs in managing resources and conditions of the geographical environment, can be achieved by either of two methods: by using the natural resources for productive purposes or, on the contrary, by refraining from doing so, that is, by foregoing the chance of increasing the national income in favour of directly satisfying current needs, this involving the maintenance of a suitably high standard of the geographical environment.

A maximalization of the national income, which constitutes a clearly fixed and quantified form of the principle of the national economy and controls the choice in the utilization of resources and conditions — especially when it comes to industrial investments — is liable to impair the attributes of the geographical environment from the viewpoint of health and recreation facilities and of its esthetic values thus disturbing its balance. The concept of quality of the geographical environment is much more difficult to quantify than factors like population or infrastructure. Usually only catastrophic conditions which signify an abrupt worsening of the properties of the geographical environment, such as for instance river pollution, are apt to call attention to the costs incurred due to a disturbance of the equilibrium. This implies the necessity of formulating the model of a balance by identifying environmental costs and benefits.

The construction of this type of a formal model is based on the introduction of the concept of an equilibrium of the environment. This concept would make it possible to compare the changing benefits in the environment resulting from optimum locations chosen, with the costs involved by distrubances of the equilibrium (which may come to light ex post), and with costs incurred ex ante in order to prevent a worsening of the environmental conditions — situations which may have to be faced in consequence of some alternative trends of economic development. However, for this sort of a model there is required a definition (a quantification) of the effect which the alternative programmes will bring about. And here arises the difficulty of establishing the monetary value of this effect. A suitable example of introducing the environmental costs and benefits into interindustry model, is given by J. H. Cumberland (1966). The model suggested by J. H. Cumberland is illustrated in the form of an input-output table for the given region. This model includes rows and columns which make it possible to identify the costs and the benefits. The former costs are incurred due to impairment of its balance and to the prevention of damage to the environment resulting from economic development. These pros and cons can be split up according to different economic branches. In this concept the rows and columns of the equilibrium of the environment constitute the framework of a conventional table showing regional input-output analysis.

Producing industry \ Purchasing industry	•	Environmental balance (B)
	Input-output table	Cost of restoring the quality of the environment
Environmental benefits (+) Q		
Environmental cost (—) C	Cost of impairment of the environment	
Environmental balance (A)		

Regional input-output table with environmental balance

Environmental balance expressed by row a should be interpreted as a measure of the effect of the environment upon the economic activity. This balance consists of the benefits of the environment by sectors, expressed in money (row Q) and of the hypothetical cost caused by the impairment of the environment (line C). Entry B seen in the balance column of the environment should be interpreted as the cost to be incurred by particular sectors in order to prevent losses of the environment, to neutralize changes of the environment harmful from the viewpoint of health conditions or esthetic values, etc., and to restore the quality of the environment. Both rows and columns can be subdivided into sub-branches consistent with corresponding environmental factors encountered in a given region, as far as relevant data for these factors are available.

Hence from the viewpoint of planning of the economic development row A and column B show the estimated values of specific benefits and costs, resulting from the operation of environmental conditions and not taken into account in the regional input-output analysis. The whole of the balance sheet of the environment can serve as set of criteria for evaluating the perspective plan of regional development from the viewpoint of the part played by the environment.

The leading conclusion to be drawn from this sort of analysis is, that is a solution expressed by Q and C, is unsatisfactory thus that value A is positive. Agreement to this solution would of necessity lead to a worsening of the quality of the environment in spite of relative economic advantages. Hence, an essential element in maintaining the balance of an environment is that the proportion should be $Q > B$.

For the problematics of prospective spatial planning, of essential importance are two further research problems referring to the use of a geographical environment.

The first is the problem of the capacity of geographical environment, and this must be examined from the viewpoint of the saturation of the environment with population and the fixed assets (in terms of their value and structure). Every attempt at defining this capacity is of necessity relative and depends on type of economic use, like industrial-urban agricultural or recreational. This attempt must be based in the first place upon the results of an equilibrium analysis, from which results one can establish the amount of investment funds required for protecting the environment. It also must be based on a comprehensive appraisal of the most appropriate way of utilizing the environment. The basis for defining marginal conditions of the capacity mentioned should be indices characterizing the saturation of the environment, derived from the standards of ecological conditions recommended for human life, and the aim of maintaining the equilibrium of the environment, — thus the realization of the two principal rules which supplement and restrict economic activities.

The second problem is how to draw up the rules for investigations of the regional structure of the country from the viewpoint of the degree of the intensity of its development, in proportion to the level dictated by the natural conditions. This requires, apart from the above mentioned indices of saturation, further empirical indices recording: overloading of the environment, hazards to its equilibrium, and determinations of resources so far unexploited that might be utilized for activiting the economy.

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A FRAMEWORK FOR AN ANALYSIS OF THE INTERNATIONAL AND INTERREGIONAL DIVISION OF LABOUR*

LUCJAN CIAMAGA

INTRODUCTION

The possibilities of applying quantitative methods to the investigation of the economic phenomena depend on the place, the object of investigation occupies in the economic system (the degree of aggregation of the object) and on the extent of statistical information available (the degree of aggregation of data). Here can be observed the rule that the smaller the area of investigation the more complete is the information on hand, and the greater is the chance of applying mathematical models, complicated only insofar as this is necessary for taking into account all, or most of, the factors essential for producing the given phenomenon. Parallel with an increase in the degree of aggregation the number of unknowns also rises, and the possibility and the scope decreases of applying mathematical models for investigations of economic conditions.

These rules are fully applicable to investigations of the branch and spatial economic structure of a country, the more so if — as is becoming increasingly necessary — this structure refers to a definite system of international economic relations. Heve one immediately comes up against the barrier of statistical information. This fact has been expressed, among other occasions, by the United Nations European Seminar of regional statistics, held in Warsaw in 1969. Thus, the report of the Statistical Bureau of EEC prepared for this session stresses that: "at the present stage of European integration regional studies have made little progress and regional policy is in its infancy. Correspondingly, the statistics, whose progress depends closely on the requirements of economic policy, are still under construction"[1].

The difficulties in obtaining the data call for caution and suggest search for

* The author undertook this attempt dealing with investigations of specialization and location of production in the framework of the Common Market countries; Cf L. Ciamaga, *Podział pracy w przemyśle krajów Europejskiej Wspólnoty Gospodarczej* (Sum.: Labour division in the industry of the countries belonging to the European Economic Community), Studia, KPZK PAN, 30, Warszawa 1969.

[1] The Statistical Office of the European Communities, *Problems of regional statistics in the European Economic Community*. Statistical Commission and Economic Commission for Europe, Conference of European Statisticians, United Nations European Seminar on Regional Statistics (Warsaw, 30 September — 8 October 1969).

an appropriate technique for investigating problems of the international and interregional division of labour among more simple deterministic models, rather than more complicated probabilistic ones. Hence the aim of the author of the present paper is to indicate a method which might be used for as accurate as possible a definition of the structure and the trends of commodity flow in international cross-sections of systems of co-operation and integration, such as CMEA (Council for Mutual Economic Assistance), Common Market, or EFTA (European Free Trade Association). At the same time it seems, that the way of collecting statistical data which B. Szybisz[2] suggests in his paper prepared for the above mentioned European Seminar, covers to a high degree all that is wanted in this matter.

The method which the present author proposes, springs from the necessity of undertaking research by several stages, proceeding along the following successive determinations:

a. rudimentary data as reconnaisance of the structure of generic production,

b. regional balances based on input-output analyses for particular regions, expressed in terms of value and quantity of commodities,

c. regional specialization of production and its "intensity",

d. the range of this specialization or, in other words, of interregional and international specialization.

THE STRUCTURE OF GENERIC PRODUCTION

The entire analysis should, in principle, be embodied in the framework of Leontief's basic schemes, which combine simplicity of construction with a wide elasticity in adaptation and plenty of possibilities of transforming information.

The investigation of the generic structure of production within a given country or region should commence from an explicit study of the appropriate matrix of its technical coefficients a_{ij}.

$$\begin{vmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{vmatrix} \quad (1)$$

With its large degree of disaggregation, this matrix affords insight into a number of essential matter; among other factors it explains what kind of production is involved, whether the production is far developed and to what degree and in what branches, — further, what type of requisites it demands for its production, the

[2] B. Szybisz, *Methods of compiling regional and industrial input-output tables*, Statistical Commission and Economic Commission for Europe, Conference of European Statisticians, United Nations European Seminar on Regional Statistics (Warsaw, 30 September — 8 October 1969).

possibilities of supplying them and, to some degree, also, what commodities are required. To answer the question how big is the total input in a given country or region, it suffices to multiply the output of each of the industrial branches by all coefficients of costs involved and to sum them up. Unless we define demands for inputs in the given production and the relevant technical interdependences, we would be unable — as P. Sulmicki points out — to make any statement on the generic structure of total production[3]. Under conditions where the matrix of the technical coefficients a_{ij} and the final product q_i are known, the production Q_i can relatively readily be defined on the basis of the following equation:

$$Q_i = \sum_{s=1}^{n} a_{ij} \; Q_j + q_i \; (i = 1,2 \ldots n) \tag{2}$$

In this way we obtain the rudimentary elements indispensable for further analyses. Next we therefore consider the matrix of the coefficients of inputs.

$$\begin{vmatrix} Q_1 \\ Q_2 \\ \cdot \\ \cdot \\ \cdot \\ Q_n \end{vmatrix} \begin{matrix} q_{11} & q_{12} & \cdots & q_{1n} \\ q_{21} & q_{22} & \cdots & q_{2n} \\ & & & \\ & & & \\ & & & \\ q_{n1} & q_{n2} & \cdots & q_{nn} \end{matrix} \begin{vmatrix} q_1 \\ q_2 \\ \\ \\ \\ q_n \end{vmatrix} \tag{3}$$

By adding in the above matrix one column marked "export" and one line marked "import", we obtain a general perception of the basic tendencies of the international or interregional division of labour for period t and area T.

REGIONAL BALANCES

Knowingt he generic structure of production we can take steps towards determining regional balances expressed in values and in quantities. Obviously, the value approach is mainly required in order to elucidate what kind of regions are involved, as well as their character and the part they play in the division of labour in the given system. However, when it comes to specializing production, the apprehension by quantities is of greater usefulness.

Useful for the investigation of regional balances are the schemes above described constructed by Leontief. According to Z. Chojnicki they enable us to "apprehend" the totality of mutual interdependences in both branch and regional cross-sections[4]. However, Z. Chojnicki refrains from closer attention to these models by reason of "their having already been discussed and applied in Polish literature"[5]. This might

[3] Cf P. Sulmicki, Teoria rozwoju regionów gospodarczych, (The theory of evolution of economic regions), *Biuletyn*, *KPZK PAN*, 1(10), 1962, p. 71.

[4] Z. Chojnicki, Modele matematyczne w geografii ekonomicznej (Sum.: Mathematical models and methods of a regional analysis), *Przegląd Geograficzny*, 39 (1967), 1, p. 124.

[5] *Ibidem.*

imply, that both drawing up a variety of models and their application in our literature has been so universal and comprehensive, that ready-made solutions are available for any sort of investigation. In reality this is not so. In investigations of the division of labour and of specialization of production the basic difficulty lies in a simultaneous *total apprehension of mutual interdependences in a cross-section by both branches and regions.*

In numerous attempts at making practical use of these models (Fajferek[6], Morawski[7], Szybisz[8]), various authors are operating with the relation: region — — branch, and branch — region. The first of these relations signifies only from where the given commodity is sent without indicating the place of its destination, while the latter relation states what has been supplied and the place of destination without telling where the commodity came from. Hence these models may be useful in investigations of regional balances, but when it is the question of applying them to interregional and international problems of specialization of production, they require further transformation and improvement.

By the term "balance" we mean the difference between outflow from, and inflow into, a region. If we have n regions and mark the value of the commodities supplied from them by $v_1, v_2, \ldots v_n$, the value of commodities received by $\bar{v}_1, \bar{v}_2, \ldots, \bar{v}_n$, and the values of commodity flow from region i to region j by p_{ij} (where $i, j = 1, 2, \ldots, n$), we can compile the table for interregional flow by the following pattern:

v_1	0	p_{12}	$\cdots$	p_{1n}
v_2	p_{21}	0	$\cdots$	p_{2n}
$\cdot$				
$\cdot$				
$\cdot$				
v_n	p_{n1}	p_{n2}	$\cdots$	0
	$\bar{v}_1$	$\bar{v}_2$	$\cdots$	$\bar{v}_n$

$$p_{ii} = 0 \; (i = 1, 2 \ldots n) \tag{4}$$

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[6] A. Fajferek, *Region ekonomiczny i metody analizy regionalnej* (The economic region and methods of regional analysis), Warszawa 1966.

[7] W. Morawski, *Przepływy towarowe i powiązania międzyregionalne na obszarze Polski* (Sum.: Commodity flows and interregional connections in Poland. A value approach), Studia, KPZK PAN, 25, Warszawa 1968.

[8] Cf B. Szybisz, *Problematyka statystycznych badań przepływów międzygałęziowych w gospodarce narodowej Polski* (Problematics of statistical studies of interbranch commodity flow in Poland's national economy), typescript.

It is readily seen from this table that $p_{ii} = 0$ ($i = 1, 2, \ldots n$), indicating that outflow and inflow of commodities to region i are in balance and therefore are left out of consideration. Summing up the above terms by lines we obtain the total value of the outflow from the given region, and summing up by columns gives the total value of the inflow into that region i. For each of them we therefore have a balance equation of outflow and a balance equation of inflow:

$$\sum_{j=1}^{n} p_{ij} = v_i \quad (i = 1,2\ldots n)$$
$$\sum_{i=1}^{n} p_{ij} = \bar{v}_j \quad (j = 1,2\ldots n) \tag{5}$$

We can also determine for each region the balance $s_i = v_i - \bar{v}_i$ ($i = 1, 2, \ldots n$).

This method can be applied to determining positive balances of particular commodities in each region considered separately; there will be only slight changes in the interpretation of the information thus obtained. Negative balances illustrate the structure of commodity demand, positive balances picture regional tendencies toward specialization. How far these tendencies conform to true trends of specialization of production in a given region, will come to light in the next stage of our investigations.

REGIONAL SPECIALIZATION OF PRODUCTION

It would be hazardous merely to look upon a positive balance for a given branch of commodities as a standard for regional specialization of production, principally because of the possibility of some non-uniformity occuring between the kind of inflow and outflow. In order to avoid a mistake of this kind, Z. Chojnicki choses for his basic standard of specialization the quotient of the percent share of shipmentes of a definite group commodities from a given region to the total shipments of the given commodity as the divident, and the quotient of the percent share of the population of that region to the total population of the country as the divisor; he calls this "coefficient of commodity specialization of a region W_{sr}"[9].

$$W_s = \frac{\dfrac{a_i}{\sum a_{i'}}}{\dfrac{S_i}{S_{i'}}} \tag{6}$$

where :

a_i = the sum of shipments of a given commodity group from region i,

$a_{i'}$ = the total of shipments of the given commodity group,

[9] Cf Z. Chojnicki, *Analiza przepływów towarowych w Polsce w układzie międzywojewódzkim* (Analysis of commodity flow in Poland, arranged by voivodships), Studia, KPZK PAN, 1, Warszawa 1961, p. 73.

S_i = the population figure of region *i*,
$S_{i'}$ = the population figure of the whole country.

Even so, there is some doubt as to the value of this coefficient,because the information it supplies is little more than what is obtained from a positive regional balance for the given commodity group. In particular there is no sound reason for considering in the divisor of W_{sr} the proportion of the population of the region to that of the whole country. Probably cf higher value in this case would be the proportion of the workers employed within the region in the production of the given commodity group to the number of workers employed in the production of the given commodity in the whole country or the whole system. This seems to be the reason, why in literature this coefficient has not been widely used.

By contrast, increasing usė is made of W. Isard's[10] coefficient of regional specialization, modeled on Florence's[11] index of concentration.

The form of this coefficient is[12]:

$$\frac{\sum_{1}^{n} + (d - c)}{100} \tag{7}$$

where:

c = the percentage of total regional production in the production of the whole area,

d = the percentage of total production of a given commodity within region i in the total production of this commodity within the whole country.

When it comes to calculating Florence's index, there is:

c = the percentage of the population of the region in the number of the population of the whole country,

d = the percentage of the population employed in industry of the region to that in the investigated area.

In both cases only positive differences are taken into account. But also met with is the following version how the coefficient of regional specialization is expressed[13]:

$$WS_i = \sum_{r=1}^{n} zr \tag{8}$$

[10] W. Isard, *Methods of regional analysis* (Polish translation: Metody analizy regionalneji, Warszawa 1965), p. 140.

[11] Cf P. S. Florence, *Investment location and size of plant*, Camridge 1948; P. S. Florence, W. G. Fritz, R. C. Gilles, *Measures of industrial distribution, iudustrial location and national resources*, Washington, D.C. 1943.

[12] I. Tarski, *Transport jako czynnik lokalizacji przemysłu* (Transport as factor in locating production), Warszawa 1963, p. 328.

[13] Cf A. Fajferek, *op. cit.*, p. 120.

where:

WS_i = the coefficient of regional specialization,

zr = $\bar{w}_{ir} - \bar{w}_r$, i.e. the absolute share of production of branch r in the total production of region i, less the share of total production of branch r in the total production of the whole area.

Here again only positive differences are taken into account.

The basis for determining the coefficient is, in the first case, the difference between the proportions of the total production of a region to the total production of the whole investigated area, and the production of the given commodity in the region to the production of the same commodity in the whole area. In the second case it is the difference between the proportions of the production of the given commodity in a given region to the total production of the region, and the total production of this commodity to the total production of the whole area.

Hence the second coefficient may be looked upon as a more accurate version of the first. Both can relatively easily be expressed in graphic form, and in practical use their results resemble each other.

At the same time, however, both coefficients show a basic deficiency, when it comes to using them in investigations of international or interregional specialization.

The results obtained from applying them fail to indicate the extent of regional specialization of production. In some cases this specialization may be of local character to such an extent, that considering it in an interregional or, even less, an international aspect, would not only be futile but outright misleading.

And nothing would be gained from what is called an absolute "intensity index" of specialization, because this index would refer only to a given region, not to a region on the background of the whole investigated area. Thus, in this case of more value would be the relative "intensity index" of specialization of the regional economy. Both these indices may be useful for determining the hierarchy of regional specialization patterns as basic data for investigations of interregional systems, and this is why they deserve closer attention.

The equation for calculating the absolute "intensity index" of regional specialization WN_r can be written:

$$WN_r = \sum_{r=1}^{n} b_{ii} \tag{9}$$

where:

b_{ir} = the absolute share of production of branch r in the total production of region i.

In an analogous manner this index for the whole area WN_o assumes the form:

$$WN_o = \sum_{r=1}^{n} or \tag{10}$$

where:

or = the proportion of the production in branch *r* to the total production in the whole area.

The maximum value of these indices equals the product $n \cdot 100$ (where *n* is the number of investigated branches), while the minimum value is $\frac{n \cdot 100}{2}$. A high value of the index is equivalent to a high "intensity" of specialization of production

With these indices as basis we can compute the relative "intensity index" of regional specialization:

$$W'N_r = \frac{WN_r - WN_o}{WN_{max} - WN_o} \tag{11}$$

where:

$W'N_r$ = 1 denotes within the region or area a maximum of specialization in the given type of production[14].

INTERREGIONAL SPECIALIZATION

By the use of "intensity" indices of specialization of production we can, arranging them by values from highest to lowest, establish the hierarchy of specialized commodities for a given region. For each region we obtain its specialized products of the 1-st, 2-nd ...*m*-th rank. Depending on how detailed our investigations are, and in an effort to keep the results thus obtained as readable as possible ,we can by the use of these data arrange a table of commodity flow, either in a square pattern which contains only regions and their specialized commodities of suitable rank, or in a rectangular pattern with regions and specialized commodities arranged in hierarchical order on the side of outflow, and regions on the side of inflow.

In the former case we obtain a square matrix (12) where p_{ij} = flow from region *i* to region *j*; here $i, j = 1,2 \ldots n$ and $p_{ii} = 0$:

j, commodity of 1-st rank / *i*, commodity of 1-st rank	1	2	...*n*	$\sum_{j=1}^{n} p_{ij}$
1	0	p_{12}	p_{1n}	
2	p_{21}	0	p_{2n}	
.				
.				
.				
n	p_{n1}	p_{n2}	0	
$\sum_{i=1}^{n} p_{ij}$				

(12)

[14] On a similar basis A. Fajferek calculates indices of absolute and relative differentiation of production (cf A. Fajferek, *op. cit.*, pp. 124—126).

This table indicates the inflow of the specialized commodity of 1-st rank from region *i* to the branch of production of 1-st rank commodities in region *j*. On the diagonal is shown the intra-regional consumption of this commodity. In this manner we have obtained one of the essential sub-groups of the group of all interrelations.

In an identical manner we can obtain sub-groups for the specialized regional commodities of 2-nd rank ... of *m*-th rank. At the same time we can investigate for particular regions the flow of all commodities by means of balance equations (5) and determine their balances from which it appears whether, and to what extent, region *j* meets its own demand for specialized commodities from region *i*, with its own specialized production.

Also feasible here is another approach. This second method of preparing a matrix for interregional flow of specialized commodities assumes the form shown in (13), where p_{ij} denotes the flow from region *i* to region *j*, and where $i\,j, = 1,2...n$, and where I, II ... *m* are the specialized commodities of 1-st, 2-nd ... *m*-th rank.

Table (13) would have to be subdivided into rectangular fields *a*, *b*, *c* ... and this would contain somewhat different information, because from this form would be apparent the inflow of the specialized commodities of 1-st, 2-nd, ... *m*-th rank from region *i* to region *j*. Constructed like this, the table is also of highly value as far as the extent of regional specialization or, in other words, the interregional specialization is concerned, because it indicates both place and kind of shipments made. In this instance the place of shipment corresponds to location of production, and the kind of shipment to its specialization.

Both forms of interrelations, shown in Tables (12) and (13), can be presented by means of matrix graphs. Of course, consideration of legibility demands certain limits to the number of interrelations shown. Experience indicates, that a graph becomes too difficult to interpret when it comprises 4 to 5 sub-groups of the group of all interrelations[15]. An example of a more simple graph with only two sub--groups can be found in a study by W. Morawski[16]. The advantage of an easily readable graph lies in its synthetic and, at the same time, very plastic presentation of the most essential interregional interrelations in the domain of specialized production. It is admissible, yet rather problematic from a practical point of view, is to compile and use a table which comprises all regions, together with all type of outflow and inflow. This sort of a table would assume the form shown below (14). Under conditions of a marked disaggregation, the use of this table would become a very difficult task, even if it were subdivided into separate fields A, B, C, ... Even so, an analysis is possible of the data this table contains in a "bi-regional" relation, i.e. in the system "each to each".

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[15] Cf *Etude comparée des tableaux d'entrées et de sorties des Communautés Européennes* Namur 1966 (Annex).

[16] Cf W. Morawski, *op. cit.*, p. 135.

	i, I, II, ... m \ j	1	2	... n	$\sum_{j=1}^{n} p_{ij}$
	1_{I}	$p_{11\mathrm{I}}$	$p_{12\mathrm{I}}$	$p_{1n\mathrm{I}}$	
	II	$p_{11\mathrm{II}}$	$p_{12\mathrm{II}}$	$p_{1n\mathrm{II}}$	
a	.				
	.				
	m	p_{11m}	p_{12m}	p_{1nm}	
	2_{I}	$p_{21\mathrm{I}}$	$p_{22\mathrm{I}}$	$p_{2n\mathrm{I}}$	
	II	$p_{21\mathrm{II}}$	$p_{22\mathrm{II}}$	$p_{2n\mathrm{II}}$	
b	.				
	.				
	m	p_{21m}	p_{22m}	p_{2nm}	
	.				
	.				
	n_{I}	$p_{n1\mathrm{I}}$	$p_{n2\mathrm{I}}$	$p_{nn\mathrm{I}}$	
c	II	$p_{n1\mathrm{II}}$	$p_{n2\mathrm{II}}$	$p_{nn\mathrm{II}}$	
	.				
	.				
	m	p_{n1m}	p_{n2m}	p_{nnm}	
	$\sum_{i=1}^{n} p_{ij}$				

(13)

Obviously, the reflections presented above which, to a certain degree, are summed up in Table (14), do by no means take in the complete problem of application of matrix computation in investigations of the international and interregional division of labour. However, it seems to represent a fairly accurate system which, provided a slight improvement is made in regional statistics, might prove useful for practical use. It also may serve as incentive to further reflections and improvements.

Table of commodity flow in a branch-region cross-section where $i, j = 1,2 \ldots n$, I, II, ... m = branches, and p_{ij} = flow from region i to region j

	j_{I} II .. m / i_{I} II . . . m	1_{I} II . . . m	2_{I} II . . . m	...	n_{I} II . . . m	$\sum_{j=1}^{n} p_{ij}$
A	1_{I} II . . . m	$p_{11\mathrm{I\,I}}$ $p_{11\mathrm{I\,II}}$ $p_{11\mathrm{I}m}$ $p_{11\mathrm{II\,I}}$ $p_{11\mathrm{II\,II}}$ $p_{11\mathrm{II}m}$ $p_{11m\mathrm{I}}$ $p_{11m\mathrm{II}}$ p_{11mm}	$p_{11\mathrm{I\,I}}$ $p_{11\mathrm{I\,II}}$ $p_{11\mathrm{I}m}$ $p_{11\mathrm{II\,I}}$ $p_{11\mathrm{II\,II}}$ $p_{11\mathrm{II}m}$ $p_{11m\mathrm{I}}$ $p_{11m\mathrm{II}}$ p_{12mm}		$p_{1n\mathrm{I\,I}}$ $p_{1n\mathrm{I\,II}}$ $p_{1n\mathrm{I}m}$ $p_{1n\mathrm{II\,I}}$ $p_{1n\mathrm{II\,II}}$ $p_{1n\mathrm{II}m}$ $p_{1nm\mathrm{I}}$ $p_{1nm\mathrm{II}}$ p_{1nmm}	
B	2_{I} II . . . m	$p_{21\mathrm{I\,I}}$ $p_{21\mathrm{I\,II}}$ $p_{21\mathrm{I}m}$ $p_{21\mathrm{II\,I}}$ $p_{21\mathrm{II\,II}}$ $p_{21\mathrm{II}m}$ $p_{21m\mathrm{I}}$ $p_{21m\mathrm{II}}$ p_{21mm}	$p_{22\mathrm{I\,I}}$ $p_{22\mathrm{I\,II}}$ $p_{22\mathrm{I}m}$ $p_{22\mathrm{II\,I}}$ $p_{22\mathrm{II\,II}}$ $p_{22\mathrm{II}m}$ $p_{22m\mathrm{I}}$ $p_{22m\mathrm{II}}$ p_{22mm}		$p_{2n\mathrm{I\,I}}$ $p_{2n\mathrm{I\,II}}$ $p_{2n\mathrm{I}m}$ $p_{2n\mathrm{II\,I}}$ $p_{2n\mathrm{II\,II}}$ $p_{2n\mathrm{II}m}$ $p_{2nm\mathrm{I}}$ $p_{2nm\mathrm{II}}$ p_{3nmm}	
C	. . . n_{I} II . . . m	$p_{n1\mathrm{I\,I}}$ $p_{n1\mathrm{I\,II}}$ $p_{n1\mathrm{I}m}$ $p_{n1\mathrm{II\,I}}$ $p_{n1\mathrm{II\,II}}$ $p_{n1\mathrm{II}m}$ $p_{n1m\mathrm{I}}$ $p_{n1m\mathrm{II}}$ p_{n1mm}	$p_{n2\mathrm{I\,I}}$ $p_{n2\mathrm{I\,II}}$ $p_{n2\mathrm{I}m}$ $p_{n2\mathrm{II\,I}}$ $p_{n2\mathrm{II\,II}}$ $p_{n2\mathrm{II}m}$ $p_{n2m\mathrm{I}}$ $p_{n2m\mathrm{II}}$ p_{n2mm}		$p_{nn\mathrm{I\,I}}$ $p_{nn\mathrm{I\,II}}$ $p_{nn\mathrm{I}m}$ $p_{nn\mathrm{II\,I}}$ $p_{nn\mathrm{II\,II}}$ $p_{nn\mathrm{II}m}$ $p_{nnm\mathrm{I}}$ $p_{nnm\mathrm{II}}$ p_{nnmm}	
	$\sum_{i=1}^{n} p_{ij}$					

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SPATIAL AND TEMPORAL CHANGES IN THE MIDDLEWESTERN RURAL ECONOMY

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INTRODUCTION

During the past two decades significant changes have taken place in the composition of rural economic structure. The level of income returns to individuals from various sectors of the rural economy has shifted in importance and magnitude. This paper focuses on the spatial and temporal variation of a sector's contribution of the direct income returns to the overall economy.

In order to accomplish this task we have drawn upon methodologies concerned with economic-quantitative taxonomies of places introduced by Kendall [9] and Hagood [6], and refined by B.J.L. Berry [1] and others[1]. These procedures have evidently not been used to address spatial or temporal variations of an industry's contribution or the overall economy in the form of direct income returns, nor have they been used to evaluate the geography of the composition of the economy. Although assessment of spatial variation of industrial magnitude and subsequent generalization through classification and regionalization of the observational entities yields much useful information, it fails to delineate spatial patterns of areal units whose economic compositions are similar, irrespective of magnitude. Hereafter, in speaking of the composition of the economy of an area or of a place, we refer to the profile of relative, rather than absolute, contributions via direct wage and salary payments by a mix of industries as its economic *structure*.

NATURE OF THE ANALYSIS

In this empirical study, we develop an objective areal classification of the structure of the middlewestern rural economy, using data collected for 899 non-SMSA counties and combinations thereof in the East North Central and West North Central states[2]. To briefly outline its scope and methodology, we first examine some short run (1953—1964) trends and functional relationships which account for spatial

[1] For examples of this extensive literature see [2, 3, 12, 13] and [15].

[2] The study area includes: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri,

variation of the relative importance of nine major economic sectors. Multivariate analysis was subsequently used to condense these sectors into three independent patterns of economic dominance. The counties' scores on these dimensions were apportioned into classes with homogeneous economic structure. These categories were first elicited for a random sample of 248 counties by a minimum distance grouping algorithm developed by Berry [2]. The remaining counties were assigned to the groups with a stepwise form of multiple discriminant analysis[3]. The analysis is culminated by examining the spatial and temporal variations of the categories.

THE DATA

Because of the close relationship between net income in an economic sector and personal income accruing to workers in that sector, an industry's relative importance in an area's economy may be approximated by its level of direct payments to employees. Hence, county level wages and salaries data for eight major industry groups in the first quarter of 1953 and 1964 were obtained from *County Business Patterns* [16]: (1) mining, (2) contract construction, (3) manufacturing, (4) transportation and public utilities, (5) wholesaling, (6) retailing, (7) finance, and (8) services. The ninth variable is a comparable approximation of net income from farming[4].

It is common knowledge that these nine industries are generally the critical sectors of the economy. Thus, the sum of wages and salary payments in the eight non-agricultural sectors and net income from farming is considered to constitute the economy of a given county.

As regards the remaining economic sectors, the agricultural support industry and miscellaneous and otherwise unclassified industries were not considered, since they account for a negligible proportion of income in even the most rural or most populous counties, respectively. A likely more relevant omission is income from employment in the various levels of government, particularly from the standpoint that several state capitals in the study area are situated in non-SMSA counties. However, it is hazardous to convert undifferentiated government employment to income at the county level.

Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. The data sources treat the following combinations of contiguous counties as single reporting units. They are used similarly here. Illinois: Brown-Schuyler; Gallatin-Hardin; Johnson-Pope; Kansas: Grant-Haskell; Greeley-Wichita; Hamilton-Kearney; Lane-Scott; Logan-Wallace; Morton-Stanton; Missouri: Atchison-Holt; Camden-Hickory; Carter-Reynolds-Wayne; Cedar-St. Clair; Christian-Stone-Taney; Clark-Lewis; Dade-Polk; Douglas-Ozark; Gentry-Worth; Harrison-Worth; Harrison-Mercer; Iron-Madison; Knox-Scotland.

[3] For a description of the stepwise discriminant analysis program see (5).

[4] The operational form of net income from farming is as follows:

$$NAI_c^s = \frac{(GAI_c)\,(PNI_s)}{4}$$

It is germane to comment on the use of the macro-scale "one-digit" industries data. Simply speaking, they are used here because more complete data are available than for any other *SIC* level. If one were to contemplate the use of wages and salaries data for less general levels of aggregation, the probability of non-occurrence increases. Moreover, we find that the "disclosure rule" is so often invoked in counties for even two-digit industries that one has considerable need for allocation of income from the state or state economic area level: the problem of unreliable data is magnified when more specific industries are enumerated for the county level. Conversely, the frequency of non-occurrence and the need for allocation are minimized by use of the major sectors data[5].

Regression-correlation analyses were performed on the raw wage and salaries data for each year. They indicate that manufacturing and the tertiary sectors are strongly interrelated and that income from the primary industries (farming and mining) varies inversely with income in the higher-order sectors. Hence, the factors which account for these relationships are deemed to be factors of absolute magnitude which reflect size of population, rather than factors capable of illuminating relative strength of an industry or set of related industries. Thus, the raw data are clearly incapable of eliciting spatial patterns of homogeneous economic structure, and it was necessary to assess the income data in an alternative way.

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where

NAI_c^s = Net agricultural income for county *c* in state *s*,

GAI_c = Gross agricultural income as defined in U. S. Bureau of Census: Table 18, Farm Characteristics, by Tenure of Operator: 1964, *Census of Agriculture*, 1964, U. S. Gov't. Printing Office, Washington, 1967; U. S. Bureau of Census: County Table 4, Value of Farm Products Sold by Source, *Census of Agriculture*, 1954, U. S. Gov't. Printing Office,

PNI_s = Percent of agricultural income of state *s* which is net income, determined by dividing total proprietor income by total state agricultural income. Total state agricultural income was taken from the following sources for 1954 and 1964, respectively: U. S. Bureau of Census: Table 463, Personal Income — Major Sources by States: 1954, *Statistical Abstract*, (77th ed.), U. S. Gov't Printing Office, Washington, 1956, and U. S. Bureau of Census: Table 360, Personal Income — Major Sources by States: 1964, *Statistical Abstract*, (87th ed.), U. S. Gov't. Printing Office, Washington, 1967.

Proprietor income was obtained from: U. S. Bureau of Census: Table 794, Value of All Farm Products Sold, with Farms Reporting, by Source of Income, by States: 1954, *Statistical Abstract*, (78th ed.), U. S. Gov't Printing Office, Washington, 1957, and U. S. Bureau of Census: Table 794, Value of All Farm Products Sold, with Farms Reporting, by Source of Income, by States: 1964, *Statistical Abstract*, (88th ed.), U. S. Gov't Printing Office, Washington, 1967.

Division by four was performed to reduce yearly income to a quarterly figure in order to compare it with the quarterly data given in *County Business Patterns*.

[5] The "disclosure rule" was encountered in approximately 10 per cent of the counties for one or more major industry groups. In order to calculate wages and salaries in these instances, we multiplied the average salary for the state in an affected sector by the central value of a business size class. These were summed for all establishments in this sector of a county's economy. A simple check on this approximation indicated a slight tendency for the wage and salary estimates to be higher than the actual values.

The data were summed over all sectors for each county to determine the proportion of a county's economy which accrues to each sector in each year. Thus, the data are rendered magnitude-free, and a profile of relative importance of all nine sectors could be constructed for each county in the study area. Such a profile describes a county's economic structure. Similarities between all 899 profiles might be used to classify the areal units directly, applying such techniques as *Q-mode* principal components analysis, vectorial analysis, or cluster analysis[6]. However, a direct approach would not permit us to isolate the fundamental dimensions of economic structure, nor would it allow us to describe their spatial and temporal variations. Hence, we use conventional *R-mode* principal components analysis which is based upon covariations between proportions of income accruing to pairs of sectors.

ECONOMIC STRUCTURE — TRENDS AND SPATIAL RELATIONS

If one considers the profile of arithmetic means of all sectors as the most probably economic structure for any rural county chosen at random, we obtain those expectations shown in Table 1. Coefficients of variation are given in Table 2.

TABLE 1. Arithmetic mean, proportion of income from economic sector. Middlewest rural counties $N = 899$

Sector	Mean 1953	Rank 1953	Mean 1964	Rank 1964	Difference 1964—1953	$\left(\frac{1964}{1953}\right)$
Mining (Mg)	.029	7	.030	9	.001	1.03
Contract Construction (Cn)	.030	5.5	.036	7	.006	1.20
Manufacturing (Mf)	.183	2	.220	2	.037	1.20
Transportation and Public Utilities (Tr)	.037	4	.052	5	.015	1.41
Wholesaling (Wh)	.030	5.5	.045	6	.015	1.50
Retailing (Rt)	.120	3	.134	3	.014	1.12
Finance (Fn)	.019	9	.033	8	.014	1.74
Services (Sv)	.028	8	.057	4	.029	2.04
Farming (Fm)	.524	1	.394	1	—.130	.75

$r_{r_{1953-1964}} = .796$

$t_{r_r} = 3.48$*

* $t_{.05,\,df\,7} \geqslant 1.90$ (one tail test)

Several short-run trends and spatial relations are evident from examination of the descriptive statistics. First, even though the overall magnitude of change might be considered small (e.g., the Spearman rank correlation coefficient (r_r)

[6] This statement assumes that existing package programs are capable of manipulating a correlation matrix whose order is 899 x 899. For a discussion of these methods in an essentially analogous situation, see [8].

TABLE 2. Coefficient of variation, proportion of income from economic sector. Middlewest rural counties
$N = 899$

Sector	1953	Rank	1964	Rank
Mining (Mg)	3.10	1	2.60	1
Contract Construction (Cn)	1.60	2	.92	3
Manufacturing (Mf)	1.08	3	.93	2
Transportation and Public Utilities (Tr)	.78	5	.73	4
Wholesaling (Wh)	.77	6	.64	7
Retailing (Rt)	.43	9	.37	9
Finance (Fn)	.63	7	.67	6
Services (Sv)	.82	4	.68	5
Farming (Fm)	.49	8	.63	8

$r_{r\,1953-1964} = .950$

$t_{r_r} = 8.05^*$

* $t_{.05,\,df\,7} \geqslant 1.90$ (one tail test)

between profiles of means is significantly larger than zero at the .05 level), several interesting changes in economic structure characterized the middlewestern rural scene from 1953 to 1964. The general impression is one of increasing emphasis on manufacturing and the tertiary activities and decreasing emphasis on the non-urban functions. As an example, farming dominates the rural economic structure in each year. However, its proportion of payments declined radically from 1953 to 1964[7]. Mining's overall contribution to the aggregate economy is small, and it decreased in rank from seventh to ninth during the eleven year interval. At the other extreme, the services best exemplify an increasingly urban-type structure for the rural middlewestern economy by doubling their contribution (from 2.8 percent of enumerated income to 5.7 percent) and rising from eighth to fourth in rank of importance. The dominant non-primary activity, manufacturing, saw its relative contribution increase by 20 percent and had the greatest absolute increase, even though its second place rank in the aggregate economy remained constant. That increasing reliance on traditionally urban activities is attributable to factors other than an increasing (and increasingly nucleated) population is probably best demonstrated by the fact that retailing maintained its 1953 rank and its contribution increased but slightly. Finally, although transportation and public utilities, wholesaling, and finance are comparatively unimportant tertiary activities and contribute little

[7] This is at least partially attributable to increases in urban sprawl, particularly in those counties contiguous with SMSA counties, and agricultural land being converted to urban activities.

to the rural economy, each sector increased its proportion of the economy by at least 40 percent, despite indifferent shifts in rank of importance.

Secondly, even though the ranks of the coefficients of variation are remarkably stable over time (the coefficient of rank correlation between coefficients of variation for the two years is .950), all but two such indices of localization are somewhat smaller in 1964 than in 1953. This general decrease is seemingly indicative of a "leveling" in economic structure, of greater ubiquity of industry, or of an increasing degree of economic diversification in the rural midwest considered as a whole. Specifically, we suggest that this decrease is a direct result of the declining importance of farming in a large number of counties, relative to the remaining sectors. Many counties which were primarily agricultural in 1953 have experienced greater development of the secondary and tertiary enterprises, of which a shift in emphasis to manufacturing is deemed the most significant change in economic structure, since some of the tertiary industries, e.g., retailing, are largely dependent upon farming. More urbanized counties whose economies were dominated by non-basic tertiary activities have also witnessed greater development of manufacturing.

As regards the spatial aspects of the typical rural county's economic structure, the following bits of information are equally evident in the summary statistics for both years.

(1) Two complimentary sectors, retailing and farming, which, aside from manufacturing, contribute most to the rural economy and which are not dependent upon a high degree of urbanization within a central place context are the most nearly ubiquitous in importance, as evidenced by their small coefficients of variation.

(2) Conversely, manufacturing, which is the second most important sector of the rural economy, has a disproportionately large coefficient of variation. This suggests that high relative strength in manufacturing, however critical to the overall middlewestern economy and even considering greater spread in 1964 than in 1953, is comparatively concentrated in the most populous counties and is either anomalous or absent in counties with small populations. Considerable localization of importance is also implied for mining and the construction industry. The former may be explained by the fact that a high degree of emphasis on mining is ultimately less dependent upon the mere presence of mineral deposits than it is upon lack of competing land uses. At the other extreme, a high proportion of wages and salaries paid to workers in the construction industry is associated with a small number of counties of the SMSA periphery which are experiencing comparatively rapid urbanization.

From the standpoint that farming and retailing may be considered ubiquitously important and relative strength of manufacturing is localized, it is reasonable to hypothesize that a rather weak areal association obtains between the relative strength of an industry and its degree of concentration. Rank correlation analyses between the profiles of means and coefficients of variation suggest that this hypothesis is viable by revealing a coefficient of —.296 in 1953 and a somewhat larger negative relationship of —.433 in 1964; neither of which is significant at the .05 level. The larger inverse areal association in 1964 is best explained by increasing emphasis on the secondary and tertiary activities relative to mining and a nodal pattern of increasing urbanization, accompanied by greater emphasis on the services in these nodes and in urban places in general.

MULTIVARIATE ANALYSES

The spatial relations between pairs of sectors were assessed with Pearson product moment correlation coefficients (r_{ij}). The correlations between sectors provide the bases for principal components analyses of urban economic structure. They are arrayed in matrix form in Tables 4 and 5. Subsequently, a correlation matrix will be denoted by *R*.

TABLE 3. Rank correlation analyses, means versus coefficients of variation

Year	r_r	t_{r_r}
1953	—.296	— .82
1964	—.433	—1.27

$t_{.05,\, df\, 7} \leq -1.90$ (one tail test)

TABLE 4. Correlation coefficients, proportion of total income from an economic sector. Middlewest rural counties, first quarter, 1953

r_{ij}	Mg	Cn	Mf	Tr	Wh	Rt	Fn	Sv	Fm
Mg	1.000	.047	—.050	.045	—.046	.003	—.035	.044	—.323*
Cn		1.000	.064	.155*	.117*	.158*	.094*	.196*	—.331*
Mf			1.000	.125*	.068*	.061	.040	.112*	—.802*
Tr				1.000	.250*	.409*	.275*	.379*	—.403*
Wh					1.000	.461*	.312*	.391*	—.316*
Rt						1.000	.463*	.644*	—.442*
Fn							1.000	.399*	—.270*
Sv								1.000	—.451*
Fm									1.000

* $|r_{.05}| \cdot df = 897 > .068$

Although the interrelationships between sectors are somewhat incidental to the study, we shall consider them briefly before turning to the multivariate analyses, since these relationships reveal much information which is useful for describing spatial and temporal variation of relative strength of the individual industries.

The *R* matrices are essentially similar. However, several elements vary somewhat in time. Using statistical significance at the .05 level to denote a functional relationship between sectors, interesting linkages obtain among the tertiary sectors and several less general patterns of association are noted. Construction, transporta-

TABLE 5. Correlation coefficients, proportion of total income from an economic sector. Middlewest rural counties, first quarter, 1964

r_{ij}	Mg	Cn	Mf	Tr	Wh	Rt	Fn	Sv	Fm
Mg	1.000	—.043	—.088*	.051	—.021	—.074*	—.043	.005	—.244*
Cn		1.000	.030	.153*	.178*	.296*	.173*	.234*	—.301*
Mf			1.000	.026	—.101*	—.074*	—.082*	.097*	—.790*
Tr				1.000	.204*	.324*	.118*	.257*	—.351*
Wh					1.000	.322*	.221*	.271*	—.208*
Rt						1.000	.320*	.476*	—.345*
Fn							1.000	.251*	—.177*
Sv								1.000	—.460*
Fm									1.000

* $|r_{.05}|, df = 897 > .068$

tion and public utilities, wholesaling, retailing, finance, and the services have positive interrelationships in both years, thus forming a stable pattern which might be termed *urban activity* in a maturely developed urban economy, since apart from retailing, these industries tend to vary directly in importance with population size and are essentially non-basic industries at the county scale. However, in the least populous counties, it is likely that such ubiquitous sectors as retailing exist primarily to serve the needs of the dispersed population and are basic industries at an aggregative level smaller than the county, i.e., they link the agricultural hinterland with the nucleated settlement. Hence, it is difficult to differentiate that component of this pattern which serves a central place function from the component which meets the demands of that proportion of a county's population which is urban. For this reason, this cluster is termed a *tertiary activities* pattern, rather than an urban activities pattern.

All sectors in this pattern vary inversely with income from farming, which suggest that it may be given an even more general label, *tertiary activity versus farming*.

In 1953, manufacturing varied directly with such relatively high threshold industries as wholesaling, transportation and public utilities, and the services, and had a high inverse relationship with farming. This, manufacturing might be generally regarded as a peripheral member of the tertiary activities cluster in 1953. Specifically, it is likely that manufacturing was areally associated with the higher level sectors in the more populous counties, but was essentially absent in counties with a small proportion of urban population. However, in 1964, as suggested earlier by greater emphasis on manufacturing in the rural Middlewest as a whole, this sector varies inversely with mining, wholesaling, retailing, finance, and agriculture, and directly with services. This is compatible with the notion of increasing development of manufacturing as part of the urbanization process in those rural counties which are attracting migrants from either the surrounding dispersed population or nearby SMSA counties.

It is germane to note here that this phenomenon is viewed as development of manufacturing within a wholly rural context, but if one were to consider a population which includes both rural and urban counties, it is likely indicative of decentralization of manufacturing.

In any event, manufacturing is sufficiently independent from all other sectors that we perceive it as a separate, self-contained pattern. Independence from the other sectors is even more apparent for mining, whose only stable relationship is an inverse areal association with farming, although it may be noted that mining varies inversely (but barely significantly) with manufacturing and retailing in 1964.

The linkages between sectors, inverse relationships, and non-associations in the *R* matrices suggest that the functional relations of rural economic structure in the middlewest may be summarized as follows:

(1) Strength in a given tertiary activity is areally associated with strength in another tertiary activity. These sectors are strongly interrelated.

(2) Manufacturing is essentially independent from the tertiary industries. Where manufacturing occurs in any significant amount, it is likely the most important contributor to a county's economy and subjugates the importance of the tertiary activities and farming.

(3) Where manufacturing is the major contributor to the economy, farming has its smallest degree of importance, as evidenced by the fact that farming has a larger negative correlation with manufacturing than any other industry.

(4) To a greater degree than any other industry, mining occurs independently from all other sectors. Mining is neither attracted nor repelled by higher-order functions. However, dependence on mining is areally associated with unimportance of farming and *vice versa*.

(5) Farming varies inversely with all secondary and tertiary sectors.

(6) There is somewhat greater spatial structuring among the economic sectors in 1964 than in 1953, as indicated by a slightly smaller number of independent relations among the industries in 1964.

PRINCIPAL COMPONENTS ANALYSES

The timeless aspects of economic structure were delineated more objectively through application of principal components analyses to the interrelationships between sectors in 1953 and 1964. The results are presented in Table 6.

The principal components are mutually independent vectors which resolve successively smaller amounts of the variance in *R*. It is taken that each sector has unit variance, so the variance to be parceled as principal components is limited by m, where m is the number of sectors [9]. The generality of each component is denoted by the magnitude of its corresponding eigenvalue (λ). The eigenvalues of a principal components solution are the largest latent roots in the m characteristic equations in which the determinant of R is set at zero:

$$\begin{vmatrix} (1-\lambda_i) & r_{12} \cdots r_{1m} \\ \cdots & \cdots \\ r_{m1} & r_{m2} \cdots (1-\lambda_i) \end{vmatrix} = 0$$

TABLE 6. Principal components analysis of economic structure

Sector	1953			1964		
	P_1	P_2	P_3	P_1	P_2	P_3
Mg	.123	.351	.851	.044	.177	.934
Cn	.357	.157	.270	.503	—.123	—.170
Mf	.422	.762	—.477	.337	.882	—.278
Tr	.611	—.078	.077	.538	—.070	.265
Wh	.592	—.304	—.119	.490	—.380	.063
Rt	.778	—.343	.025	.701	—.363	—.057
Fn	.579	—.370	—.065	.448	—.375	—.108
Sv	.761	—.244	.069	.714	—.093	—.001
Fm	—.803	—.589	.012	—.792	—.594	—.068
Eigenvalue	3.208	1.488	1.055	2.727	1.607	1.072

This results in as many components as variables, but fewer than m are conceptually significant if there is dependence in R. The rank of a correlation matrix may be approximated by the number of principal components whose eigenvalues are equal to or larger than one. Using this criterion, the analyses isolate three orthogonal patterns of association which may be used in lieu of the nine economic sectors to more succinctly describe the geographic characteristics of rural economic structure. These vectors ($f = 3$) are the fundamental dimensions of economic structure, or the relevant principal components which illuminate those factors that account for the relationships between the sectors. In each year, but three principal components resolve approximately 60 percent of the variance in R. The "significant" principal components (P_1. P_2, P_3) are the column vectors in Table 6. The intersections of the rows and columns are the "factor loadings", or correlations between sectors and components. The proportion of unit variance in each sector which accrues to each component may be obtained by squaring these elements. Summing a sector's squared "factor loadings", over the columns obtains the proportion of its unit variance which is explained by all three patterns. It may be noted that the fundamental dimensions of economic structure best account for the variance in the manufacturing and farming sectors, and are least able to replicate spatial variation of relative strength of the construction and transportation and public utilities industries.

IDENTIFICATION OF PRINCIPAL COMPONENTS OF RURAL ECONOMIC STRUCTURE

The initial "factor loadings" were rotated to simple structure, using a varimax criterion, in order to label the three largest principal components of economic structure[8]. It is emphasized that these principal components are patterns of relative strength or importance, rather than factors of magnitude of income creation.

In both 1953 and 1964, the first dimension (P_1) is a bipolar tertiary activities--agriculture pattern. Since the tertiary functions correlate positively with this pattern and farming has an inverse association, it is labeled *importance of tertiary activity*. The second component (P_2) is *importance of manufacturing*, and the third (P_3) is obviously *importance of mining*. The independent patterns of rural economic dominance derived from the principal components analyses conform with those derived subjectively from inspection of the R matrices.

COUNTY SCORES ON PRINCIPAL COMPONENTS OF ECONOMIC STRUCTURE

Prior to the principal components analyses, it was necessary to consider spatial and temporal variation of rural economic structure in the context of nine indices of economic strength and their interrelationships. It is now possible to do this much more succinctly, using only three variables which are products of the principal components analyses; the problem of classification is facilitated by considering a county's performance on three orthogonal, composite variables or component scores which quantify and index the importance of the principal components of economic structure, rather than the importance of the individual sectors.

The component scores for each year were obtained by premultiplying $P\lambda^{-1}$ by Z, where P is an initial "factor loading" matrix, λ^{-1} is the inverse of a diagonal eigenvalue matrix ($\lambda = p'p$), and Z is a matrix of standard scores on the nine sectors. Multiplying λ^{-1} by P is tantamount to dividing the "factor loadings" by the eigenvalues of the largest principal components, which orthonormalizes the component scores.

CLASSIFICATION OF COUNTIES ON DIMENSIONS OF ECONOMIC STRUCTURE

The observations were classified on the principal components of rural economic structure with the minimum distance grouping algorithm (CØNGRØUP) and stepwise multiple discriminant analysis. The classes were established with the former, using a random sample of 248 observations, and the remaining counties were apportioned with the latter[9].

The initial taxonomic procedure is appealing because of its simplicity and objec-

[8] For a lucid treatment of the varimax method of rotation and principal components analysis, see [7].

[9] For a description of the CØNGRØUP program see [11]. It was necessary to employ discriminant analysis because the congroup routine is evidently limited to 248 observations on an IBM System 360-65 digital computer, irrespective of the number of items of information for each site. Moreover, discriminant analysis puts the grouping procedure on a firm statistical basis.

tivity. A county is represented by a point in three dimensions by x, y, z coordinates corresponding to its scores on the three largest principal components of rural economic structure. The greater the squared distance between points, the greater the dissimilarity between counties; i.e., two counties located near each other in threedimensional space are more nearly alike as regards economic structure than two counties whose component scores are widely separated in three space. The squared distances between points were arrayed in a 248 x 248 matrix. Closest neighbors in three space were combined and their coordinates replaced by a centroid, reducing the D^2 matrix to order 247 x 247. The process was repeated until all counties were represented by a single centroid at step 247. At any step, the groups have the greatest possible internal homogeneity, considering prior combinations, and the degree of abstraction increase with each combination. It is left to the investigator to determine how many groups are required for a meaningful classification of the areal units, subject to maximizing homogeneity within classes and maximizing distance between class centroids. Since the three dimensions of economic structure include three independent patterns of economic dominance, *viz.* tertiary activity, manufacturing, and mining, and one which occurs at the expense of an orthogonal pattern in each year (agriculture), we conclude, *a priori*, that the most judicious classification is one which indicates that a county's economy is dominated by one of four general types of activity. Using this schema, a county was labeled after the 244th combination as either (1) a tertiary activities county, (2) an agricultural county, (3) a manufacturing county, or (4) a mining county.

The utility of the pre-determined four-category classification of the counties in the sample is tentatively suggested by the fact that the categories are sufficiently homogeneous for easy identification upon inspection of the sets of component scores and their respective arithmetic means in each category (Table 7). Each category consists of counties that have high absolute magnitudes of one of the largest principal components of rural economic structure, and indifferent scores on all others. The tertiary activities counties have high positive values of P_1, whereas the agricultural counties have high negative scores on this bipolar component. The manufacturing counties have high positive scores on P_2, and those counties in the mining category have high positive magnitudes of P_3.

The usefulness of the four-category schema is further suggested by several statistical tests in the discriminant analysis. Before the previously unconsidered counties were assigned to the established categories by the use of linear discriminant functions and consideration of the probability that a given county properly belongs to category i *vis a vis* the alternative probability that it has membership in each of the three remaining categories, the ability for each set of component scores to discriminate between categories of economic dominance, the significance of difference between vectors of means on the principal components for all possible combinations of categories, and the overall significance of discrimination were assessed statistically.

TABLE 7. Mean score on principal components by categories, sample of 248 counties classified by CØNGRØUP

Category	n_i	p_1	p_2	p_3
1953				
Tertiary Activities (T)	64	.768	—.895	.273
Manufacturing (M)	81	.364	.785	—.673
Agriculture (A)	88	—1.042	—.465	.021
Mining (E)	15	.562	1.624	3.046
1964				
Tertiary Activities (T)	31	1.696	—.856	—.361
Manufacturing (M)	93	.338	.811	—.160
Agriculture (A)	108	—.906	—.594	—.139
Mining (E)	16	.239	.725	3.805

p_1 = Tertiary Activities — agriculture (Bipolar: (+) Tertiary Activities (—) Agriculture)
p_2 — Manufacturing
p_3 = Mining

These tests are summarized in Tables 8 and 9, together with the discriminant functions for each category for each year. Significance of the appropriate *F*-ratio

TABLE 8. Discriminant functions for categories, principal components of economic structure

Component	F 1953	F 1964
p_1 — Tertiary Activities — Agriculture	113.16*	216.83*
p_2 — Manufacturing	164.11*	111.65*
p_3 — Mining	173.20*	168.41*

1953:

$$\hat{T}_i = .996\,pi_1 - 2.038\,pi_2 + 1.026\,pi_3 - 1.456$$
$$\hat{M}_i = 1.212\,pi_1 + 2.650\,pi_2 - 1.912\,pi_3 - 1.904$$
$$\hat{A}_i = -2.553\,pi_1 - 2.190\,pi_2 - .168\,pi_3 - 1.838$$
$$\hat{E}_i = 3.175\,pi_1 + 5.127\,pi_2 + 8.947\,pi_3 - 18.684$$

1964:

$$\hat{T}_i = 4.761\,pi_1 - .672\,pi_2 - .435\,pi_3 - 4.403$$
$$\hat{M}_i = 1.816\,pi_1 + 2.318\,pi_2 - .116\,pi_3 - 1.257$$
$$\hat{A}_i = -3.599\,pi_1 - 2.338\,pi_2 - .676\,pi_3 - 2.371$$
$$\hat{E}_i = 2.587\,pi_1 + 2.676\,pi_2 + 8.589\,pi_3 - 17.619$$

* $F_{.05,\ df\ 3,242} > 2.40$

TABLE 9. *F* Matrix. Discrimination between categories of economic structure, sample of 248 counties

1953	T	M	A	E
T	x	125.87*	81.86*	159.44*
M		x	175.06*	179.30*
A			x	220.55*
E				x
Wilks' Lambda = .048, F_A = 161.69**				

1964	T	M	A	E
T	x	69.57*	169.29*	160.68*
M		x	219.18*	155.29*
A			x	231.43*
E				x
Wilks' Lambda = .040, F_A = 179.62				

* $F_{.05,\ df\ 3,242} \geqslant 2.40$
** $F_{.05,\ df\ 9,589} \geqslant 1.90$

at the .05 level is accepted as evidence that (1) a composite variable successfully discriminates between categories of economic structure (Table 8), (2) a category is different from another category (Table 9), and (3) on the whole, the categories differ one from another (Table 9). If all three conditions are met in both analyses, the four-category classification schema may be considered as viable. To summarize the results in the most general manner, the fact that all conditions are met gives added substance to our prior subjective interpretation of the utility of our schema[10]. As might be expected, the mining counties differ most from all others and the mining component is the best discriminator between categories of economic structure. It is also illuminating that while manufacturing was a better discriminator than the bipolar tertiary activities-agriculture component in 1953, the situation is reversed in 1964, which also points to greater ubiquity of manufacturing in the rural Middlewest in 1964.

The entire classification procedure is summarized in Tables 10 and 11. It may be germane that a small number of counties in the sample of 248 had their group memberships changed by the discriminant analysis, thereby pointing to the need for statistical assessment of the validity of group membership as determined by the minimum distance algorithm, although these changes are of little consequence in this analysis.

[10] For thorough treatments of tests of significance in discriminant analysis, see [4] and [14]. For an excellent example of the use of discriminant analysis see [10].

TABLE 10. Counties classified on dimensions of economic structure by CØNGRØUP and discriminant analysis

Number in Category, 1953

		Assigned by Discriminant Analysis				
		T	M	A	E	Sum
Classified by CØNGRØUP	T	57	0	7	0	64
	M	4	66	11	0	81
	A	0	0	88	0	88
	E	1	2	0	12	15
	Sum	62	68	106	12	248
Previously Unclassified		153	195	273	30	651
	Sum	215	263	379	42	899

Number in Category, 1964

		Assigned by Discriminant Analysis				
		T	M	A	E	Sum
Classified by CØNGRØUP	T	31	0	0	0	31
	M	5	85	3	0	93
	A	1	4	103	0	108
	E	1	0	0	15	16
	Sum	38	89	106	15	248
Previously Unclassified		113	241	271	26	651
	Sum	151	330	377	41	899

TABLE 11. Middlewest rural counties classified on three dimensions of economic structure

Category	Dominant Type of Economic Activity	n_{1953}	n_{1964}
1	Tertiary Activities	215	151
2	Manufacturing	263	330
3	Agriculture	379	377
4	Mining	42	41
	Total	899	899

The spatial distributions of the categories are shown in Figs. 1 and 2. As regards their composition, the categories are essentially stable over time, although all possible changes occurred in varying frequency and in varying degrees of signi-

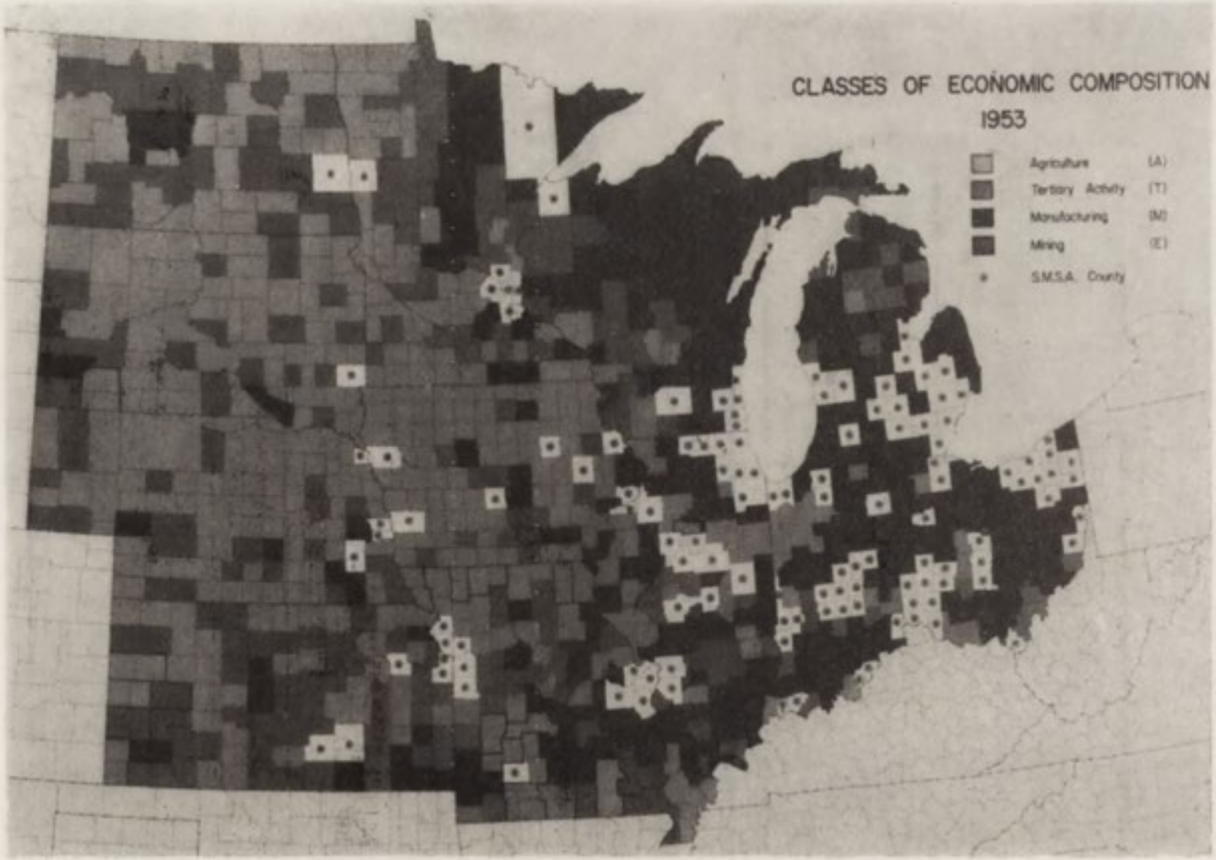
CLASSES OF ECONOMIC COMPOSITION
1953
Agriculture (A)
Tertiary Activity (T)
Manufacturing (M)
Mining (E)
S.M.S.A. County

Fig. 1

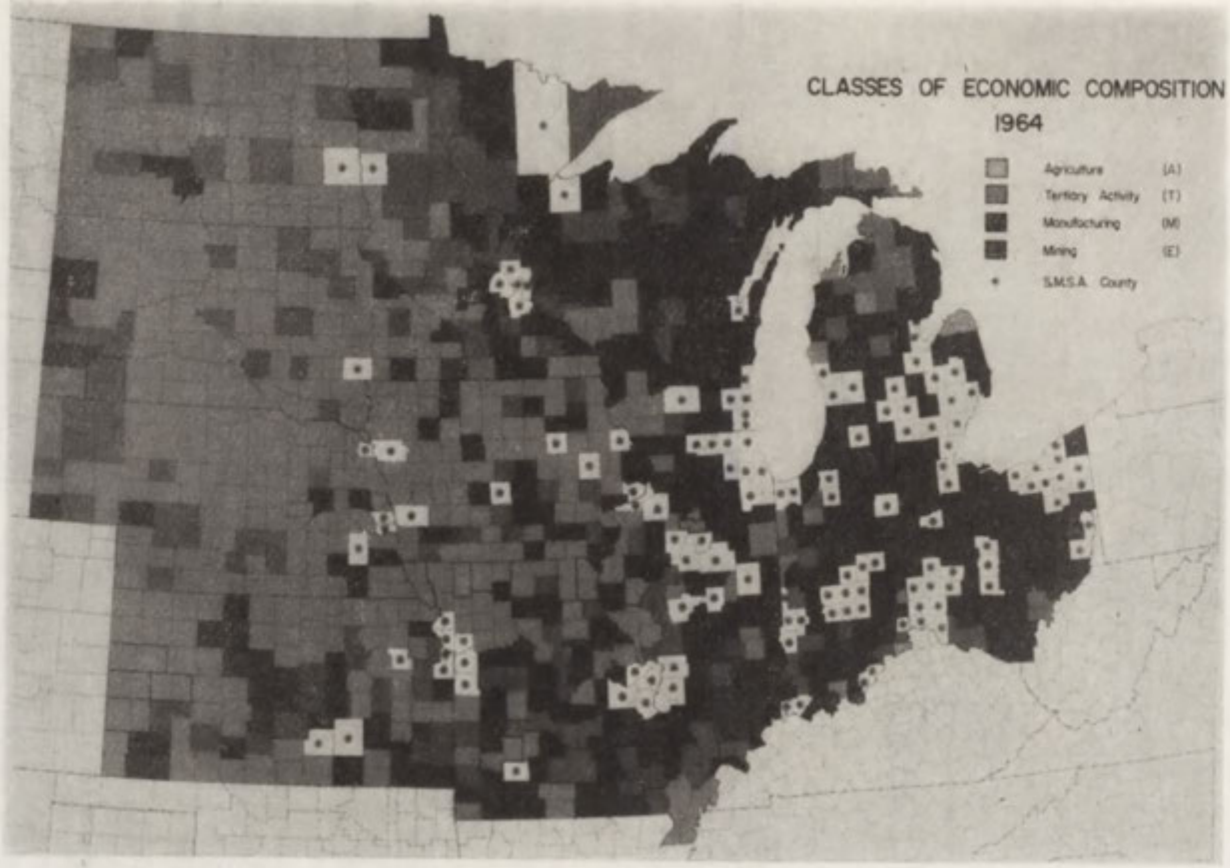
CLASSES OF ECONOMIC COMPOSITION
1964
Agriculture (A)
Tertiory Activity (T)
Manufacturing (M)
Mining (E)
S.M.S.A. County

Fig. 2

ficance (Table 12). In particular, manufacturing received the largest number of new members, and the number of counties in the tertiary activities category declined considerably between 1953 and 1964. The agriculture and mining categories contain approximately the same number of counties in both years.

TABLE 12. Frequency of stability and change in categories of economic structure

		To Categories, 1964				
		T	M	A	E	N_{1953}
From Categories, 1953	T	103	44	57	11	215
	M	25	227	5	6	263
	A	17	48	311	3	379
	E	6	11	4	21	42
N_{1964}		151	330	377	41	899

The maps of the spatial distributions of the categories reveal several static characteristics of gross economic structure. The following generalizations were formulated from visual inspection of these maps:

(1) Agriculture dominates the economic structure of the largest number of counties and agricultural dominance is concentrated in the West North Central states.

(2) As a whole, the tertiary activities are also essentially concentrated in the less populous West North Central states. The tertiary activities and agricultural categories appear to form a mosaic pattern which is associated with comparatively intensive farming in the agricultural heart of the Middlewest. However, the tertiary activities are more important than agriculture in marginal farming areas to the North and South.

(3) Manufacturing dominates the economic structure of the majority of counties in the East North Central states and is the most important category in areas near major urban complexes, regardless of location.

(4) Mining is least important, and predominance of mining is associated with coal, metallic ore, and petroleum production near the periphery of the Middlewest.

(5) The spatial distributions of the categories are characterized by a high degree of contiguity. This is to say that adjacent counties have a higher probability of similar class membership than non-adjacent counties. This is perhaps the most singularly geographic conclusion which can be drawn from this analysis.

Inasmuch as changes in location are of primary interest here, the spatial distribution of a category in 1953 reasonably approximates its spatial distribution in 1964. For example, the relationship between all categories for 1953 and 1964 may be expressed by a non-parametric index of similarity, the coefficient of mean square contingency. Even after combination of the primary industries categories for purposes of statistical validity, the magnitude of this index ($C_o = .642$) is significant at the .05 level (Table 13). Therefore, the categories' locations do not fluctuate randomly and most of those locational changes which will be generalized later are deemed to be meaningful and significant departures from economic inertia. A series of fourfold point correlation analyses, whose summary statistics are *Phi* coefficients, was also conducted to determine to what degree the locations of the individual categories in 1953 predict their locations in 1964. The analyses (Table 13)

TABLE 13. Relationships between spatial distributions of similar categories of economic structure. 1953—1964

Category	$\Phi_{1953-1964}$
Tertiary Activity (T)	.466
Manufacturing (M)	.662
Agriculture (A)	.695
Mining (M)	.483
All Categories*	$C_o = .642$

* In view of statistical requirements, the primary categories, agriculture and mining, were combined in calculating the coefficient of mean square contingency (C_o).

suggest that the spatial distributions of the manufacturing ($\Phi = .662$) and agriculture ($\Phi = .695$) categories are the most stable over time, and that tertiary activity ($\Phi = .466$) and mining ($\Phi = .483$) are the least stable. In the case of tertiary activity, its comparatively high degree of instability is interpreted as resulting from a combination of two characteristics, each of which reflects the population size of a county. In the less populous counties, it is suggested that the distinction between dominance by the tertiary activities and dominance by agriculture is subtle. Therefore, slight changes in sources of income or prices for agricultural products may result in a county being classified as oriented toward the tertiary activities in one year and as agricultural in another. However, in more populous counties, increasing emphasis on manufacturing has subjugated the role of the tertiary activities.

Meaningful interpretation of the instability of the mining category is rather tenuous. As is indicated by the maps, this component tends to dominate the economic structure of traditionally strong mining counties in both years. However, nearly an equal number of counties shifted from mining to a different category as shifted from another category to mining. It is likely that a shift away from emphasis on mining is best associated with declining coal or metallic ore production, followed by either the development of low value added manufacturing in remote areas of the Middlewest or spread of manufacturing from the SMSA to adjacent rural counties. New emphasis on mining seems to correlate with recent petroleum production in sparsely populated counties which formerly belonged to either the agricultural or tertiary activities categories and with declining low value added manufacturing south of the "American Manufacturing Belt" in the eastern Middlewest.

These and other interesting changes in location of the categories of economic structure may be observed by inspecting Table 12 and Figure 3. In Table 12 the incidence of stability and change is summarized in matrix form and those counties which underwent changes in group membership are defined in Fig. 3.

Six hundred and sixty-two (662) counties remained in the same category, and 237 are in a different category in 1964 than in 1953. Interestingly, both the greatest incidence and highest proportion of counties which changed categories are located in the West North Central states. One might be tempted to postulate that the rural economic structure of the less highly urbanized western Middlewest is in greater flux than it is in the more populous eastern states. However, this is negated by the fact that the most frequent shift in categories in such agricultural states as the Dakotas, Kansas and Nebraska is from tertiary activities to agriculture. As stated earlier, we regard this as a spurious trend.

However, additional trends are clearly evident. Two of these reflect what we believe is a significant change in the Middlewest's rural economic structure, viz., greater emphasis on manufacturing and declining importance of agriculture and the tertiary industries. The first of these is from agriculture to manufacturing. Forty-eight counties whose economies were formerly agricultural are now classified as manufacturing counties. This trend is most pronounced in certain counties in the "Corn Belt" of the central Middlewest which are contiguous with or near SMSA counties.

The second pronounced shift is from domination by the tertiary activities to greater relative importance of manufacturing. Forty-four counties exhibit this trend. Most of these are situated in the East North Central states and the eastern half of the West North Central states. Again, the trend is most clearly evident in counties which are located near major metropolitan centres.

Neither of the two less frequent changes in group membership is deemed as critical to the composition of the middlewestern economy as a shift to manufacturing, nor are they considered spurious. The first trend is from manufacturing to the tertiary industries. This pattern of change, which may be interpreted as the demise of low value added manufacturing, occurred in 25 counties which are mainly located in areas of marginal agricultural productivity along the northern and southern boundaries of the East North Central states and in Minnesota and Missouri. The second trend is from agriculture to the tertiary industries. Although this might be disregarded as simply the opposite of a shift from the tertiary activities to agriculture, we deem it as having greater relevance, particularly since it is compatible with an economic growth process, and secondly, because it has an entirely different set of locations than the change from tertiary activities to agriculture; it occurs most often in areas of higher population densities and decreasing emphasis on agriculture.

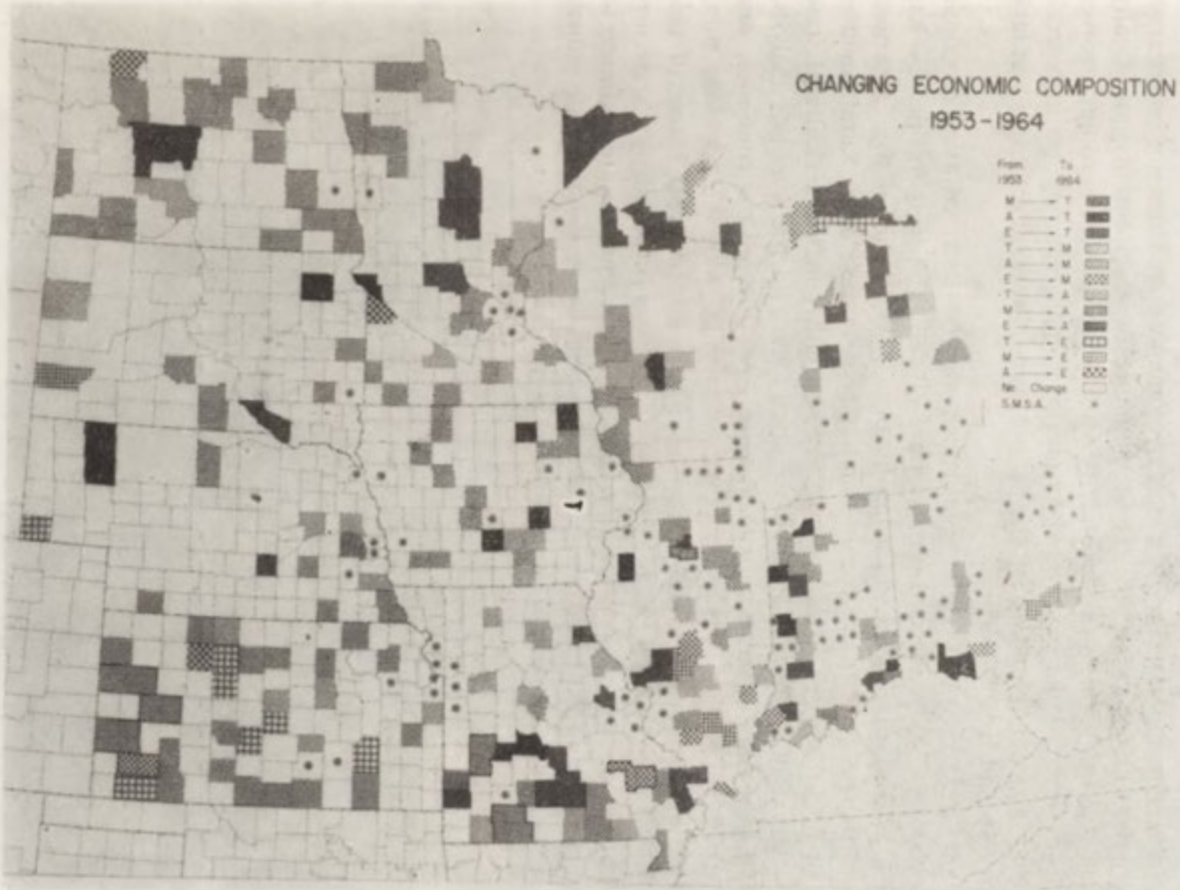
CHANGING ECONOMIC COMPOSITION
1953 - 1964
From 1953
To 1964
M → T
A → T
E → T
T → M
A → M
E → M
T → A
M → A
E → A
T → E
M → E
A → E
No Change
S.M.S.A.

Fig. 3

CONCLUSIONS

Considering the results of this analysis, it is evident that two processes of economic change have affected or are at work in generating the spatial distribution of gross economic structure in the rural Middlewest.

The first is a temporal process of changing economic dominance which is characterized by the following sequence: (1) agriculture, (2) tertiary activity, and finally (3) manufacturing[11]. This sequence may be short-circuited, i.e., a county evolves directly from agricultural dominance to dominance by manufacturing, but in general, the sequence appears to hold except for the presence of mineral resources and lack of competing land uses.

A second process, which is spatial in nature, may be described as an economic growth process. Clearly, the two processes are related. The temporal process has been most active in the area which has historically been part of the "American Manufacturing Belt" or situated near this highly urbanized area. Rural counties located farthest from this industrial area are still either in the agricultural state or supply agricultural hinterlands and based upon some evidence from this analysis, are slowly evolving toward economic maturity. As this process continues, one might expect a westward expansion of manufacturing, with the populous rural counties being dominated by manufacturing. The eventual areal extent of this westward shift is conjectural. At the same time, counties surrounding mature metropolitan economies in the eastern Middlewest have reached or are beginning to reach the manufacturing or third stage of development. Thus, the economic growth pattern is active at the local as well as the regional level.

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[11] If a county were to eventually become heavily urbanized, it is likely that a fourth step im the sequence would be a return to tertiary activity of a non-basic nature.

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AN ATTEMPT TO DETERMINE THE DEGREE OF INDUSTRIALIZATION OF VOIVODSHIPS AND POVIATS

STANISŁAW RÓG

Initially, all investigations into the degree of industrialization of individual regions in Poland were largely based upon one measure only, namely the number of employees per 1000 inhabitants and per 100 sq.km. This was due to the fact that no other statistical data were available in relation to industries in their territorial cross-sections. Only exceptionally was it possible to obtain some additional statistics such as the size of production, or the power of installed machinery driven by electrical energy, for certain industry groups, like cement production, metallurgical industries, etc.

At present, statistical information is much richer. Data collected during the Industrial Census of 31. 12. 1965 are quite extensive and make it possible to evaluate the degree of industrialization of regions, voivodships, poviats and industrial centres in a much more precise way. For example, the following indices can be computed per 1000 inhabitants and per 100 sq.km for individual plants:

— employment, including apprentices and workers employed in cottage industries;
— employment in a given industry group;
— gross product expressed in comparable prices;
— gross value of fixed assets;
— gross value of machinery and equipment;
— gross value of fixed assets;
— power of installed machinery and power transmission equipment in kW;
— power consumed in kWh;
— the area occupied by the plant;
— percentage of the area occupied by the buildings to the total area occupied by the plant.

Indicators known as "indices of industrial intensity" are of great importance in the evaluation of the degree of industrialization of the region. The following can be computed from the material collected during the Census:

— gross value of fixed production assets per 100 zlotys of net production;
— value of machinery and equipment per 1000 zlotys of net production value;
— gross value of fixed production assets and

— value of machinery and equipment per:
one employee;
one employee working during the main shift;
— value of machinery and equipment per 1 sq.m of production area;
— percentage of new fixed assets in the total value of fixed assets;
— power of installed electric motors in kW per employee working during the main shift;
— electrical power consumed per employee of a given industry group;
— the coefficient of shift rotation;
— percentage of employees working in:
automatically controlled jobs
mechanized jobs
non-mechanized jobs;
— number of commuters per 1000 employees.

With such a wide range of indicators available it would seem that the researcher should be able to select the best index determining the degree of industrialization of a region. Then he might, in addition, analyse the remaining indices and thus fulfil the assigned task. The problem, however, is not that simple, as no single indicator exists on which one could base the investigation and obtain objective results. For example, the employment index, which is a measure most commonly used for this purpose, when expressed in terms per 1000 inhabitants and per 100 sq. km undoubtedly throws a certain light on the problem of the degree of industrialization. When we say that every fourth, for example, inhabitant of a given voivodship or poviat is employed in industry, this index quite clearly determines the degree of industrialization of this area.

We should not, however, forget that due to automatic control of production processes, being nowadays rapidly developed, the evaluation of the degree of industralization on the basis of the employment index may often be distorted. The following example can illustrate the changes that may occur in the volume of employment due to automation of production. In the Huls Works in Nordheim, Westphalia, there are two plants; one is old, and the other new and automatically controlled. The old plant employs 10,000 workers and produces approximately 36,000 tons of synthetic rubber a year, while the new plant, started in 1957, employs only 400 workers and produces 45,000 tons[1].

Moreover, the type of industrial production carried on in a region greatly influences the actual participation in the economic life of the area. Employment in textile and food industries differs, for example, from that in the electrical machinery and equipment industry. That is why false results may be obtained when we base our research on employment only. Some more examples to illustrate this problem will be given below. Index number of net production is often thought to be the most

[1] M., Miller, *Automatisierung, Wohlstand oder Elend? Die Wirtschaft*, Berlin 1957.

adequate indicator for the determination of the degree of industrialization and the best tool to be used in various regional analyses. This opinion originates from the fact that it reflects in a single "number" not only the value of labour output but also, partially, the utilization of the means of work. This index is, undoubtedly, very valuable but still not without defects. If, for example, light industries or food industry, are concentrated in a given area, the index of net production shows a very high degree of industrialization.

The following table illustrates this problem.

TABLE 1. Net production in current prices per 1 employee of a given industry group (apprentices and workers employed in cottage industries are excluded): In 1968 in thousand zlotys

Industry group	Net production	Net production turnover tax deducted	Number of employees	Net production per employee	
				with tax	without tax
1. Enterprises producing spirits and alcoholic beverages	3,200,054	58,603	865	3,699.5	67.7
2. Woolen yarn and fabrics manufactures	743,146	132,308	2,929	253.7	45.2
3. Iron works	1,021,984	1,021,984	8,672	117.8	117.8
4. Cement works	169,832	169,832	2,347	72.3	72.3

Net production per employee in enterprises producing alcoholic beverages is more than 30 times higher than that of, for example, iron works; while net production of textile industry enterprises is more than 15 times higher than that of iron works. It seems obvious, therefore, that the investigation of regional industrialization should be based either on net product (turnover tax deducted) or gross output plus amortization quota. The turnover tax is only a fiscal instrument and as such it distorts the findings. Indices computed on the basis of this category of net production, as shown by the figures given above, do not greatly differ one from another. Moreover, it is a well known fact that there are some factors which influence the volume of net production but not of gross output. These are factors regulating, first of all, the share of material costs in the value of production. In case of lower material costs net production will be higher even when the physical volume of production remains the same.

Similarly, any of the remaining indicators if applied separately, will not produce correct results. Fixed assets presented in various forms, for example, are a valuable tool in the investigation of the spatial structure of industry. However, if the evaluation of the degree of industrialization is based exclusively on this category of measures, results obtained will be unreliable if no other measures are simultaneously taken into consideration. The capital-output ratio of such industries do not induce the economic expansion of the area to such a degree as, for example, the manufacture of electric machinery and equipment. Even if these indices are applied in relation to the "active group" of fixed assets, i.e. to machinery and equipment, the degree of industrialization computed on their basis will not be indentical in all cases.

DETERMINING THE DEGREE OF INDUSTRIALIZATION OF VOIVODSHIPS

The short characteristics of ceratin indicators included at the beginning of the present paper, is followed by the description of research during which an attempt was made to evaluate the degree of industrialization of individual voivodships by means of two methods: (1) the "traditional" method based on the analysis of a set of measures determining the degree of industrialization of individual voivodships; (2) the factor analysis.

From among a great number of indices on which this type of investigation could be based, nine were selected and computed per 1000 inhabitants, and five — per 100 sq.km.

It should be made clear that this set of measures cannot adequately determine the degree of industrialization of different voivodships. On the other hand, no such set has ever been compiled so far, which would adequately take into account all factors of so complicated a mechanism as industry, in particular in relation to its branch structures, specific production processes, etc. We hope, however, that the set of indices selected during our studies might provide better opportunities for the analyses of actual state of industrialization.

For the sake of our investigation, cities having the rank of voivodships (known as "city-voivodships"), were included in the area of the voivodship in which they are situated. Otherwise, the findings would not be comparable, especially in relation to these five voivodships where city-voivodships form separate units, following an administrative rather than an economic division. The percentage of inhabitants of the administrative centre of the voivodship in the total population of the voivodship is often higher than that of the city-voivodship in the total population of the voivodship plus the population of the city-voivodship.

For example, the population of the Szczecin voivodship amounted to 782,000 people on 31 December 1967, of which 332,000 i.e. 36.9 per cent were inhabitants of the city of Szczecin. The population of the Gdańsk voivodship amounted to 1,393,000 people, of which 552,000 i.e. 39.6 per cent lived in the conurbation of Gdańsk, Gdynia and Sopot. On the other hand, the percentage of the population living in the city of Poznań (which forms a separate unit) in the voivodship total plus the inhabitants of the city, was only 17.1 per cent (the respective figures at 31 December 1967 being 447,000 and 2,602,000. The following table presents the data for other voivodships and city-voivodships:

Warsaw-city and the Warsaw voivodship — 3,765,000 in which Warsaw = 34.0 per cent

Cracow-city and the Cracow voivodship — 2,699,000, in which Cracow = 30.9 per cent
Łódź-city and the Łódź voivodship — 2,426,000, in which Łódź = 30.9 per cent
Wrocław-city and the Wrocław voivodship — 2,481,000, in which Wroclaw = 19.6 per cent

The figures listed above seem convincing enough to justify the inclusion, for the purpose of the present study, of the city-voivodships in the units that surround them.

The analysis carried out by means of the first method was based on the traditional index of employment per 1000 inhabitants. The findings are presented in Table 2.

Figures in Table 2 denote the ranks of the voivodships for each of the measures included in the investigation. For example, the Łódź voivodship (the city of Łódź included) is in the 8th place, when the value of fixed assets was the selected criterion; in the 7th — according to the criterion of power installed; and in the 11th — according to the value of investment outlays. The Cracow-voivodship (Cracow-city included) is in the 3rd place according to the value of net production, and in 2nd place according to the criteria of machinery installed, energy consumed and the value of investment outlays. Similarly, the Warsaw voivodship is in the 10th according to the number of employees, in the 6th according to the value of net production, in the 7th according to the value of new fixed assets, or the value of investment outlays in 1961—65, or the gross value of fixed assets, or the value of machinery and equipment (the latter indicators in terms per 100 sq.km) and in the 12th — according to the value of fixed assets or power of installed energy transmission equipment. The Katowice voivodship is the only one which is in 1st place according to all the indicators. The ranking for the remaining voivodships changes depending on the criterion selected as the basis of the investigation.

A more detailed analysis of the data included in Table 2 indicate that the places taken by separate voivodships alter according to the criterion selected.

On the basis of this classification Table 3 was compiled to show how many indicators give the same ranking to each voivodship.

If we compare the classification of voivodships according to employment (Table 2, Column 1), with that presented in Table 3, we see that only two, namely the Katowice and Białystok voivodships, have retained their previous places. The remaining voivodships are placed differently. For example, on the basis of employment as the classification criterion (Table 2) the 2nd place is occupied by the Łódź voivodship (including Łódź-city) and on the basis of Table 3 this place is undoubtedly taken by the Cracow voivodship.

Table 3 makes it possible not only to classify the voivodships according to the degree of industrialization, but also to put them in the following five groups:

Group I, characterized by the high degree of industrialization, contains only the Katowice voivodship;

TABLE 2. Voivodships ranked on the basis of the fourteen indicators

Voivodships	Employment	Net product in million zlotys: total	Net product in million zlotys: without turnover tax	Gross value of fixed assets: total	Gross value of fixed assets: machinery and equipment	Gross value of fixed assets: new fixed assets	Power of installed energy transmission equipment in kW	Electrical power consumed in thousand kWh	Investment outlays in current prices in 1961—65 in million zlotys	Number of employees	Gross value of fixed assets in million zlotys: total	Gross value of fixed assets in million zlotys: machinery and equipment	Gross value of fixed assets in million zlotys: new fixed assets	Power of installed energy transmission equipment in kW
	per 1000 inhabitants									per 100 sq.km				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Katowice	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Łódź	2	2	2	8	5	7	7	6	11	2	5	6	7	5
3. Wrocław	3	4	3	2	4	4	4	4	3	4	3	4	4	3
4. Opole	4	5	5	3	2	3	3	3	4	6	4	5	3	4
5. Cracow	5	3	4	4	3	2	2	2	2	3	2	3	2	2
6. Gdańsk	6	7	6	6	12	5	10	12	9	5	6	8	5	6
7. Poznań	7	8	8	9	6	8	5	7	5	7	8	9	9	7
8. Zielona Góra	8	9	11	7	7	13	8	10	13	13	13	13	14	13
9. Bydgoszcz	9	10	9	10	10	10	9	11	12	9	9	11	11	9
10. Warsaw	10	6	7	12	9	7	12	8	7	8	7	7	6	8
11. Szczecin	11	11	10	5	8	9	6	5	8	12	11	2	12	12
12. Kielce	12	13	13	13	13	11	13	13	10	10	12	12	10	11
13. Rzeszów	13	12	12	11	11	6	11	9	6	11	10	10	8	10
14. Koszalin	14	15	14	14	14	17	14	17	15	15	15	15	17	17
15. Olsztyn	15	17	16	16	16	18	16	16	17	17	16	17	16	15
16. Lublin	16	14	15	15	15	14	15	14	14	14	14	14	13	14
17. Białystok	17	16	17	17	17	16	17	15	16	16	17	16	15	17

TABLE 3. Voivodships classified according to the ranking for each of the 14 indicators

Voivodships	Ranks																
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII
1. Katowice	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2. Cracow	—	7	4	2	1	—	—	—	—	—	—	—	—	—	—	—	—
3. Wrocław	—	1	5	8	—	—	—	—	—	—	—	—	—	—	—	—	—
4. Opole	—	1	5	4	4	—	—	—	—	—	—	—	—	—	—	—	—
5. Łódź	—	4	—	—	3	2	2	1	—	—	1	1	—	—	—	—	—
6. Poznań	—	—	—	—	3	5	1	1	1	1	—	2	—	—	—	—	—
7. Gdańsk	—	—	—	—	2	1	4	4	3	—	—	—	—	—	—	—	—
8. Warsaw	—	—	—	—	—	2	5	3	1	1	—	2	—	—	—	—	—
9. Bydgoszcz	—	—	—	—	—	—	—	—	6	4	3	1	—	—	—	—	—
10. Szczecin	—	1	—	—	2	1	—	2	1	1	3	3	—	—	—	—	—
11. Zielona Góra	—	—	—	—	—	—	2	2	1	1	1	—	6	1	—	—	—
12. Rzeszów	—	—	—	—	—	2	—	1	1	3	4	2	1	—	—	—	—
13. Kielce	—	—	—	—	—	—	—	—	—	3	2	3	6	—	—	—	—
14. Lublin	—	—	—	—	—	—	—	—	—	—	—	—	1	8	4	1	—
15. Koszalin	—	—	—	—	—	—	—	—	—	—	—	—	—	5	5	—	4
16. Olsztyn	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	7	4
17. Białystok	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	5	7

Group II, averagely industrialized, contains the voivodships: of Cracow, Wrocław, Opole, and Łódź;

Group III, with medium degree of industrialization, contains five voivodships: Poznań, Gdańsk, Warsaw, Bydgoszcz and Szczecin;

Group IV, characterized by a low degree of industrialization, contains three voivodships: Zielona Góra, Rzeszów and Kielce;

Group V, with the lowest degree of industrialization: the Lublin, Koszalin, Olsztyn and Białystok voivodships.

The method used for grouping was a relatively simple one, therefore certain doubts may be felt as to for example, whether the 6th place of Poznań and the 7th of Gdańsk have been correctly assigned.

In the second stage of our study the factor analysis was also used. The latter method, which can be applied only when a computer is available, makes it possible to construct some synthetic, multi-feature indicator, by engaging summary features and ordering the analysed units on their basis. The analysis was again based on the 14 indicators described above. We do not propose to analyse this method here in any detail, as it has been described in many studies, including a special publication issued by the Central Statistical Office[2]. Moreover, this method will be dealt with

[2] *Określenie poziomu rozwoju ekonomicznego powiatów* (Economic growth of poviats: A tentative study based on factor analysis), Statystyka Regionalna, 14, Warsaw 1965.

in a later part of this paper concerned with the degree of industrialization of poviats. The order in which the voivodships should be classified on the basis of the factor analysis is as follows:

1. Katowice	5. Łódź	9. Warsaw	13. Kielce	17. Białystok
2. Cracow	6. Gdańsk	10. Szczecin	14. Lublin	
3. Opole	7. Poznań	11. Zielona Góra	15. Koszalin	
4. Wrocław	8. Bydgoszcz	12. Rzeszów	16. Olsztyn	

In two cases only the order differs from that presented in Table 3, namely the Wroclaw voivodship is placed 4th, while in Table 3 it is 3rd (the 4th place being taken by Opole), and Warsaw moved down from the 8th to 9th (Bydgoszcz being taken 9th in Table 3). Following a detailed analysis of certain other indicators and in particular those which characterize the branch structure of industries, we decided to accept the classification and the five groups compiled on the basis of Table 3.

DETERMINING THE DEGREE OF INDUSTRIALIZATION OF POVIATS

All poviats i.e. 317 rural and 74 urban ones, were included in the analysis. For the sake of the correctness of analyses, and in agreement with the principle previously, described, urban poviats were merged with surrounding rural poviats. However according to the procedure adopted by the Working Group on Regional Statistics of the Statistical Scientific Council[3], the following 17 cities having the ranks of poviats were treated as separate units:

(a) Bytom, Chorzów, Czeladź, Dąbrowa-Górnicza, Katowice, Mysłowice, Ruda Śląska, Siemianowice, Sosnowiec, Świętochłowice and Zabrze; all of them are situated in the Upper-Silesian Industrial District, form a continuous belt, are united by common boundaries and do not lie in the area of other poviats.

(b) Gdańsk, Sopot and Gdynia — this conurbation cannot be included in any poviat because it exerts great influence on the economy of the large neighbouring area.

(c) Zgierz and Pabianice, which are situated in the Łódź poviat; Zgierz borders directly with the city of Łódź and Pabianice is only 17 km from Łódź. Since they form a kind of unity with Łódź in relation to the voivodship as a whole, it would be incorrect to include them in the poviat of Łódź.

(d) Tomaszów Mazowiecki, a town which borders with the following poviats: Piotrków Trybunalski, Rawa Mazowiecka and Brzeziny situated in the Łódź voivodship and with Opoczno situated in the Kielce voivodship.

The analysis was based on the following indices calculated per 1000 inhabitants and per 100 sq.km of the area:

[3] Cf. *Statystyka powiatów*, 1, p.42, published by the Central Statistical Office, Warsaw, 1968.

— employment (including apprentices and workers employed in cottage industries);

— gross output;

— gross value of fixed assets;

— electrical power consumed.

In addition, the following indices were used:

— the area occupied by the plant per 1 sq.km. of the country's area;

— electrical power consumed per worker of the given industry group. Altogether the degree of industrialization was computed on the basis of 10 indices.

In comparison with the indices applied in the analysis of the degree of industrialization of voivodships, the index of net production was left out, as net production

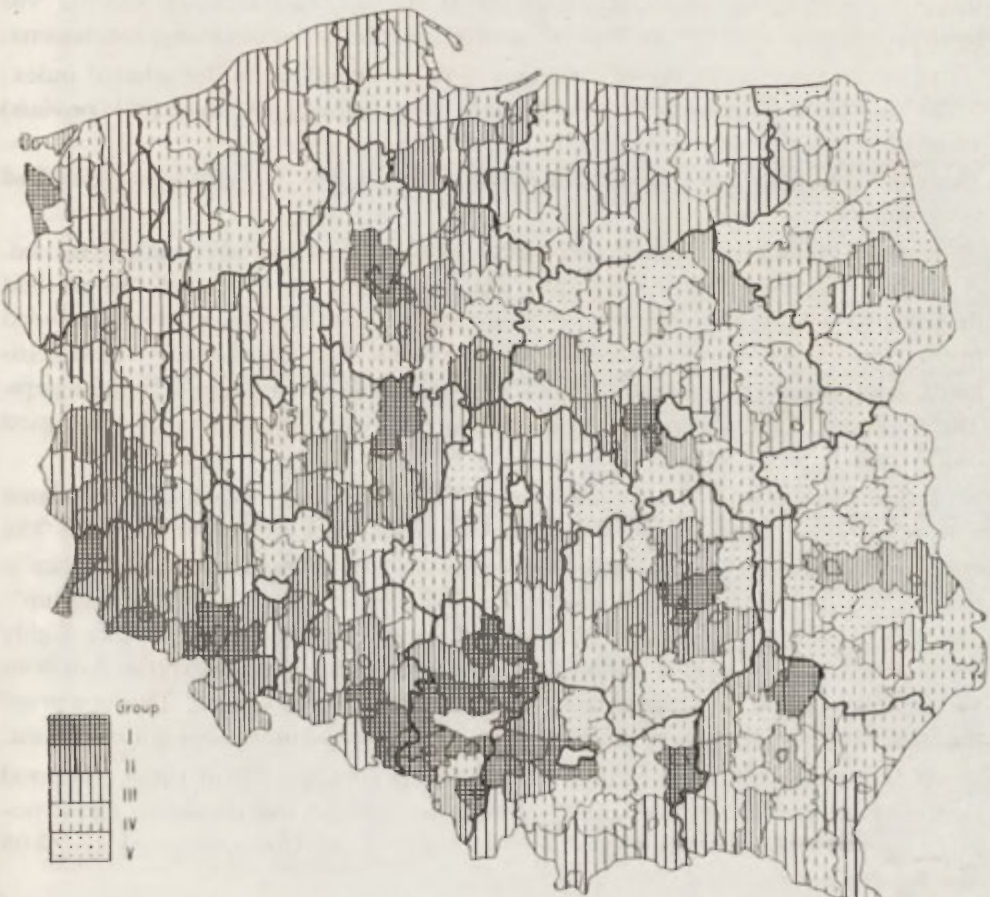

Fig. 1. Degree of industrialization of poviats

Due to small scale of the map poviats of Group VI are disregarded. The city-voivodships and Upper Silesian conurbation are marked with blank space is computed only for the whole group of plants forming one enterprise, and not for separate plants. The value of fixed assets was considered in total, without differentiating the value of machinery and equipment, as the former index sufficiently determines the impact of the value of fixed assets on the degree of industrialization for poviat cross-sections. Moreover, the index of installed power transmission equipment was excluded, as electrical energy consumed seemed to be an adequate illustration of the power factor. The volume of power consumed which characterizes, to a certain extent, the progress in the mechanization of work, was computed in three variants, namely per 1000 inhabitants, per 100 sq.km and per worker employed in a given industry group.

The goal of the investigation was — as in the case of voivodships — to rank the poviats according to all the indices listed above. The traditional method was used. The analysis of the indices led among others, to the following conclusions:

1) the ranking of the poviats changed greatly depending on the selected index;

2) an objective classification of such a large number of units (391 poviats) when only a few indices are used, is difficult.

3) the findings would have been much more reliable if a synthetic index had been applied.

It seems that such a synthetic measure is obtainable when factor analysis is used. All numerical data were, therefore, analysed again by means of this method in order to determine a synthetic measure and to distribute information included in these 10 indices among independent components. The normalization of investigated features and the computation of their correlation matrix were the initial steps. The selection of indices should be traeted as tentative. The matrix of correlation coefficients is presented in Table 4.

The analysis of the Table 4 shows that the indices are rather highly correlated with each other. There are only a few coefficients which are lower than 0.5. The only coefficient which is characterized by its own different information carrier is that of the "electrical power consumed per worker of the given industry group". The indices of employment, production, and fixed assets per 100 sq.km are highly correlated, while the degree of correlation between these features expressed in both versions, i.e. per 100 sq.km and per 1000 inhabitants, is much lower. This is a proof that the features of industrialization described by these two indices are quite different.

After the normalization of the indices and the computation of results the total sum of points on the scale of indistrialization dimension was obtained. The divergence between these points oscillates between +15.69 (for Oświęcim) and 2.06 (for Sejny poviat).

Subsequently, all poviats were ranked in a declining order in respect to the degree of industrialization, and put into five groups, as in the case of voivodships.

Group I contains 27 *highly industrialized* poviats (including merged ones), determined by points from 15.69 to 3.15;

TABLE 4. The matrix of correlation coefficients for the indices used in determining the degree of industrialization of poviats

Indices		Employment	Gross output	Value of fixed assets	Electrical power consumed	Employment	Gross output	Value of fixed assets	Electrical power consumed	Area occupied by the plant per 1 sq. km of the country's area	Electrical power consumed per worker of the industry group
		per 100 sq.km				per 1000 inhabitants					
Employment	per 100 100 sq.km	1.00	0.96	0.92	0.66	0.82	0.70	0.65	0.49	0.63	0.22
Gross output		0.96	1.00	0.91	0.72	0.82	0.81	0.71	0.60	0.66	0.33
Value of fixed assets		0.92	0.91	1.00	0.83	0.74	0.69	0.80	0.70	0.78	0.40
Electrical power consumed		0.66	0.72	0.83	1.00	0.52	0.57	0.69	0.90	0.65	0.65
Employment	per 1000 inhabitants	0.82	0.82	0.74	0.52	1.00	0.88	0.77	0.51	0.64	0.23
Gross output		0.70	0.81	0.69	0.57	0.88	1.00	0.80	0.64	0.65	0.39
Value of fixed assets		0.65	0.71	0.80	0.69	0.77	0.80	1.00	0.79	0.85	0.54
Electrical power consumed		0.49	0.60	0.70	0.90	0.51	0.64	0.79	1.00	0.69	0.81
Area occupied by the plant per 1 sq.km of the country's area		0.63	0.66	0.78	0.65	0.64	0.65	0.85	0.69	1.00	0.44
Electrical power consumed per worker of the industry group		0.22	0.33	0.40	0.65	0.23	0.39	0.54	0.81	0.44	1.00

TABLE 5. The numbers of poviats grouped according to the degree of industrialization in individual voivodships

Voivodships	Total number of poviats	Groups of poviats: Highly industrialized	Averagely industrialized	Medium industrialized	Low industrialized	Very low industrialized	City-poviats not merged with rural poviats
POLAND	317	27	65	116	71	38	17
of which merged poviats	56	18	25	12	1	—	—
I. *Highly industrialized*							
Katowice	14	9	3	1	1	—	11
of which merged poviats	8	7	1	—	—	—	—
II. *Averagely industrialized*							
Cracow	17	4	2	3	6	2	—
of which merged poviats	4	2	—	2	—	—	—
Wroclaw	27	5	15	5	2	—	—
of which merged poviats	4	3	1	—	—	—	—
Opole	14	3	5	6	—	—	—
of which merged poviats	4	1	3	—	—	—	—
Łódź	16	—	2	9	3	2	3
of which merged poviats	2	—	1	1	—	—	—
III. *Medium industrialized*							
Gdańsk	13	—	3	8	2	—	3
of which merged poviats	2	—	1	1	—	—	—
Poznań	29	1	6	19	3	—	—
of which merged poviats	5	—	3	2	—	—	—
Warsaw	28	1	5	5	10	7	—
of which merged poviats	5	1	2	1	1	—	—
Bydgoszcz	21	1	4	8	7	1	—
of which merged poviats	5	1	4	—	—	—	—
Szczecin	13	1	1	7	3	1	—
of which merged poviats	1	1	—	—	—	—	—
IV. *Low industrialized*							
Zielona Góra	16	—	7	7	2	—	—
of which merged poviats	2	—	2	—	—	—	—
Rzeszów	21	1	5	8	6	1	—
of which merged poviats	3	1	1	1	—	—	—
Kielce	19	1	4	6	2	6	—
of which poviats	4	1	3	—	—	—	—
V. *Very low industrialized*							
Lublin	19	—	2	4	5	8	—
of which merged poviats	3	—	2	1	—	—	—
Koszalin	13	—	—	7	6	—	—
of which merged poviats	2	—	—	2	—	—	—
Olsztyn	18	—	—	10	8	—	—
of which merged poviats	1	—	—	1	—	—	—
Białystok	19	—	1	3	5	10	—
of which merged poviats	1	—	1	—	—	—	—

Group II with 65 *averagely industrialized* poviats; points from 2.71 to 0.002;

Group III gathering 116 *medium industrialized* poviats; points from — 0.03 to — 1.19;

Group IV — 71 poviats characterized by a *low degree of industrialization*, from — 1.20 to — 1.69;

Group V — 38 poviats with the *lowest degree of industrialization*, from — 1.70 to — 2.06.

Moreover, a separate *Group VI* includes 17 urban poviats which, due to their geographical situation, could not be merged with rural poviats surrounding them, as well as 5 city-voivodships.

The above division into five groups, made on the basis of the factor analysis, shows that no distinct differences exist between the neighbouring poviats at the end of the one group and those at the beginning of the other. This is particularly true of the last three groups.

Group III ends with — 1.19 point and group IV begins with —1.20, so the difference is only —0.01. A similar situation occurs in Group V.

It should, however, be emphasized again that this division is a result of a tentative study and may be corrected following some further research in this field.

Table 5 throws some additional light on the problem by showing the numbers of poviats grouped according to the degree of industrialization in individual voivodships, which were similarly classified in the earlier part of the paper.

Out of the total number of 317 poviats[4] 27, i.e. 8.5 per cent are highly industrialized, 65, i.e. 20.5 per cent are averagely industrialized, 116, i.e. 36.6 per cent, are medium-industrialized, 71, i.e. 22.4 per cent, are low, and 38, i.e. 12 per cent, very low industrialized.

The detailed analysis of the Table reveals that 80 per cent of poviats merged with the city-poviats fall in the first two groups. Their degree of industrialization is therefore influenced primarily by urban poviats.

The pattern of the table is consistent with the results obtained for voivodships. Further investigations (not detailed here for lack of space), by means of factor analysis method, confirmed the fact that a high value of one of the factors may considerably distort the final picture. For example, the poviat of Cracow was ranked 13th out of 317 poviats when the factor analysis was used, while on the basis of the index of employment it was ranked 172th.

A close analysis of various indices proves that the classification based on the employment index is the nearest to the actual state. The 13th place, allocated on the basis of the factor analysis, is due to the unproportionally high (in comparison

[4] We are using the term "poviat" although it is not very precise, as in the total number there are 57 urban poviats merged with rural poviats, which makes the total number of administrative units 374. Moreover, we should add 17 city-poviats not merged with rural poviats to obtain the grand total of 391.

with other units), index of the electrical energy consumed, as large aluminium works, which use great amounts of power, are situated in this poviat.

Therefore, when factor analysis is used for determination of the regional level of industrialization, one should remember that although the synthetic measure of the general development makes it possible to classify and regionalize the investigated units, it is not sufficient for the evaluation of the degree of industrialization in all individual cases. For the latter purpose a system of indices must be worked out and various analytical and statistical methods applied. Only this form of research will yield correct conclusions as to the further socio-economic development of the investigated region.

Central Statistical Office, Warsaw

TENDANCES DE LA PHYSIOGRAPHIE URBANISTIQUE EN POLOGNE

(Les problèmes de la protection du milieu physique de la ville)

WIESŁAWA RÓŻYCKA

Quarante ans se sont écoulés depuis l'élaboration en Pologne du premier plan de ville d'après des recherches sur les conditions physiques faites spécialement dans ce but[1]. Les résultats de ces recherches ont été notés sur une carte à l'échelle 1 : 25 000, sous le titre ,,Projet d'utilisation des alentours d'Otwock compte tenu des particularités physiographiques" (Fig. 1). Les conditions hydrogéologiques servaient de critère d'évaluation. On avait constaté en effet qu'elles étaient diverses et exerçaient une influence sur les traits caractéristiques du climat, des sols ainsi que sur la répartition et les types de végétation. Le territoire de la ville et de ses environs fut divisé en de plus petites surfaces. Leur description indique à quelle fonction chacun de ces espaces se prête en premier lieu.

Les années suivantes virent le développement rapide des idées de planification par suite de l'expansion de Varsovie[2] ainsi que la genèse d'ouvrages traitant du milieu physique de la ville[3] réalisés dans le cadre d'études devant servir aux plans d'aménagement du territoire[4].

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[1] S. Z. Różycki, *Ocena sytuacji Otwocka z punktu widzenia geologicznego i hydrogeologicznego dla celów wyznaczenia granic rejonów uzdrowiskowych* (Evaluation de la situation d'Otwock du point de vue géologique et hydrogéologique pour le tracé des limites des régions de stations climatiques). Związek Miast Polskich, Archiwum.

[2] J. Chmielewski, Sz. Syrkus avec la collaboration de J. Hryniewiecki, S. Z. Różycki et T. Tillinger, *Warszawa funkcjonalna* (*przyczynek do planu urbanistycznego regionu Warszawy*) (Varsovie fonctionnelle, contribution au plan de la région de Varsovie). Warszawa, 1934, SARP. Selon la déclaration des auteurs, la division en "zones d'utilisation" découlait, entre autres, de l'analyse des conditions géologiques, morphologiques et celles du sol. Cela trouva son expression dans le partage du terrain du plan de la grande Varsovie en cinq secteurs; par ex. la zone A: "Sur la rive droite de la Vistule, entre la voie de communication transcontinentale et le coude de la Vistule appuyé à Czersk, est située la partie supérieure de la terrasse de dune de Praga. Elle est recouverte partiellement de forêts de connifères, et son sous-sol est le plus souvent perméable. Cette partie de la région correspond sur notre schéma à l'arrière-pays formant un arc d'habitations et de villes d'eau".

[3] J. Chmielewski a écrit en 1938: "La structure de la région de Varsovie est formée en premier lieu par des facteurs physiographiques..." *Planowanie regionalne okręgu warszawskiego* (Planification régionale du district de Varsovie), Sprawozdanie 1938.

[4] W. Różycka, Problemy i zadania fizjografii urbanistycznej (Problèmes et tâches de la physiographie urbanistique), *Przegląd Geograficzny*, 27, (1955).

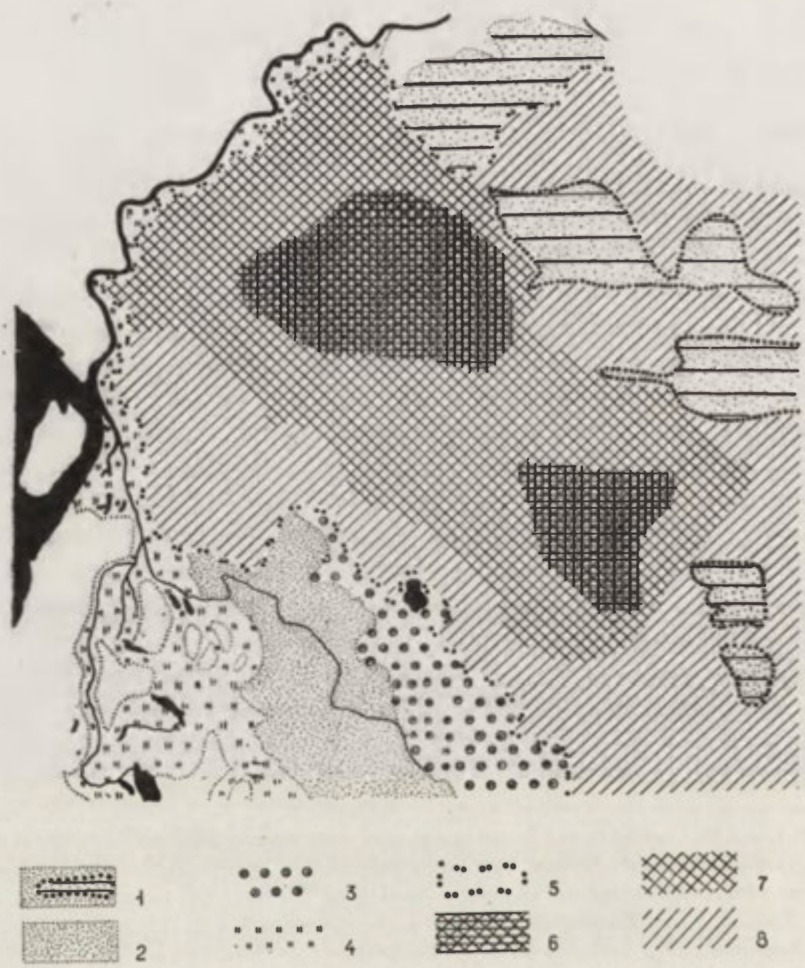


Fig. 1. Otwock — Projet d'utilisation du terrain d'Otwock et de ses alentours après analyse de ses particularités physiographiques

Echelle 1 : 25 000

Elaboré par Dr. St. Zb. Różycki, 1942

Terrains d'exploitation agricole

1. Terrains de cultures sur argiles à blocaux; 2. Terrains de culture sur les formations de sables et de limons alluviales sableux de la terrasse de Karczew; 3. Pâturages et préries sur la terrasse de Karczew; 4. Terrains bons pour la culture des légumes et l'élevage sur la terrasse d'inondation

Terrain boisé

5. Limite du terrain „vert" (boisé); 6. Terrains „secs" — sanatoriums; 7. Terrains „sains" — estivaux; 8. Parcs et forets

Dans les années d'après-guerre on observe un vif intérêt pour les problèmes de planification spatiale, on dresse des plans de reconstruction, d'agrandissement et de construction de nouvelles villes et d'unités residentielles dans toute la Pologne[5]. Le développement de la planification spatiale et l'élaboration de nombreux plans d'aménagement du territoire destinés à des quartiers de villes et petit à petit à des espaces toujours plus vastes embrassant des villes avec leurs proches alentours sont suivis par la parution d'ouvrages traitant des conditions physiographiques, nommés „documentation physiographique[6]".

En passant en revue les ouvrages traitant du milieu physique des villes, rédigés compte tenu des besoins de ces plans, on peut donner bien des examples où l'attention du physiographe est attiré sur l'examen des éléments particuliers du milieu dans le but de déterminer les differentes fonctions du terrain de la ville[7]. On propose que cette tendance, née entre les deux guerres, soit nommée „fonctionnelle". Le trait caractéristique principal des ouvrages de la tendance fonctionnelle est la recherche de terrains se prêtant le mieux aux diverses fonctions de la ville. Cette recherche est basée sur des études des éléments particuliers du milieu physique.

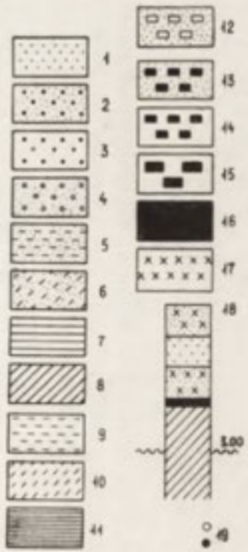
Par suite de l'énorme destruction du pays la reconstruction de la Pologne débuta par l'édification de nouvelles unités residentielles et de quartiers residentiels à la périphérie des grandes villes. Le plan général servait en même temps de plan détaillé et souvent de plan de réalisation. Dans cette manière simplifiée d'agir il n'y avait pas de place pour réfléchir au choix de la localisation dans le plein sens du terme. Cela suscita l'élaboration d'ouvrages physiographiques visant à la connaissance des conditions de sols, des conditions hydrogéologiques, autrement dit, à la connaissance des conditions nécessaires à la construction d'édifices. Plus tard ce type d'ouvrage servit aux besoins des plans détaillés. Sur la Fig. 2 se trouve la description de la carte de qualification d'un quartier de Varsovie (Marymont). Les cartes sont tracées à l'échelle 1 : 2 000. La division du terrain examiné est basée sur des prémisses géomorphologiques; la caractéristique des sols et l'évaluation des conditions de constructions y sont données. On propose de donner à cette tendance le nom de tendance "géotechnique". Dans les ouvrages de cette tendence l'évaluation embrasse un emsemble choisi de traits caractéristiques du milieu physique.

Parallèlement à la tendance géotechnique, et en partie d'après ce genre de travaux, se développent à partir de 1950 des ouvrages inspirés par des sujets ayant trait aux plans à long terme des villes. Localiser et former les quartiers residentiels devient le problème principal de ces plans. En cherchant des endroits appropriés

[5] A. Kotarbiński, *Rozwój urbanistyki i architektury polskiej w latach 1944—1964* (Développement de l'urbanisme et de l'architecture en Pologne de 1944 à 1964), PWN Warszawa 1967.

[6] W. Różycka, *op. cit.*

[7] W. Różycka, *Metody oceny warunków fizjograficznych dla potrzeb planowania miast* (Méthodes d'évaluation des conditions physiographiques pour les besoins de la planification des villes), Prace Geograficzne IG PAN n° 90, PWN, Warszawa 1971.



Division en unites naturelles et la qualification du terrain

Signes	Unites naturelle	Risque inondation en cas de rupture des digues de protection, valeur limitée au dessus du niveau moyen de la Vistule	Caracteristique des sols	Evaluation des conditions de construction
noir sur brun	Escarpe de Varsovie	Délimite la vallee de la Vistule	Preponderance des glissemets	Défavorables
brun	Plateau diluvien	Environ 20 m au-dessus du niveau moyen de la Vistule	Serie des morenes et formations inter-moreniques, preponderance de sables fins	très bonnes
orange foncé	Terrasse de dune /Otwock/	Au-dessus de la vague d'inondation, 6-10 m au-dessus du niveau moyen de la Vistule	Sables moyens	très bonnes
orange	Terrasse alluvienne ancienne /de Praga/ A - partie au-dessus de l'escarpe	Au niveau de la vague d'inondation catastrophique, jusqu'à 6 m au-dessus du niveau moyen de la Vistule	Alluvions sablonneuses anciennes	bonnes
jaune-foncé	B - zone du „mort-bras" de la rivière	Au-dessus de la vague d'inondation catastrophique, 3-5 m au-dessus du niveau moyen de la Vistule	Alluvions sablonneuses anciennes et tourbes vaseuses	défavorables
jaune	Terrasse d'inondation ancienne A - partie au-dessus de l'escarpe	Un peu au-dessus de la vague d'inondation normale, jusqu'à 4,5 m au-dessus du niveau moyen de la Vistule	Alluvions sablonneuses récentes	faibles
jaune-clair	B - zone du „mort-bras" de la rivière	Au niveau de la vague d'inondation normale, 2,5-3,5 m au-dessus du niveau moyen de la Vistule	Alluvions récentes de sables vaseux et tourbes vaseuses	défavorables
vert-clair	Terrasse d'inondation récente A - partie riveraine	Au niveau de la vague d'inondation normale; 2,0-3,5 m au-dessus du niveau moyen de la Vistule	Alluvions très recentes se sables et de poussières	faibles
vert	B - zone du „mort-bras" de la rivière	Au-dessus du niveau de la vague d'inondation normale Jusqu'à environ 2 m au-dessus du niveau moyen de la Vistule	Alluvions très récentes de sables et de vases	mauvaises
vert foncé	vallees de petits cours d'eau	Au niveau de la vallee de la Vistule	Alluviens sablonneuses et vaseuses	mauvaises
bleu	Petits réservoirs d'eau n'existant plus		Sédiments vaseux ou remblais	défavorables

Fig. 2. Legende de la carte de Qualification du terrain de Marymont (quartier de Varsovie)

Echelle 1 : 2 000

Elaborée par Aleksander Sieczkowski, 1957

Designation des sols sur les profils

1. sables fins; 2. sables moyens; 3. sables gros; 4. sables gros mélangés avec du gravier; 5. sables poussiereux; 6. sables argileux et argiles m sablonneuses; 7. sables argileux; 8. argiles moréniques; 9. poussieres; 10. argiles poussiereuses; 11. argiles; 12. sables mélangés avec humus; 13. sables vaseux; 14. vases minéralo-organiques; 15. vases; 16. tourbes; 17. remblais; 18. profils des forages à l'echelle 1 : 200; le niveau de l'eau au moment de l'execution du forage est indiqué en bleu; 19. forages

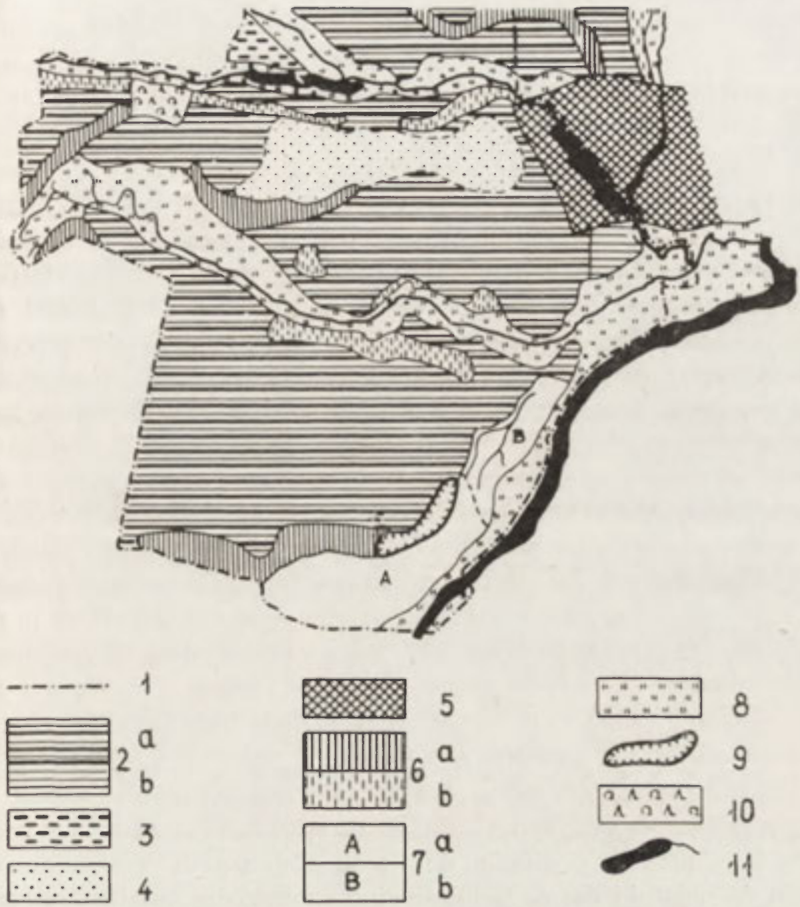


Fig. 3. Tomaszów Mazowiecki — Evaluation préliminaire du terrain pour le plan d'aménagement

Echelle 1 : 10 000

Elaborée par Z. Stala, 1953

1. Limite de l'élaboration
2. Terrains se prêtant avant tout à la construction; valeur agricole en général mediocre. Sols de IV et V catégorie; blé et pommes de terre: a. Eaux souterraines situées à plus de 2,0 m au dessous du niveau du terrain b. Eaux souterraines situées à moins de 2,0 m au dessous du niveau du terrain
3. Terrains convenant à la construction, valeur agricole moyenne. (Sols de III catégorie). Froment et partiellement betteraves
4. Terrain de sables mouvants (friches) qu'il faudrait stabiliser
5. Terrains occupés par l'industrie nocive. Localisataon correcte dans la perspective de l'agrandissement futur de la ville
6. Terrains occupant les bords des vallées fluviales aux pentes très abruptes (à 5—10% et même plus). L'aménagement de terrains de ce genre pose de gros problèmes quant au mode de construction: a. Terrains déconseillés à la construction intense (bon ensoleillement); b. Terrains déconseilles à la construction (mauvais ensoleillement)
7. Terrains se prêtant avant tout à l'aménagement de terrains de sport et d'espaces verts (Sol de IV catégorie convenant surtout au boisement): a. Se prêtant aussi à la construction (eaux souterraines à plus de 2,0 m au desous du niveau du terrain); b. Déconseille à la construction. Eaux souterraines à moins de 2,0 m au dessous du niveau du terrain — de plus, risque d'inondation (de submersion du terrain) en cas de crue excessive
8. Terrains de terrasses d'inondation, se prêtant avant tout aux prés et pâturages déconseillés à la construction (en raison du peu de profondeur des eaux souterraines, des risques d'inondation, de l'affaisement des sols faibles et des conditions climatiques et sanitaires défavorables)
9. Terrains occupés autrefois par des carrières de calcaire et de marnes 10. Forêts 11. Eaux

aux quartiers residentiels l'urbaniste tend à subordonner à cette fonction d'autres fonctions de la ville. La protection de la santé des habitants est sa force motrice. Relativement à ces tendances se forme une tendance pour laquelle on pourrait proposer le nom de „qualificative."

Dans l'un des premiers ouvrages physiographiques visant à l'évaluation des terrains du point de vue de la construction d'habitations (Tomaszów Mazowiecki), les unités géomorphologiques furent caracterisées du même point de vue[8]. Trois ans après, le même auteur, en effectuant une carte relative à „l'Evaluation préliminaire du terrain pour le plan d'aménagement "à l'échelle 1 : 10 000, élargit le domaine des recherches à tous les éléments du milieu physique et procedé à une évaluation complexe d'après les résultats d'études géologique, géomorphologiques, hydrogéologiques, climatiques et d'études du sol (Fig. 3). En conséquence, elle enrichit la carte de qualification en proposant d'autres formes d'aménagement des terrains déconseillés à la construction des habitations (vergers, cultures agricoles, pâturages, forêts). Au fur et à mesure qu'on acquiert de l'expérience et que se développe l'aménagement du territoire, les ouvrages de la tendance dite „qualificative" se différencient quant à leur précision. On prend pour principe de composer des ouvrages physiographiques préliminaires, généraux et détaillés. Dans la pratique, le principe de l'évaluation en raison des exigences de la construction d'habitations est réalisé dans les „ouvrages physiographiques généraux" composés pour les besoins des plans à long terme des villes et de leurs ensembles.

Un autre exemple d'approche de l'évaluation nous est fourni par la *Map of physiographical zonning for urban development especially for residential use and public open spaces*[9]. L'analyse des résultats des recherches des éléments particuliers du milieu physique et la bonitation de chacun d'eux permit l'évaluation complexe du terrain du point de vue de la localisation correcte des quartiers residentiels et celui des „terrains ouverts" dans la ville. La division en 3 degrés en zones a été appliquée (zone apte à la localisation de quartiers d'habitations, zone apte avec restrictions, zone déconseillée). Dans la zone apte avec restrictions on cite successivement les traits caractéristiques diminuant le degré d'utilité et on indique un autre mode d'utilisation qui assurerait l'introduction dans la structure spatiale de la ville des terrains ouverts. On procéda de même avec les terrains déconseillés à la localisation des quartiers d'habitations.

L'évaluation complexe basée sur les resultats de l'examen des éléments particuliers qui permet d'isoler les espaces accusant une différente aptitude à une fonction indiquée à priori est donc le trait caractéristique fondamental des ouvrages de la tendance qualificative.

[8] Z. Stala, *Tomaszów Mazowiecki. Opracowanie fizjograficzne ogólne* (Tomaszów Mazowiecki. Elaboration physiographique générale), Geoprojekt Warszawa, 1950, 1953 (Archives).

[9] W. Różycka, Physiographic research in town and country planning. *Geographia Polonica*, 3, 1963.

Tableau 1. Légende de la carte d'évolution préliminaire du terrain en vue du plan d'aménagement visant à la transformation de la localité Firlej en un centre de repos (les zones choisis) Élaborée par H. Rewska, 1963

Zone	Situation et relief du terrain	Conditions géotechniques du sol	Conditions hydrologiques	Conditions du sol	Conditions climatiques	Recommandations
			Terrains favorables à la localisation de centres de repos			
I jaune	Terrains situés au sud est de la partie supérieure du terrain de dunes boisées Prédominance de pentes à 2%	Sables le plus souvent fins, lâches, moyennement denses, non perforés jusqu'à la profondeur de 4,5 m	Situation des eaux souterraines: plus de 3,0 et 4,0 m dans les parties supériures de la zone; (au dessus de 2,0 m dans les parties inférieures)	Sables peu liés de la V catégorie des sols arables	Conditions climatiques et sanitaires favorables	Terrain très favorable à la localisation d'installations permanentes. On peut admettre une pression sur le sol de 2,2—2,6 kg/cm² Sur le terrain boisé il faut projeter pour sa protection uniquement une cohstruction dispersée
II vert	Terrain situé dans la partie inférieure d'une petite vallée peu profonde et dans le voisinage immédiat d'un lac; dans la petite vallée pentes à 2%, dans le reste de la zone prévalent celles à 5—8%	Sables le plus souvent fins, lâches, moyennement denses, non perforés jusqu'à la profondeur de 4,5 m Sols en général tourbeux	Eaux souterraines situées à moins de 1,0 m (au dessus du niveau du terrain) — peuvent monter periodiquement d'environ 0,5 m à 1,0 m; risque de marecages sur les parties plates du terrain	Sables d'humus des V—VI catégories des sols arables	Conditions climatiques défavorables à la construction des instalations des centres de repos en raison d'une grande humidité dé l'air	Ce terrain ne peut être utiliser que pour des instalations saisonières (cabanes de camping, tentes etc.) Décon — seillé à la construction permanente
			Bords du lac du point de vue de la création d'une plage			
B_{Ia} jaune	Bords sud du lac en partie couverts d'osier	Sables de la plage d'une épaisseur de plusieurs mètres	Eaux souterraines à moins 1,0 m de profondeur	—	Conditions climatiques et sanitaires très favorables à la création d'une plage	Le bord possède des conditions favorables à la création d'une plage à condition d'enlever les buissons qui rendent difficile l'accès au lac
			Terrains peu recommandés à la localisation de centres de repos, convenant très bien à developpement de la construction d'habitats			
III A brun clair	Terrain situé dans la partie nord-est de la zone étudiée en dehors des batiments, pentes 2%	Dans la partie ouest de la zone preponderance de sables fins, lâches, moyennement denses; les argiles à blocaux au dessous Dans la partie est des poussières sablonneuses, avec stratifications des argiles poussiereuses à consistance faible et de sables poussiereux denses	—	Sables argileux légers, IV b catégorie des sols (partie ouest de la zone) et sables agrileux légers sur des poussières de la cat. IVA des sols arables (partie est de la zone)	Terrain dont les conditions climatiques sont favorables à la construction d'habitations	Terrain aux conditions physiographiques favorables. Cependant, vu son éloignement du lac et de la forêt, moins recommandé à la localisation d'instalation, convient avant tout à l'agrandissement de la localité En creusant les fondations des bâtiments jusqu'à 15—20 m au dessous du niveau du terrain, on peut admettre une pression sur le sol de 18—20 kg/cm² dans la partie ouest de la zone et de 16—18 kg/cm² dans la partie est
			Terrain déconseillé à la localisation de centres de repos, peu recommeandé à la construction de logements, convenant avant tout aux cultures			
IV brun	Terrain situé dans la partie nord-ouest de la zone étudiée, plat, pentes à 2%	Argiles à blocaux sablonneuses, en général denses; poussières sablonneuses non pérforés jusqu'à 4,5 m, parfois avec stratifications de sables au dessous	Eaux souterraines situées à moins de 1,0 m dans les parties sud et ouest de la zone (terrains humides) ailleurs en général à plus de 1,5 m au dessous du niveau du terrain	Sols légers faits d'argiles à blocaux de la cat. IIIA des sols arables (partie nord). Sables argileux légers de la cat. IVB des sols arables (partie sud)	Conditions climatiques un peu moins favorables que dans les zones V et IV. (Partie marécageuse, plus grande humidité de l'air)	Terrain aux conditions physiographiques un peu moins favorables, éloignement du lac et de la forêt, déconseillé à la localisation d'installations du centre de repos étant donné le peu de profondeur des eaux souterraines — moins favorable à la construction d'habitations. Il serait recommandable de laisser cette zone à l'agriculture étant donné que le sol y est un peu meilleur que dans les autres zones
			Terrain aux conditions défavorables à la localisation d'habitationset de centres de repos			
V rouge	Terrain situé dans le creux proche du lac qui forment partiellement des cavités sans écoulement des eaux. Pentes à 2%	Dans les cavités sans écoulement des eaux tourbes sur sables; dans les restes de la zone, sables de dune peu liés et médiocrement compacts	Eaux souterraines situées en général à moins de 1,0 m. Dans les cavités — humidité, dans la partie est — étangs après. enlèvement de la tourbe Le niveau des eaux souterraines peut monter periodiquement de 0,5—1,0 m et l'étendue de l'humidite s'élargir	Tourbes des categ. V et VI des sols arables	Terrains dont les conditions climatiques et sanitaires sont défavorables à la construction d'habitations (grande humidité de l'air, possibilité d'inversion de la température)	Terrain dont les conditions géo-hydrologiques, climatiques et sanitaires sont défavorables à la construction d'habitations et à la localisation d'installation de centres de repos, il serait recommandable, âpres une amélioration convenable du terrain, d'utiliser la partie ouest de la zone comme prés, la partie est comme viviers

En même temps, les travaux effectués depuis 1945 dans les tendances citées eurent dans ces dernières années pour résultat des essais fructueux de liaison de la méthode qualificative à la méthode fonctionnelle. Un example en pourrat être la légende de la carte ,,Evaluation préliminaire du terrain pour le plan d'aménagement du point de vue de la transformation de la localité Firlej en un centre de repos[10]". Cette légende indique qu'on recherche une fonction pouvant servir de directive au plan d'aménagement et qu'il faut en même temps établir le placement des éléments de cette fonction sur le terrain. L'auteur a isolé une série de zones qui accusaient une différence quant au degré d'aptitude à la ,,localisation des centres de repos" (Tabl. 1.) et a indiqué dans la rubrique ,,recommandations" quelles fonctions devraient ou ne devraient pas être introduites sur le terrain examiné. Dans cet ouvrage deux échelles de cartes furent appliquées: 1 : 25 000 et 1 : 2 000. Cela est à la fois un exemple d'une élaboration physiographique préliminaire et d'une élaboration physiographique détaillée effectuées parallèlement pour les besoins des études sur le développement future de la localité donnée.

L'union des deux méthodes donne d'intéressants résultats. Le partage du terrain effectué d'après les résultats d'examens complexes des éléments particuliers et de la bonitation de ceux-ci donne un point de départ relativement ,,objectif" pour l'évaluation. Les indications et les contre-indications expriment l'aptitude du terrain à d'autres fonctions que celles de l'habitat. Ceci permet aux auteurs du plan à long terme de choisir un terrain en vue d'autres fonctions en dérogeant le moins possible aux exigences de l'hygiène et de la santé publique. Autant dans les travaux de la tendance fonctionnelle que dans ceux de la tendance qualificative sont recherchées les voies menant à l'évaluation non seulement des conditions physiques mais aussi de toutes les modifications résultant de l'activité humaine. On détermine la génèse des phénomènes naturels et antropogéniques et leur relation, ce qui permet de prévoir les modifications futures. L'évaluation qualificative unie à l'évaluation fonctionnelle permet de présenter une série cartographique et descriptive. Y sont montrés les traits caractéristiques qui, selon le genre du plan, devraient exercer une influence sur la conception de la structure spatiale à l'échelle d'un ensemble de villes et d'unités residentielles ou bien d'une partie de celles-ci (plans généraux, plans détaillés).

On a caractérisé et montré à l'aide d'exemples quelle était la différence entre la méthode fonctionnelle et la méthode qualificative et en quoi on avait intérêt à les appliquer simultanément. Au cours de plusieurs dizaines d'années on a effectué en Pologne quelques milliers de travaux de ce genre en utilisant différemment les deux méthodes[11]. Elles sont toujours unies par le principe d'une évaluation com-

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[10] H. Rewska, Opracowanie fizjograficzne miejscowości Firlej (Elaboration physiographique de la localité Firlej). Geoprojekt, Warszawa, 1963.

[11] M. Więckowski, Problems of geographical environment in the system of spatial planning in Poland. *Geographia Polonica*, 14, 1968.

plexe de tout le terrain examiné. Elles forment un groupe d'ouvrages fondamentaux.

On peut encore attirer l'attention sur un autre groupe qui embrasse les ouvrages complémantaires. Ce sont des élaborations de problèmes sélectionnés, comme par exemple les conditions du sol et les conditions hydrologéologiques ou bien les conditions hydrologiques déterminant les possibilités de l'approvisation en eau. ou encore des recherches sur les conditions de l'hygiène et du climat. En 1963 on commença à présenter les résultats des premières recherches faites à Varsovie[12] en tirant des conclusions spatiales à l'aide de deux cartes: d'une carte de ,,restrictions physiographiques" et d'une deuxième, donnant l'évaluation complexe de l'aptitude des autres parties du terrain, sans restrictions, aux fonctions prévues par les principes du programme. Sur la carte de restrictions physiographiques sont indiquées l'étendue des marécages, les pentes inaptes à la construction, les zones déconseillées, car soumises à l'émission de poussières et de gaz provenant des entreprises industrielles etc. Sont indiqués également les terrains ayant une valeur unique et nécessitant par là des zones de protections (Fig. 4).

L'appréciation du paysage joue également en Pologne un rôle traditionnel importent. "Les éléments plastiques du milieu géographique reproduits sur les dessins et complétés par des photographies, montrent à l'urbaniste la beauté du terrain pouvant être mise à profit dans le projet d'aménagement du territoire. En partant de zones déterminées de terrains jouissant d'un beau paysage et d'une bonne perspective et après analyse de la répartition des espaces verts, des réservoirs et cours d'eau, des bâtiments, des routes au trafic plus au moins intense etc. l'urbaniste peut faire une évaluation critique de la silhouette ou bien de la formation spatiale convenant au terrain donné[13]. Il convient de signaler que dans un tel type d'ouvrage sont soumis à une évaluation non seulement les conditions pyhsiographiques mais aussi les infrastructures.

Autant au groupe d'ouvrages fondamentaux qu'à celui des ouvrages complémentaires viennent sans cesse s'ajouter de nouvelles conceptions; on recherche de nouvelles méthodes.

Cet article ne traite pas à fond toutes les initiatives méthodiques. L'auteur n'a cherché qu'à indiquer les tendences au sein desquelles on peut et doit rechercher des solutions convenant aux exigences sans cesse nouvelles des plans d'aménagement du territoire des villes et de leurs agglomérations.

Le but principal des études physiographiques, conformément à la Loi sur la planification spatiale, est la création de bases pour un plan spatial devant assurer une

[12] B. Czechowicz, *Mapa ograniczeń dla planu kierunkowego Warszawy* (Carte des restrictions pour le schéma directeur de Varsovie). Pracownia Urbanistyczna m. st. Warszawy, 1963 (Archives).

[13] Z. Biernacki, *Charakterystyka i ocena krajobrazowo-plastyczna Warszawy* (Caractéristique et évaluation du paysage de Varsovie). Pracownia Urbanistyczna m. st. Warszawy, 1961 (Archives).

Signe	Facteur de restriction	Champ de restriction
vert	Complexes sylvestres	Restriction des fonctions autres que climatiques
bleu	Eaux de surface	Restrictions de l'utilisation, par suite des besoins de l'exploitation des eaux et loisirs
bleu clair	Inondations de la Vistule	Restriction des investissements dans le bâtiment et en agriculture
bleu	Humidité permanente du terrain	Restriction de la construction
brun	Sols organiques peu resistants	Restriction de la construction standardisee
	Remblais profonds et terrains dévastes	Restriction de la construction standardisee et des cultures
	Menace de glissement de l'escarpe	Restriction de la construction
brun	Pentes abruptes dans la zone de l'escarpe	Restriction de la construction standardisée, des transports et des cultures
orange	Ecarts climatiques defavorables	Restrictions de la construction de logements bas et moyens de l'industrie nocive et des cultures craignant le gel
jaune	Sols cultivables de très bonne qualite	Restrictions de toutes les fonctions autres que l'agriculture, eventuellement les espaces verts de la ville
vert en rouge	Sites dignes de protection	Restriction de toutes les fonctions autres que les loisirs adaptées aux exigences du site
rouge	Zones de protection autour des sites	Restriction des fonctions qui menacent le site à protéger
rouge	Zones de protection des conditions hydrologiques optimales	Restriction dans les changements du niveau des eaux souterraines et de surface
rouge	Zones de protection des prises d'eau	Restriction de la construction et d'autres fonctions pouvant polluer les eaux
violet	Zones normatives d'isolation des points nocifs	Restriction de la construction de logements et de centre de repos
violet	Zones normatives d'isolation des points nocifs destinés à être liquidés dans le plan a long terme	Restriction temporaire de la construction de logements et de centres de repos
vert	Limite intérieure de la ceinture verte climatique de la ville	Restriction de la construction industrielle
vert	Directions principales d'aération d'un terrain à forte densité de construction	Restriction de la construction et de l'industrie
	Limite du terrain sur lequel l'intensité du bruit dépasse 80 décibeles	Restriction de la construction intensive de logements

Fig. 4. Varsovie — Légende de la carte de restrictions physiographyques

Echelle 1 : 20 000

Elaborée par B. Czechowicz et son équipe, 1964

solution convenable du point de vue de la nature[14]. Les critères fondamentaux de ces solutions spatiales convenables sont: conditions physiques et psychiques optimales obtenus dans le plan en garantissant à l'homme de bonnes conditions de travail, de logement et de repos (régeneration des forces physiques et psychiques);

[14] Ustawa z dnia 31 stycznia 1961 r. o planowaniu przestrzennym (Loi du 31 janvier 1961 sur la planification spatiale). Dziennik Ustaw PRL nr 7 z dnia 13 lutego 1964 r.

garantie des conditions nécessaires à une bonne utilisation des réserves de la nature; effets économiques et autres qu'économiques d'utilisations des valeurs naturelles du terrain ainsi que réduction au minimum des collisions entre plan d'aménagement et conditions naturelles.

Tout ce qui a été dit jusqu'à présent au sujet des tendences de la physiographie urbanistique se rapporte à la planification locale. Le problème de recherches sur les conditions physiographiques devant servir aux besoins de la planification régionale n'a pas été abordé. Les plans régionaux exercent une influence fondamentale sur les principes de programme des plans locaux. Les fonctions mal assignées, du point de vue des valeurs naturelles, à une unité d'habitat rendent difficile, et parfois impossible l'adaptation des plans locaux aux postulats de la documentation physiographique. C'est pourqui le développement des recherches physiographiques pour les besoins de la planification régionale semble être trés important. En suivant cette voie, les collisions mentionnées plus haut peuvent être évitées.

Dans la planification régionale on préfére nettement la tendence fonctionnelle. En ce qui concerne les méthodes d'évaluation des conditions physiographiques dans les plans régionaux il faut noter un retard considérable par rapport aux besoins. L'évaluation de l'utilité fonctionnelle du terrain dans un plan régional est indispensable en raison de sa protection contre une surcharge, et, en conséquence, contre une dévastation dont les symptômes sont notés par la littérature scientifique de nombreuses disciplines autant naturelles que techniques.

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EVOLUTION OF THE LATE-GLACIAL DRAINAGE SYSTEM IN THE NE PART OF POMERANIA

JÓZEF SYLWESTRZAK

The problem of how toward the decline of the Pleistocene, the drainage system of the NE part of Pomerania took its shape, and especially how the Reda-Łeba and the Cashubian Pradolinas developed, has been the topic of a great deal of literature [3, 5, 8, 10, 13 — 16, 25, 28, 29, 32, 34]. A wide variety of opinions is noticeable concerning the number of terraces in the pradolinas mentioned, and on the directions in which the pradolina waters must have been escaping.

The complicated valley system of the NE part of Pomerania has developed at the time the inland ice retreated from the principal end moraines of the Pomeranian Stage [9, 10, 14, 32], from the Cashubian-Warmian Phase in the Bytow and Cashubian Lake Districts, and from the Strzebielino and Gardno Phases in the eastern part of the Słupsk Plain and the Słowińska Coastal Zone [31, 32] (Fig. 1, Table 1). The farthest southward extent of the inland ice sheet, the northward slant of the morphological surface emerging from under the ice, and constant changes in the level of the erosive base were the factors which influenced the direction in which the meltwater streams were escaping. On the whole, during the decline of the Pleistocene one may distinguish in this area three principal phases in the evolution of the drainage system, these phases corresponding to three pradolinas:

Stage I, linked with the Pomeranian Pradolina,

Stage II, linked with the Reda-Łeba Pradolina,

Stage III, linked with the Cashubian Pradolina.

I. The Pomeranian Pradolina. Attention was paid to the Pomeranian pradolina (Fig. 1) by K. Keilhack [14]. It extends inside the principal end moraines of the Pomeranian Stage [6, 7, 9, 13, 14, 32, 34], and its evolution goes back to the following agencies: (1) to the maximum range of the inland ice; (2) to the slant of the plateau surface in N and NE direction; (3) to the run of the main chain of end moraines of the Pomeranian Stage.

The formation of this pradolina and particularly of its eastern sector, should be linked with the Cashubian-Warmian Phase distinguished by L. Roszkówna [24]; in the west this phase takes in the Szczecin moraines. R. Galon [9, 10] holds, that the meltwater flowing westward by way of the Pomeranian Pradolina has been escaping into the sea north of Rügen Island.

Fig. 1. Geomorphological map of NE part of Pomerania

1. ground moraine; 2. end moraines; 3. outwashes and erosive plains due to meltwater flow; 4. meltwater valleys; 5. flow directions of outwash streams; 6. fluvial channels and valleys; 7. pradolinas; 8. alluvial cones; 9. peat plains; 10. dunes
I. Pomeranian Pradolina; II. Reda-Łeba Pradolina; III. Cashubian Pradolina
A. Cashubian-Warmian Phase; B. Strzebielino Phase; C. Gardno Phase

The Pomeranian Pradolina starts near Barlomino village, SW of Wejherowo [13, 14, 34]. Here it consists of three outwash levels (I at 170 m a.s.l., II at 160—150 m a.s.l., and III at 140 m a.s.l.). At these altitudes the meltwater streams were initially escaping southward; afterwards they turned westwards. The highest level starts with an erosive plain situated somewhat above 170 m a.s.l. near Barlomino, and this plain is incised, on the average, to a depth of 10 m into the moraine plateau. This level developed at the time when the inland ice of the Cashubian-Warmian Phase reached its farthest extent in the Cashubian Lake District. The remaining two outwash levels in the Pomeranian Pradolina correspond to stoppages of the inland ice during its recession from the Cashubian-Warmian Phase. Interesting fragments of this pradolina can be observed in, for instance, the neighbourhood of Poblocie, Strzepcze, Linia, and Niepoczolowice, as well as along the Bukowina River.

II. The Reda-Łeba Pradolina. The recession of the inland ice upon the line of what is called the Strzebielino Phase [32] initiated the second period of the drainage evolution in NE Pomerania (Fig. 1, Table 1). During this period the dominant feature became the Reda-Łeba Pradolina, which at the same time was the principal hydrographical axis during the decline of the Pleistocene.

In the early part of this second period the evolution of the drainage from the region under discussion was closely linked with the history of the Gdańsk Ice Łake. While the Strzebielino Phase lasted the Gdańsk Ice Łake was occupying the southern part of today's Gdańsk Bay and constituted, initially, the local base of erosion for the waters of the Reda-Łeba Pradolina. Ł. Roszkówna [22] believes the period in which the Gdańsk Ice Łake came into existence to coincide with the recession of the Vistula ice lobe from the end moraines of the Cashubian-Warmian Phase. It is therefore conceivable, that the first evolutionary stage of the Gdańsk Ice Łake witnessed the participation of meltwater streams which were escaping from the Chwaszczyno end moraines southward into the region of Pruszcz Gdański, by way of the marginal channel of the Vistula lobe.

While the Strzebielino Phase lasted and during the initial part of the Gardno Phase [32] it was the Reda-Łeba Pradolina which was carrying off the waters from this region. Opinions vary at to the origin of this valley, and some are entirely conflicting [3, 5, 13, 14, 16, 26, 32, 34]. Keilhack [14] believed that in the Reda-Łeba Pradolina, the water ran westward and that this flow took place in what he considered Phase XI of the inland ice retreat in Pomerania. Keilhack's [14] opinion was shared by A. Schmidt [25], P. Sonntag [27, 28] and K. Bülow [5]. By contrast B. Augustowski [3] asserts that the pradolina flow, before it started escaping into the southern part of the Gardno-Łeba Łowland, (which B. Augustowski calls the Lake Łeba Basin), went westward into the Łupawa river by way of three depressed areas which dissect the Główczyce Plateau approximately in an E-W direction. A. Marsz [16], who studied the geomorphological evolution of the Reda-Łeba Pradolina, disputes an evolution of this pradolina by phases, and questions a presumably predominant share of meltwater flow in its formation.

In the light of field examinations which the author of the present paper [30—32] made on the Lębork and the Główczyce Plateaus, he suggests a revision of the opinions hitherto held as to the origin of the Reda-Łeba Pradolina, and as to the directions in which the water was believed to have been flowing at the level of the high terraces of this pradolina.

At the time of the second period in which the valley system was developing in the region under discussion, the margin of the inland ice ran north of this pradolina, which was then in the stage of formation [3, 14, 32, 34]. Any northward

TABLE 1. Evolutionary phases of Reda-Łeba Pradolina on background of inland ice recession, and development of main stages in valley system of NE Part of Pomerania towards Pleistocene decline

Period	Pomeranian Pradolina				Period of stoppage of inland ice / Inland ice recesion from N part of Cashubian Lake District and from principal end moraines of Pomeranian Stage
I					
II	Reda-Łeba Pradolina				
	Geomorfological facts	Phase	Period	Flow direction in Pradolina	Period of inland ice stoppage
	a) meltwater streams flooded the depressions of the rough ice accumulation and the end basins along the E-W sectors of the pradolina	1	A	—	Strzebielino Phase
	Formation of: b) 82—80 m a.s.l. outwash sheet between Warszkowo and Rybne, and high outwash sheet of Piaśnica River			eastward (only eastern sector of Pradolina was in operation)	
	c) the Luzino-Gościcino depression (called Górski Plateau) and the 72—68 m a.s.l. outwash sheet between Warszkowo and Rybne			eastward (Pradolina is not yet an undiversifed land form)	Rzechocino Phase
	d) pradolina becomes an undiversified land form, with the Kniewo bend its component element	2		eastward into Gdańsk Ice Lake	Stowięcino Stoppage Będziechowo — Chrzanowo Stoppage
	Development of: e) 60 m terrace (?)				Gardno Phase
	f) 50 m terrace				

	g) 40 m terrace a) last track of meltwater runoff on Lębork Plateau, southward into pradolina		3	B	westward, into the sea	Nieznachowo — Odargowo Stoppage
	b) runoff of outwash streams by system of marginal valleys on Lębork Plateau, westward into pradolina		4			
III	Formation of Cashubian Pradolina	Formation of Reda-Łeba Pradolina				
	there developed:					Inland ice retreat into area of Southern Baltic
	a) 25—19 m a.s.l. b) 15—12 m a.s.l. terrace c) 8—6 m a.s.l. l. terrace d) flood terrace	Region of Białagóra and Łebieńce: h) watershed divide (Reda-Łeba) between Bożepole and Strzebielino i) overflood terrace		C	eastward into Gdańsk Ice Lake, and westward into the sea	
		j) flood terrace				

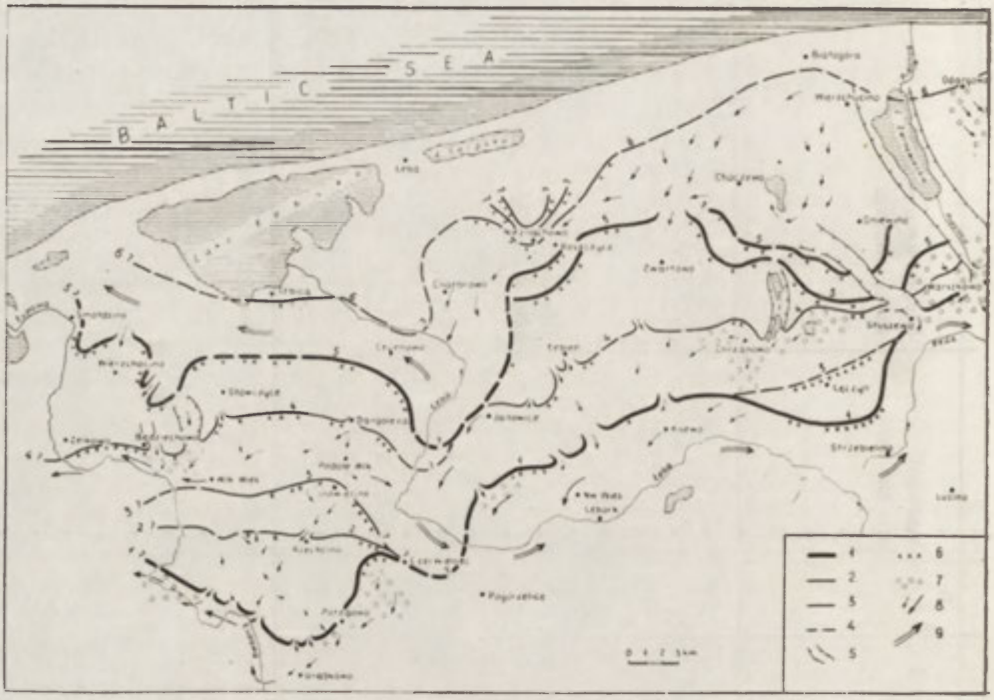

Fig. 2. Phases and Stoppages of Inland Ice in Eastern Part of Słupsk Plain and Słowińskie Coastal Region

1. Phases (1,5); 2. Inland Ice Stoppages (2, 3, 4, 6); 3. identified line of ice stoppage; 4. probable line of ice stoppage; 5. subglacial channels; 6. end moraines; 7. outwash sheets; 8. directions of meltwater runoff; 9. directions of water flow in pradolina

flow was blocked by the inland ice; westward and southward, runoff was obstructed by the southern parts of the Główczyce Plateau rising to some 100 m a.s.l. and by the plateaus of the Cashubian and Bytow Lake Districts with their 170—220 m a.s.l. altitudes. On the other hand the meltwater streams and, later on, the pradolina flow, had favourable runoff conditions in an eastward direction, because the morphological surface of the NE part of Pomerania had an eastward slant.

In the evolution of the Reda-Leba Pradolina and of the entire valley system connected with it, several successive periods may be distinguished, resulting from the gradual recession of the inland ice over the Główczyce and Lębork Plateaus and the Cashubian coastal region. During the first period of the pradolina's formation (see Table 1, Fig. 2, Phase 1 and Stoppage 2), only the eastern part of the pradolina, from Kniewo to Reda, was in operation. At that time the waters, accumulated near Lębork and Strzebielino, ran eastward into the Reda-Leba Pradolina, cutting their way across what is called the Górska Plateau and carving out the Luzino--Gościcino depression.

During the Stowięcino Stoppage (Fig. 2, Stoppage 3) the Reda-Łeba Pradolina had come into existence in its entire length, from Stowięcino in the west to the Gdańsk Bay in the east. At this time a few scarp-foot flattenings were also formed, situated near Strzebielino and the Chynowiec State Farm. These the author assigns to a 60 m terrace [3, 13, 32].

An important period in the development of the Reda-Łeba Pradolina was the Będziechowo-Chrzanowo Stoppage (Fig. 2, Stoppage 4). The 50 m terrace was formed at that time, and the flow which created this terrace ran eastward. Near Reda this flow turned south and issued into the Gdańsk Ice Lake, after forcing its way between the ice filling the Gdańsk Bay and the slope of the Gdańsk Plateau, much dissected by erosion. Evidence of this direction of runoff is in the pradolina itself the inclined surface of a number of fragments of this 50 m terrace, slanting from 53.2 m a.s.l. in the west, between Niebędzino and Żelazkowo, to 46—45 m a.s.l. at Orle and to 42.6 m a.s.l. at Reda in the east (Fig. 3). Also into the Gdańsk Ice Lake were escaping the pradolina waters at the time of the farthest extent of the inland ice during the Gardno Phase, which had on the Główczyce Plateau its counterpart in the end moraines of the Wierzchocino—Wolin train and on the Lębork Plateau in the Roszczyce moraine [32].

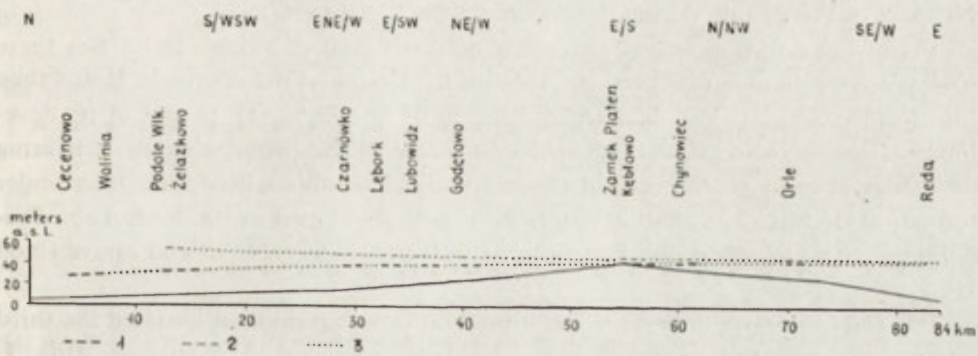

Fig. 3. Longitudinal profile of inclination of 50 m and 40 m terraces in Reda-Łeba Pradolina

1. pradolina floor; 2. 40 m terrace; 3. 50 m terrace

Following the recession of the inland ice from the line of stoppage it had during the Gardno Phase, an essential change in the runoff of the pradolina waters set in. Due to their level being at a higher altitude, the waters from the Gdańsk Ice Lake swept westwards by way of the pradolina into the Baltic Ice Lake. On their way they formed what is called the 40 m terrace, and in this way they initiated the second phase in the evolution of the Reda-Łeba Pradolina (see Table 1). Hence it was for he most part water flow from the Gdańsk Ice Lake which sculptured the pradolina valley at the level of the 40 m terrace. It is remarkable that traces of the 40 m terrace are more often in evidence than those of the 50 m terrace. Fragments of the 40 m terrace have been identified, for instance, west of Reda near Orle, along Łake Łubowidzkie, near Nowa Wieś, Żelazkowo and Cecenowo (Fig. 3). Much like the 50 m terrace, the 40 m terrace is an erosive terrace incised in boulder clay, in submorainic fluvioglacial deposits or, as near Lębork, in loams [3, 31, 32]. However, because both these terraces of the Reda-Łeba Pradolina originated from meltwater streams escaping in opposite directions — the 50 m terrace due to its eastward, and the 40 m terrace to its westward flow — particular reaches of the pradolina show different terrace altitudes for each of the terraces. In the east, at Reda, there is no difference between them, because here the 40 m terrace started its incision into the 50 m terrace. Westward the relative height of the 50 m terrace with regard to that of the 40 m terrace gradually increases until it reaches as much as 22 m near Podole Wielkie.

In consequence of the inland ice recession to the line of the Nieznachowo-Odargowo Stoppage (Fig. 2, Stoppage 6), there developed on the Lębork Plateau a system of marginal valleys: the Choczewo, Przebędowo and Bargędzino valleys, and the valley of Charbrowska Struga. The meltwater runoff in these valleys towards the pradolina ends the second evolutionary period of the Reda-Łeba Pradolina and, at the same time, the second phase of the formation of the drainage system in the NE part of Pomerania during the decline of the Pleistocene.

Following a further inland ice retreat onto the area of today's Baltic Sea there took place the junction between the Gdańsk Ice Lake and the open sea. It was then that the Reda-Łeba Pradolina entered the third (see Table 1) period of its development; at the same time it abandoned its role as the principal track delivering meltwater streams to the sea, in favour of the Cashubian Pradolina then under formation. It was then that a watershed divide developed in the Reda-Łeba Pradolina near Strzebielino and Bożepole, as well as low terraces at and above flood level.

III. *The Cashubian Pradolina.* The formation of this pradolina initiated the third and last phase in the evolution of the drainage system in NE Pomerania (Fig. 1, Table 1) and this pradolina became the principal valley draining this region westward, into the Baltic Sea.

In the formation of the Cashubian Pradolina one may also distinguish several successive phases. Evidence for this are surviving terrace levels, extending at altitudes 25—19 m, 15—12 m, and 8—6 m a.s.l. respectively, observed near Żarnowiec, Białagóra, Łebieniec [30]. Corresponding terraces can be seen in the Żarnowiec channel, reflecting the changes which were taking place in the water level of the pradolina flow.

In its present-day shape the Cashubian Pradolina is by no means a uniform continuous land form; east of Kępa Pucka some of its sectors now lie submerged in the sea [1, 3, 8, 15, 16, 21, 28, 29, 33, 34]. However, because the evolution of the Cashubian Pradolina proceeded in interdependence with the inland ice retreat into the area of the Southern Baltic, any detailed discussion of this topic would exceed the scope of the present paper. It only seems worth calling attention to the fact, that of decisive influence upon the formation of this pradolina were the waters of the Vistula, after this river had definitely taken its northward course, as well as the waters of the Niemen River. R. Galon [9, 10] assigned the time of the Vistula's northward turn to the Alleröd and mentioned that, at that time, the Gdańsk Bay was part of the Baltic Ice Lake, and that the issue of Vistula and Niemen waters into the Baltic Ice Lake initiated the so-called Baltic Phase, the last stage in the evolution of the river network of the Baltic Coast [9, p. 115]. The most recent research made by L. Roszko [22] in the lower Vistula valley, based on palynological and geomorhpological examinations, rather indicates that the northward turn of the Vistula took place during the Bölling; in B. Rosa's [22] opinion this period corresponds to the phase of origin of the Baltic Sea.

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DIFFERENTIATION IN HYDROGRAPHIC CONDITIONS OF SOUTH POLAND IN THE LIGHT OF DETAILED HYDROGRAPHIC MAPPING

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The construction of a *Detailed Hydrographic Map* of Poland based on mapping in the field was suggested by Professor M. Klimaszewski in 1950 and declared to be one of the basic tasks of physical geography by the Congress of Polish Science in 1951. In the years 1951 to 1953 work on this map was initiated by all geographic centres in Poland. Since 1954, mapping and construction of the hydrographic map of Southern Poland has been supervised by the Cracow Department of Geomorphology and Hydrography (directed by Professor M. Klimaszewski) in the Institute of Geography, Polish Academy of Sciences.

Mapping in the field is the basic method of hydrographic research. Its main purpose is to "recognize the circulation of water in the different drainage basins on the background of, and in relation to the other elements of the geographic environment" [7]. The *Hydrographic Instruction* prepared by hydrographers of the Institute of Geography, PAN, and of the university centres [6—8] establishes common principles of hydrographic mapping in Poland. These include methods of studying the hydrographic phenomena in the field and of constructing both the hydrographic map and explanatory text on the basis of results obtained. The hydrographic map is being prepared to the scale of 1 : 25 000 and published in sheets at 1 : 50 000. This is a basal — analytical map because of its content. With orography and lithology in the background (with special reference to permeability) this map shows the first horizon of useful underground waters (hydroisobases or zones of underground water occurrence at differing water table depth), together with all water phenomena and undertakings (see Table of Signs, *Instruction* 1964). An integral part of the map is the explanatory text. It includes the characteristics of geographic environment and the description and interpretation of surface and underground water occurrence. Furthermore, interconnections and relation to other elements of the natural environment and that transformed by man are being explained and quantitative assessments made. Their changeability in time as well as data on water economy and their effect on the development of hydrographic conditions are being considered. As a result various hydrographic regions can be delimited and characterized.

Problems of this map, and its significance for both scientific and practical purposes have been the subject of a number of articles [4, 7, 9—11]. Works on methods of hydrographic research, hydrographic conditions in different drainage basins or regions (e.g. explanatory text to the sheets, master and doctoral dissertations), and papers on a specific problem or for special purposes (e.g. regional planning, drainage plans) show that the applied method of hydrographic studies is the bess method of water research from the geographic point of view. References on methods of hydrographic research and on results of hydrographic mapping in the field are included in the bibliography [5, 11, 17].

Maps compiled so far clearly show that both hydrographic conditions and types of water circulation are varied in different regions of Poland. The attached samples of maps of Southern Poland include those of the Silesian Upland (A), the Miechów Upland (B), the Lublin Upland (C), the Sandomierz Basin (D), the Carpathian Upland (E), the Beskid Wysoki (High Beskid) (F), and the Tatry Wysokie (High Tatra) (G), as well as the *Hydrographic Map of the Western Tatra Mountains.* All reveal various patterns of hydrographic phenomena. These maps are representative of regions of different hydrographic conditions which in turn derive from differing geological structure, ground permeability, relief, degree of afforestation, microclimatic factors and man's economic activities.

Map sample B refers to the MIECHÓW UPLAND. Low relief (up to 60 m) and slope angles (0 to 5^{0}) and a high permeability of the fissured loess covers and the strongly fractured Cretaceous marls are responsible both for the prevailing infiltration (surface runoff is less) and high underground retention. Underground waters occur at depths of up to 5 m in the valley floors and up to 60 m on elevations. This indicates that the underground water table is independent of the land relief [3]. In the Cretaceous marls, fissure- and stratified waters occur at two horizons [1—3]. The lower (major) horizon is well developed in the whole region. It is marked by wells and springs, which issue in valley floors where marls contact with the poorly permeable alluvia. Proof of the large water resources retained in this horizon are the few but very abundant springs (discherge up to 150 l/sec). The upper discontinuous horizon (eastern part of the area) shows small water recources (lack of springs) and reacts rapidly to supplies of rain-and meltwater. In contrast to its rich resources of underground water, the plateau has little surface waters. The network of perennial rivers is sparce (0,5 km/sq.km) whereas the temporary river net is dense (3 km/sq.km). The perennial streams which follow the diaclases trending in WWN-EES, NNE-SSW, NS and WE directions are occasionally fed by surface flow from rain- and meltwater and regularly by underground waters (valley springs of high discharge showing small changes). This is why the perennial streams maintain a balanced water level and discharge with short high water levels and an absence of low-water periods typical of mountain rivers. Their low unit flow of 3 l/sec/sq.km and low runoff coefficient (12,5 to 14,5 per cent) is due to the escape of channel water into the fissured substratum. Here underground waters follow the eastward dip of Cretaceous marls [2, 3].

Hydrographic conditions are similar in the LUBLIN UPLAND (map sample C) formed by a Cretaceous siliceous limestone called opoka and by loess covers. The highly fissured rocks, small altitude differences (up to 70 m) and gentle (0 to 5^{0}) slopes are favourable for infiltration and underground water retention. Hence the characteristic feature of this area is its wealth of underground water where as the extensive divides are waterless. All suface water phenomena are concentrated in the river valleys. The major reservoir of underground waters occurs in the Cretaceous rocks of differing permeability and retentiveness. This is why the Lublin Upland contains several water-bearing layers and fissures [16] (hydroisobases, boundary of different water-bearing horizons).

In the valleys the water table lies at depths of 2 to 5 m, and on the valley slopes up to 40 m; while at the boundary of the higher level the depth diminishes rapidly (5 to 10 m) and then rises again. Various horizons are represented by fissure-springs and fissure-layered springs [16]. The extensive lower major horizon — being the most productive one — is drained by perennial streams. This results in an outflow of underground waters in the form of rich single springs or lines of springs. In this horizon, fluctuations are smaller than those at the valley floors of the higher horizons with low discharges. Even so, reaction to inflow of precipitation- or meltwater is more rapid due to the dense network of fissures in the Cretaceous rocks. This also is responsible for a relatively poor development of the perennial river system, the density of which is only 0,47 km/sq.km, or only half that of the episodic river network. Perennial streams following the major directions of fissures in the substratum (S-N and SEE-NWW) [15] drain the underground waters which feed them regularly (springs with less changing discharge at valley floors). Periodically precipitation and meltwaters increase the perennial river flow. Hence water levels and flow volumes are fairly uniform. A characteristic feature, similar to conditions in the Miechów Upland, is the escape of water from river channels into fissures of the substratum. In this region the unit flow is about 3 l/sec/sq.km [15], and the coefficient of runoff is about 15 per cent.

In contrast to the Upland regions discussed above, the SANDOMIERZ BASIN (map sample D) is characterized by a shallow water infiltration into the sandy and sandy-clayey Quaternary deposits underlain by clays. Surface runoff is lacking due to lowland features of the Basin. Groundwater occurs at depths of 0,5 to 2 m, only in dunes does it drop to a depth of 2,0 to 5,0 m. This shallow groundwater table is responsible for the small active retention of the area. As result, during periods of heavy rainfall, and specially of snowmelt and rising water level in the streams, the groundwater table also rises to the surface and swamps the meadows. Hence, the shallow groundwater table and gently inclined slopes lead to the formation of swamps. Because of drainage these are usually temporary swamps. Scattered over the swamps are small lakes (ox-bow lakes) and fish ponds. The area is drained by a dense network of perennial rivulets (2 km/sq.km), for the most part corrected, and by a system of drainage ditches. Closely interrelated are the water level in the streams and the groundwater table. Compared with the upland and mountain regions, high discharges occur here with a certain time lag. They are less profuse and of longer duration. In this region the unit runoff is about 5 l/sec/sq.km and the coefficient of runoff is some 30 per cent.

The CARPATHIAN UPLAND is represented by map sample E. This area shows a prevalence of surface runoff over ground infiltration due to considerable altitude differences (some 250 m) and slope inclinations (10 to 20°), dense dissection, deforestation, and small permeability of both the flysch substratum and the slope coverings. However, the high water capacity of these coverings retards runoff and obstructs water infiltration into the substratum. Thus conditions are unfavourable for deep infiltration, and scant water resources occur in this area. The groundwater reservoirs in fissures and waterbearing beds developed in series of steeply dipping sandstones, separated from one another by impervious shales. The small number of springs (1 spring/2 sq.km) and their low discharges (0,1 to 0,5 l/sec) indicate how small are the water resources in these rock reservoirs. Most frequently shallow groundwaters occur in the slope coverings and feed bog-springs, trickling outflows and small springs in the waste materials. Evidence of the small volume, and high variability of water resources in the waste is given by seasonal outflow and dessication of the upper portions of streams. The effect of the low ground permeability is that in the Carpathian Upland there prevails a fairly dense perennial system of streams (2,5 km/sq.km) which carry little water. For the most part it is precipitation- and meltwater which feeds these streams, while groundwater contributes little. This explains the conspicuous fluctuations in water levels and discharges, and the persistent low water levels. In this area the unit flow is 16—17 l/sec/sq.km, the runoff coefficient about 50 per cent.

Hydrographic conditions in the medium-height mountains of the Flysch Carpathians as illustrated by the HIGH BESKID (map sample F.) are different. Infiltration is made easy by the fairly permeable sandstones and slope coverings prevailing here, and by the high percentage of forests. However, the unfavourable high relief and inclinations, and a dense valley system (5 km/sq.km) reduce the retentiveness of the ground in favour of surface runoff, especially during periods of torrential rains. The groundwater is stored in beds of Magura sandstone and in other formations. The most abundant water horizon extends from between 900 and 1200 m above sea level [13]. A characteristic feature of this area is the great number of groundwater outflows — springs and bog springs (some 25/sq.km) with small discharges (0,1 to 0,5 l/sec) [13, 14]. Seasonal reservoirs of underground water which occurs in minor and changeable quantities are found in the waste coverings. Greater water resources are noted in land-slides where there occur many springs and bog springs. At the floors of the major valleys the groundwater table lies at depths of 0 to 2 m.

The perennial river system is dense (3,5 km/sq.km) and stream gradients are steep. Therefore streams cause heavy erosion. Rivers are fed by precipitation and meltwater, and by groundwater. Water levels and discharges vary considerably.

High discharges occur abruptly because of the steep gradients but their duration is short. The unit flow is here 21 to 23 l/sec/sq.km, the coefficient of runoff some 56—60 per cent [13].

The HIGH TATRA (map sample G) is a high-mountainous region composed of crystalline rocks. It shows a glacial relief. Characteristic of this region is the high and rapid surface runoff on the rocky crests and very steep slopes whose inclination exceeds 30°. Above the timber line slopes consist o crystalline rocks without a covering of waste and vegetation. On the other hand, where debris sheets and moraine materials cover the land, surface conditions are favourable for infiltration. Retention is also aided by the high percentage of snowfall and long duration of the snow cover and its slow melting [20,21].

Retention of the crystalline bedrock is small as shown by the few seasonal fissure springs and leakages of very low discharges (0,1 to 0,2 l/sec) that supply only 3 per cent of water [20]. Groundwater in greater quantities occurs in this region mostly in the cover deposits. In the lower slope segments debris coverings carry seasonal trough-flowing waters of varying quantities. These waters are rapidly supplemented during rainfall and snowmelt, but equally rapidly the above mentioned reservoirs release their water into the lower morainal reservoirs and lakes. Springs fed by water from the debris coverings supply about 7 per cent of water. The most abundant morainal reservoirs developed in the glacier cirques and troughs. Numerous springs with rather high discharges (up to several litres per second) occur here. These springs constitute 65 per cent of all springs in the region discussed and supply some 90 per cent of water [20]. The density of springs in the crystalline glaciated region is 10 to 15/sq.km. Numerous lakes of glacial origin characterized by their small areas but great depths act as retention basins for surface waters. They store water they receive from underground flow, snowmelt and rainfall. Oscillations of water level reach some scores of centimetres. Water level is highest during periods of snowmelt, and lowest in autumn and winter.

The area consisting of crystalline rocks has a fairly dense network of perennial rivers (1,5 km/sq.km). However, of higher density is the system of episodic and seasonal rivers using numerous chutes. These rivulets also depend on the widespread occurrence of coverings consisting of debris and moraine materials. Hence, meltwater, groundwater and precipitation contribute to the alimentation of the perennial streams. The course of water levels shows two maxima: in spring due to melting of snow, and in summer due to rains. Apart from this there are low water levels of long duration in autumn and winter. However, high water levels in the streams are mitigated by lake basins, and by debris and moraine coverings which delay water supply from the slopes into the river channels. In this area the unit flow is about 35 l/sec/sq.km and the coefficient of runoff is some 70 per cent [20].

Water circulation is different in the high-mountainous karst region of fluvial relief (*Map of the WESTERN TATRA*). This area is built of highly fissured limestones and dolomites. In the upper forest zone and the dwarf pine zone conditions are favourable for water infiltration and underground retention. Because of the steep slopes (average more than 25°, maximum above 70°) and high stream gradients [21], surface runoff occurs only during torrential rains, whereas less intense rains are completely absorbed by the permeable ground. The intensity of surfacial runoff is lessened by the high percentage of forest cover (65 per cent) [18,21]. As a result of the high retentiveness of the substratum abundant water reservoirs occur at great depths in the crevasses. Karst waters are drained by the consequent major streams to feed a few Vauclusienne springs at the valley floors. Spring discharges are some hundred litres per second. In the karst region of the Western Tatra the density of springs is very small (2 to 3/sq.km) but they discharge more than 3000 litres of water per second [18,21]. Further evidence of the high retentiveness of the substratum is the high coefficient of ground runoff exceeding 70 per cent [21]. In contrast to the aboundant resources of underground water and the concentration of surfance water phenomena in the major river valleys the interfluves are waterless. The density of the system of perennial rivers is only 0,35 km/sq.km. Much greater (0.95 km/sq.km) is the density of periodical creeks [18]. For the most part, perennial streams are fed by underground karst waters, less by meltwater and precipitation. Compared with rivers in mountainous drainage basins where the retentive ability of the substratum is small, the perennial streams draining a karst area show fairly constant water levels and discharges. Two maxima are being observed here — in summer and spring a rainfall maximum and a secondary snowmelt maximum. Water levels are low in early autumn and winter. Although retention is high, the karst area shows high values of unit flow (some 50 l/sq.km) and high runoff coefficient (more than 80 per cent) [21]. This is due to the steepness of slopes and high stream gradients, and to inflow of underground water from neighbouring drainage basins.

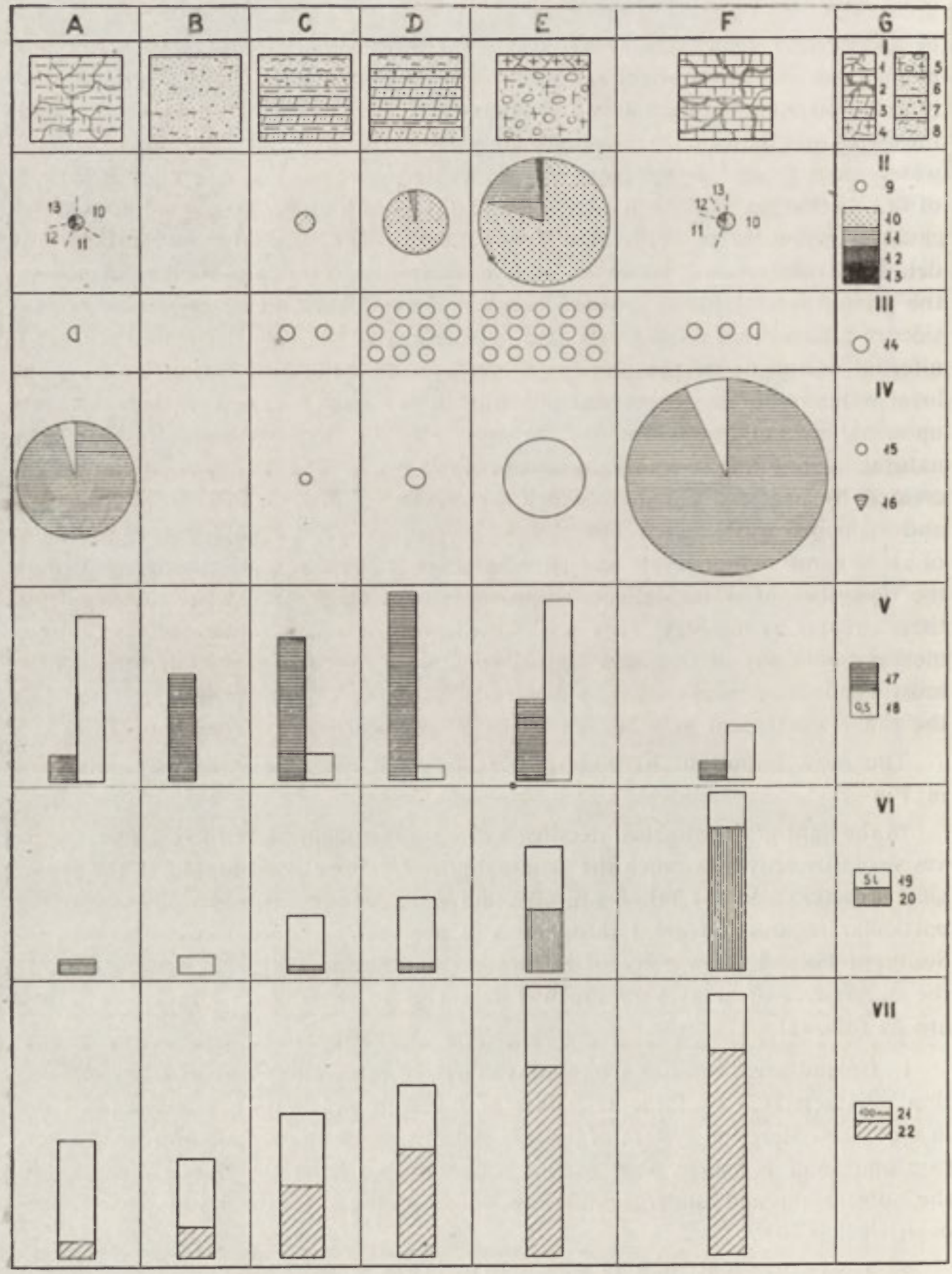
An example of transformed hydrographic conditions is given by the map of the southern part of the SILESIAN UPLAND (sample A). This area is composed of slightly permeable Carboniferous shales and sandstones. The relief has suffered considerable transformation by man. In the predominant part of this region the natural conditions of runoff and infiltration have been disturbed. Anthropogenic land forms which occupy 20 to 50 per cent of the total surface, the heavy concentration of urban and industrial settlements, and mining activities (subsidence hollows, formation of water basins on divides) obstruct surface runoff and cause changes in flow directions (municipal sewer systems). They also counteract infiltration and promote water retention on the surface (artificial reservoirs, swamps) [12,19]. Under conditions of this kind it is difficult (and often impossible) to define the watersheds. In most cases it is due to man's interference that features of surface retention such as swamps and water basins appear. Usually they occur on the divides or on the shallow valley floors that are covered with slightly permeable alluvia or incised into the shallow groundwater table in the slope coverings. The formation of swamps and reservoirs is due to small stream gradients and the diminishing erosive power of streams where the latter were impounded by dikes or channels clogged with waste, and to subsidence hollows and mining pits. Reservoirs formed in subsidence hollows are most typical of this area. The scantiness of groundwater resources must be ascribed to conditions unfavourable for infiltration, brought about not only by man but also by the slight permeability of the substratum. Shallow groundwater (0 to 2,0 m) occurs in the sandy and sandy-clayey Quaternary deposits which mantle the slopes and the valley depressions. Only a few natural surface outflows of groundwater occur there. Springs are rare (one spring per several square kilometres) and of low discharges. On the divides it is the disturbed hydrographic conditions which cause groundwater to occur at differing depths. The lack of wells prevents any detailed examinations. However, it is characteristic of this area that in general the groundwater table is lowered because of the formation of reservoirs in subsidence hollows and mining pits, and of pumping of groundwater from the Carboniferous sediments by the numerous mines — an additional factor depleting the local water resources. The surfacial runoff in the area discussed depends not only upon natural conditions but, for the most part, on the interference of man. The natural river system is scanty and carries little water. The density of streams is increased by artificial channels which supply the natural streams with industrial and municipal waste water. The obvious consequence is a high degree of pollution of all streams. Water levels and flow volumes in these streams depend mostly on the quantities of water delivered into them, and on what has been drawn from these streams by industry. This is why the unit flow which, under normal environmental conditions of this area should be some 5 l/sec/sq.km may at times attain most astonishing values, even as much as 20 l/sec/sq.km, and why in certain cases the runoff coefficient may be as high as 80 per cent [12].

The most important hydrographic features of the areas discussed are shown in Fig. 1.

In the light of the attached detailed hydrographic maps and of Fig. 1 one observes very distinctly how much the geographic environment, and especially the geological structure and the relief, are affecting water conditions and resources in the particular regions. Of great influence also are man's economic undertakings. In Southern Poland the variety of infiltration and surface runoff is responsible for the occurrence of areas very much different as to their water circulation. These are as follows:

1. Upland areas built of Cretaceous marls, of infiltration type of water circulation, characterized by large resources of underground water circulating mainly in crevasses. Here the system of surface streams under the regime of groundwater, rain and snow is sparse. Part of this water escapes from the river channels into the substratum and underground into neighbouring drainage basins. The runoff coefficient is low.

2. Basin areas consisting of sandy and sandy-clayey deposits underlain by clays of infiltration type of water circulation. Characteristic features are the lack of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surface runoff, shallow groundwater, a high surface retention, a groundwater-rainy-snowy regime of rivers and a low runoff coefficient.

3. In the Flysch Carpathians water circulation occurs by surface flow or by a combination of surface flow and infiltration, depending on the lithological composition of the flysch rocks. Here the streams derive water from precipitation and snowmelt and, partly, from groundwater; the runoff coefficient is high.

On shales of the Carpathian Upland surface runoff predominates. It is reduced by the high capacity of slope coverings, whereas the deeper substratum contains very little water. Here the system of surface streams is fairly dense.

On the other hand, the sandstone area of the medium-height mountains also shows a considerable surface runoff, but the retention ability of its substratum is much higher, so that more groundwater is being stored in fissures and water-bearing strata. The network of surface streams is more dense here.

4. The high-mountainous crystalline area with its glacial relief and its water circulation by surface flow and infiltration is characterized by an ample surface runoff on the slopes, by rich underground water reservoirs and by abundant surface waters in the valley floors. The rivers are fed by snowmelt, groundwater and precipitation. The runoff coefficient is very high.

5. The high-mountainous karst area of infiltration type of water circulation, differs from the upland karst by its more ample resources of groundwater which circulates more rapidly and at greater depths. The network of rivers fed by infiltration, snow and rain, is sparce and the groundwater is supplemented by water from nearby drainage basins. The coefficient of runoff is very high.

6. In areas whose environment has been considerably transformed by man the natural hydrographic conditions are disturbed. This results in changes of the natural directions of flow, in worsened conditions of infiltration, in reduced underground water resources and lowering of the underground water table, in an artificial increase in surface retention and river net, pollution of flowing waters, disturbed fluvial regime and the abnormally raised coefficient of runoff.

Fig. 1. Hydrographical features of regions in Southern Poland

A. Upland Region — marly (Miechów Upland); B. Basin Region — sandy (Sandomierz Basin); C. Foothill Region — shaly-sandstone (Carpathian Upland); D. Intermediate Mountain Region — sandstone-shaly (Wysoki Beskid); E. High-Mountain Region — crystalline (High Tatra); F. High-Mountain Region — limestone-dolomites (Western Tatra); G. Explanations

I. Basins of underground water: 1. in jointed marls; 2. in jointed limestones; 3. in sandstones; 4. in jointed crystalline rocks; 5. in moraines; 6. in sand; 7. in alluvia; 8. in waste

II. Number and discharge of springs: 9. diameter of circle equals 20 springs; discharge: 10. up to 1 l/sec; 11. from 1 and 10 l/sec; 12. from 10 and 100 l/sec; 13. more than 100 l/sec

III. Spring density: 14. number of springs per 1 sq.km

IV. Water quantity supplied by springs: 15. diameter of circle denotes 25 l/sec; 16. among the above, springs supplying more than 100 l/sec

V. Density of fluvial network, in km/sq.km: 17. perennial streams; 18. periodic streams

VI. Unit runoff in l/sec/sq.km: 19. total runoff; 20. therein flow from springs

VII. Precipitation — runoff: 21. precipitation in mm; 22. therein runoff in per-cent value of precipitation

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HYDROGRAPHIC MAP OF THE WESTERN TATRA MTS.
1 : 50 000

EXPLANATORY NOTES

State border

SURFACE FLOW AND INFILTRATION

Hypsometry

Contour lines: in Tatra Mts. every 40 m
in Podhale „ 20 m

Surface water divides 1. orographic
2. uncertain

Main European divide
Divide of the II-nd order
Divide of the III-rd order
Divide of the IV-th order
Divide of the V-th order
Divide of an outflowless area situated at the watershed
Gate in the divide
Swallow-hole

Lithology of the surface materials

Strongly permeable materials
Limestones fissured
Dolomites fissured
Limestones and dolomites fissured
Rock debris
Accumulation of boulders
Morainic covers
Sand and gravel covers

Less permeable materials
Sandstone
Conglomerate
Sandstone and shale complexes with a thin waste cover
Conglomerates and limestones
Limestones and shales
Clay and sand covers with boulders
Little permeable materials
Shale and sandstone complexes with a thin waste cover
Impermeable materials
Granite, metamorphic slates, in some places quartzite
Marl
Clay and marl shales, clay shales with a thin waste cover
Peat

SWAMP AND STAGNANT WATER

Swamp permanent
Swamp temporary
Drained fields
Lake
Little lake
Pond permanently filled
Ox-bow lake temporarily filled with water

NATURAL OUTFLOW OF UNDERGROUND WATER

Linear groundwater outflow
Intermittent spring with an outflow
Permanent spring with an outflow
Spring without an outflow

UNDERGROUND WATER

Depth of the water table measured in wells
0—1 m
1—2 m
2—5 m
5—10 m
10—20 m
Discharge of the spring
up to 0.1 l/sec
0.1— 0.5 „
0.5— 1.0 „
1.0— 5.0 „
5.0— 10.0 „
10.0—100.0 „
over 100.0 „
Mineral spring
Line of springs
Spring used by people

Bog-spring
Leakage
Trickling outflow

RIVER — NET

Natural streams
with the width of bed in m 0—1
,, ,, ,, ,, ,, ,, ,, 1—3
,, ,, ,, ,, ,, ,, ,, 3—10
,, ,, ,, ,, ,, ,, ,, 10—30
Stream disappearing in sediments
Stream with sections of permanent water disappearance
Seasonal stream
Place of a single measurement of discharge
Direction of flow
Rapids and steps in river bed
Waterfalls
Undercut river banks
Area covered by catastrophic floods

Utilization of streams
Shore bands
Spurs
Gravel screen
Watertight casing of the river bed
Inlet and outlet of a stream
Stream in a closed water-channel
Polluted stream
Draining ditch working permanently
Mill-channel

Observations points
Precipitation gauging station
Climatological and synoptic station
Stage of streams and flow gauge stations
Points of repeated measurements of discharge

ÉCOULEMENT DANS LE BASSIN DU RIO ACONCAGUA

TADEUSZ WILGAT

L'expédition de la Société Géographique Polonaise en Amérique du Sud, à bord du yacht „Śmiały", a réuni au Chili des matériaux hydrométriques, non publiés jusqu'à présent, gui permettent de caractériser l'écoulement dans le bassin du Rio Aconcagua[1]. Ce fleuve de 175 km (bassin de 7222 km^2) traverse le Chili central pour gagner la mer au Nord de Valparaiso. Etant donné les conditions thermiques favorables à l'agriculture dans les parties inférieures du bassin et la période de sécheresse estivale, les eaux du R. Aconcagua sont largement utilisées à des fins d'irrigation. L'importance du fleuve se trouve augmentée du fait de la situation du bassin dans la partie la plus peuplée du pays, près des principaux centres économiques.

1. DONNÉES NUMÉRIQUES

Dans le bassin du R. Aconcagua les mesures hydrométriques concernent 24 profils (Fig. 1). Compte tenu des dimensions du bassin, le nombre des stations hydrométriques est assez important. Les données hydrométriques ne sont cependant pas satisfaisantes. Les stations furent organisées et gérées par diverses institutions, ce qui ne favorisa guère la continuité ni l'homogénéité des observations. Seules quelques séries d'observations embrassent sans interruption au moins quelques dix ans, ou plus. Les données de nombreuses stations sont incomplètes ou simplement fragmentaires. Des données aussi fragmentaires, surtout en ce qui concerne la partie inférieure du bassin, sont sans utilité pour le calcul de l'écoulement, car là où l'activité humaine influe de façon décisive sur la quantité d'eau dans le lit fluvial il n'y a pas de corrélation entre les débits enregistrés par différentes stations.

Les données numériques relatives aux moyennes mensuelles de débits nous ont été fournies par l'entreprise hydro-electrique ENDESA de Santiago du Chili. L'analyse de ces matériaux montre qu'ils comportent des erreurs, surtout pour les

[1] La présente étude constitute le fragment d'un ouvrage plus vaste (publié dans *Dokumentacja Geograficzna*, 4—5, 1971); pour cette raison elle ne comporte aucune analyse de facteurs topographiques et climatiques façonnant l'écoulement.

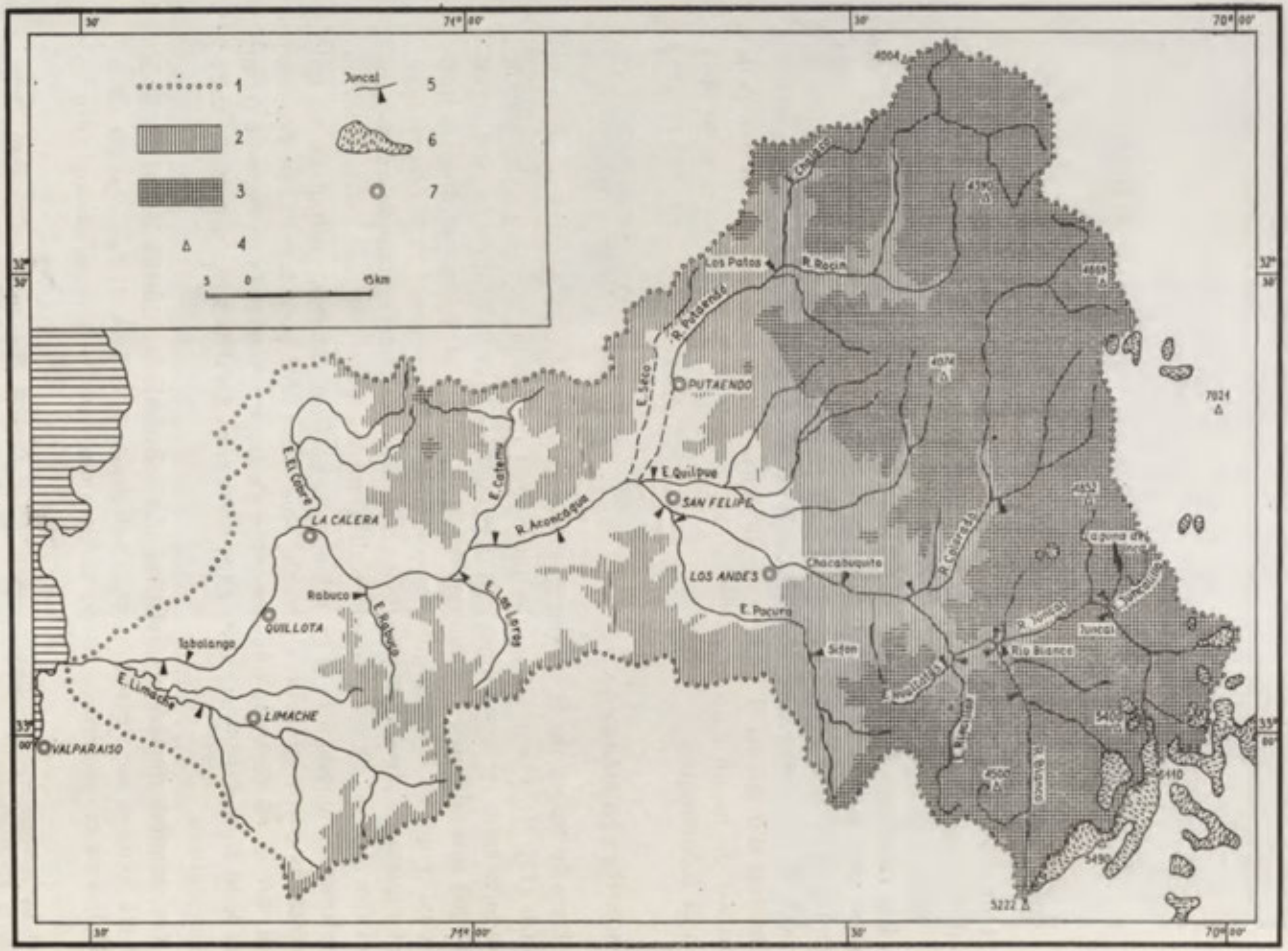

Fig. 1. Stations hydrométriques dans le bassin du R. Aconcagua

1. Ligne de partage des eaux; 2. Terrains élevés au-dessus de 3000 pieds (914 m); 3. Terrains élevés au-dessus de 7000 pieds (2137 m); 4. Sommets. Altitude en m; 5. Stations hydrométriques; 6. Glaciers; 7. Villes

années moins récentes. Les matériaux numériques de toutes les stations ont été contrôlés en vue d'éliminer les erreurs flagrantes et de supprimer les interruptions dans le but d'allonger les séries trop courtes. Nous avons fait un certain nombre de graphiques afin d'établir la corrélation entre les débits annuels et mensuels moyens des stations voisines ou formant des bassins qui présentent des conditions géographiques analogues. A titre d'exemple, nous donnons des graphiques qui montrent la corrélation entre le débit moyen annuel du R. Aconcagua à Rio Blanco et à Chacabuquito (Fig. 2), ainsi que le débit du R. Aconcagua à Chacabuquito et celui du R. Colorado à l'embouchure (Fig. 3). Les coefficients de corrélation sont respectivement 0,89 et 0,92.

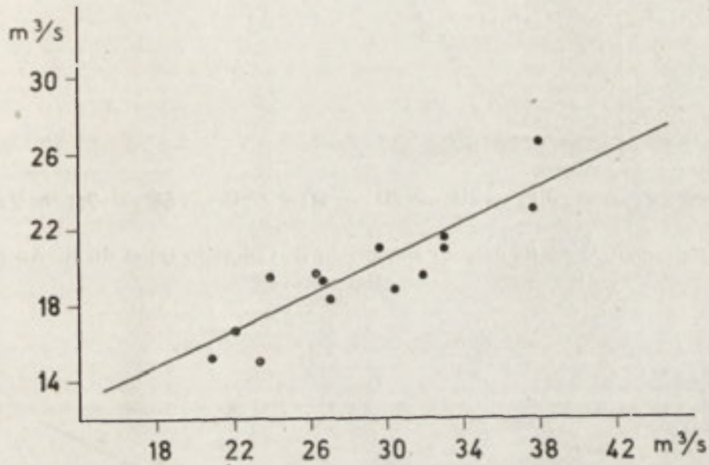

Fig. 2. Corrélation entre débits moyens annuels du R. Aconcagua à Rio Blanco (y) et à Chacabuquito

La corrélation entre les débits moyens mensuels n'apparaît pas avec la même netteté, mais suffit quand même pour certaines stations à compléter les donnêes. C'est à titre d'exemple que nous présentons le graphique de corrélation entre les débits moyens de décembre du R. Aconcagua et du R. Blanco à Rio Blanco (Fig. 4). Le coefficient de corrélation est dans ce cas, très élevé et se monte à 0,93.

On a calculé les données manquantes à partir de l'équation de régression linéaire, ou bien, complété celles-ci en vertu de l'hypothèse que le rapport entre les débits moyens mensuels de deux stations équivaut au rapport des valeurs moyennes de plusieurs années concernant une période pour laquelle les deux stations ont des données.

Pour nos calculs statistiques nous avons finalement retenu les matériaux réunis par 10 stations disposant de données s'étendant sur 11 années au moins. Ces périodes ne sont cependant pas simultanées ni égales et s'avèrent souvent discontinues

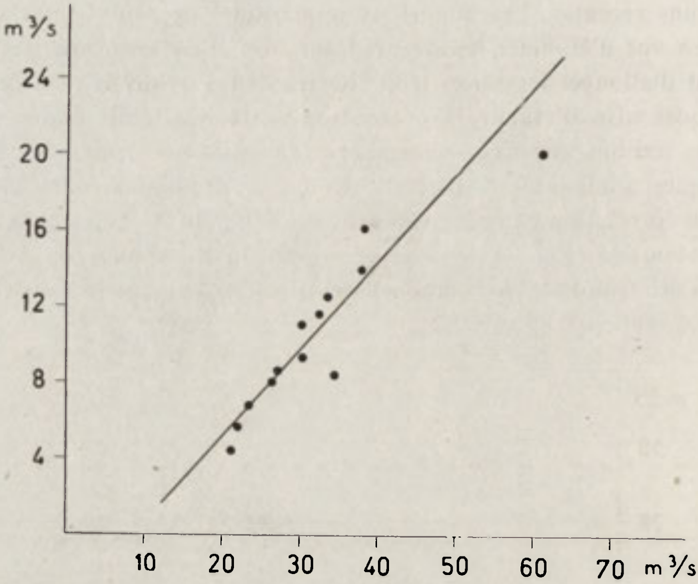

Fig. 3. Corrélation entre débits moyens annuels du R. Colorado (y) et du R. Aconcagua à Chacabuquito

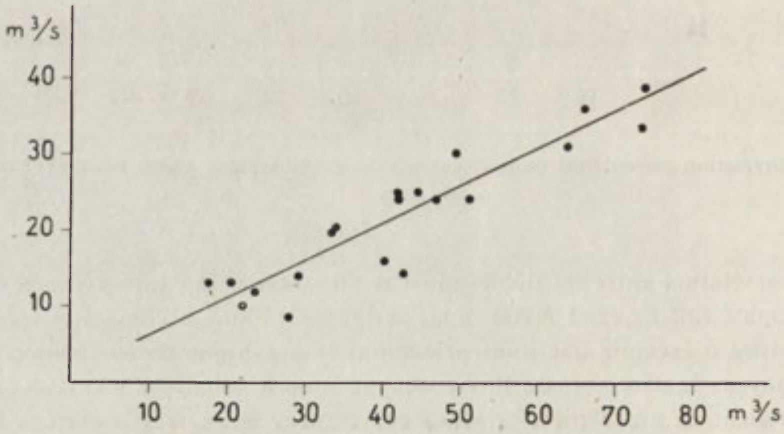

Fig. 4. Corrélation entre débits moyens de décembre du R. Blanco à Rio Blanco (y) et du R. Aconcagua à Rio Blanco

Trois stations disposent, en outre, de données pour 6 années successives (Tabl. 1). Les autres ne disposent que de très peu de données et deux d'entre elles (Panquehue et Puento Colmo) ne fournissent pas d'observations continues pendant 1 année entière.

La répartition des stations à séries suffisamment longues est assez avantageuse. Ces stations sont situées dans la partie haut montagneuse du bassin, constituant la principale source d'alimentation. Deux stations ont une importance fondamentale

TABLEAU 1. Longueur des périodes d'observation

Cours d'eau et station	Période de l'observation	Nombre d'années	Série d'observations continues	Nombre d'années
Juncal à Juncal	1914—1960	26	1943—1960	18
Juncalillo à l'embouchure			1943—1960	18
Juncal à Rio Blanco	1914—1957	27	1943—1957	15
Blanco à Rio Blanco	1914—1960	21	1953—1960	8
Aconcagua à Rio Blanco	1915—1963	27	1943—1963	21
Riecillos à l'embouchure			1931—1941	11
Colorado à l'embouchure	1915—1952	28	1939—1952	14
Aconcagua à Chacabuquito			1937—1963	27
Pocuro à Sifon			1931—1949	19
Putaendo à Los Patos			1940—1965	26
Blanco à Saladillo			1943—1948	6
Hualtatos à l'embouchure			1930—1935	6
Rabuco à l'embouchure			1960—1965	6

pour le calcul de l'écoulement: Chacabuquito, qui ferme le bassin supérieur du R. Aconcagua à la sortie de la chaîne principale des Andes (Cordillera de los Andes), et Los Patos où le Rio Putaendo, principal affluent du R. Aconcagua, débouche de la haute montagne. Ces deux stations, ainsi que Sifon sur l'Estero Pocuro, contrôlent la plupart des eaux s'écoulant de la partie haute du bassin. Echappent cependant au controle les eaux s'écoulant par les rigoles d'irrigation dont les points de départ sont situés en amont de ces stations. Il en est de même des eaux servant à l'irrigation locale dans les régions montagneuses ainsi que des eaux de l'Estero Quilpué s'écoulant du massif principal.

2. DÉBIT MOYEN ANNUEL

La question se pose de savoir si, pour le régime fluvial en cause, les séries de données sont suffisantes pour permettre de déterminer, avec une approximation satisfaisante, le module. Pour y répondre nous avons fait des calculs destinés à montrer les variations de la valeur moyenne du débit en fonction de la durée de la période d'observation. La figure 5 présente les résultats. Nous avons calculé pour chaque station le débit moyen (en m^3/s) pour 2, 3, 4 années et plus; chaque valeur se trouve exprimée en % du débit moyen calculé sur une période de plusieurs années, ce dernier considéré comme étant égal à 100% indépendamment de la durée de la série d'observation. Comme il ressort du diagramme, les périodes de quelques années donnent de très grandes différence pour ce qui est de la valeur moyenne. Seules les périodes de 15 ans environ donnent des valeurs approchant de celles obtenues à partir de périodes de plusieurs années.

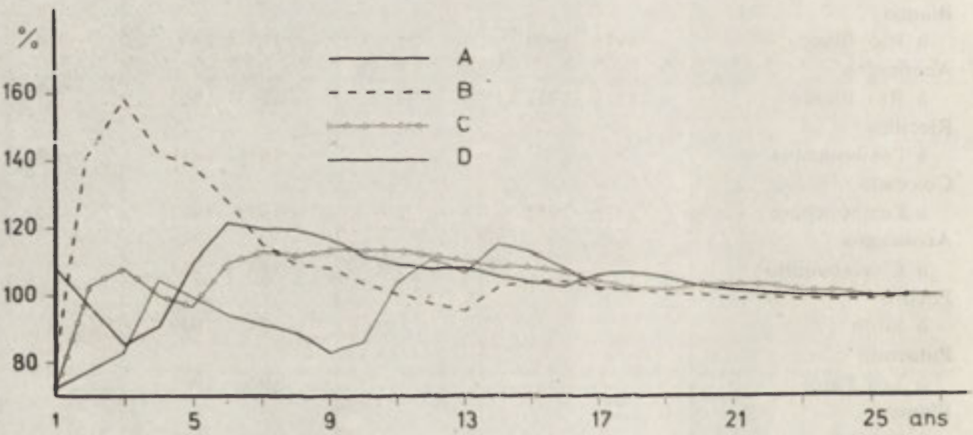

Fig. 5. Variation de la moyenne annuelle des débits en fonction de la durée totale d'observation

A. R. Aconcagua à Chacabuquito; B. R. Putaendo à Los Patos; C. R. Juncal à Juncal; D. E. Pocuro à Sifon

Avec un tel procédé, la forme de la courbe, figurant la variation de la moyenne annuelle des débits en fonction de la durée totale d'observation, est déterminée, en grande partie, par le fait que les premières années présentent soit des valeurs proches de la moyenne de plusieurs années (Chacabuquito) soit des valeurs qui s'en écartent notablement (Los Patos, Sifon). Les années à écoulement exceptionnellement grands ou petits influent moins sur la forme de la courbe lorsqu'elles se situent vers la fin de la période d'observation. Pour éviter l'influence des années initiales de la série sur le résultat, on a calculé les valeurs moyennes consécutives pour des périodes de différentes durées. Le tableau 2 présente les résultats. Il ressort du tableau que les moyennes d'une période d'une quinzaine d'année peuvent différer de plus de 10%. Même les moyennes de 20 ans diffèrent à Los Patos de presque 10%. Il faut par conséquent considérer les séries de périodes de moins de 20 ans uniquement comme des valeurs approximatives.

TABLEAU 2. Débit moyen annuel

Cours d'eau et station	Moyennes consécutives					
	de 10 ans		de 15 ans		de 20 ans	
	en m^3/s	en % de la moynne de nombreuses années	en m^3/s	en % de la moyenne de nombreuses années	en m^3/s	en % de la moyenne de nombreuses années
R. Juncal à Juncal	5,6—5,9	96,6—101,7	5,6—5,9	96,6—101,7		
R. Aconcagua à Chacabuquito	29,2—37,4	90,1—115,1	29,2—36,1	91,3—111,1	30,4—33,6	93,5—103,4
E. Pocuro à Sifon	0,89—1,24	85,6—119,2	1,03—1,17	99,0—112,5		
R. Putaendo à Los Patos	6,6—8,9	77,2—104,1	7,6—9,1	88,9—106,4	7,7—8,6	90,1—103,4

C'est à partir de toutes les années d'observation que nous avons calculé, pour les 10 stations choisies, le débit moyen annuel. Les séries comportent de 11 à 28 années et elles se situent entre 1914 et 1963. Afin de diminuer l'erreur dans l'appréciation des débits moyens annuels et d'obtenir des valeurs plus proches des valeurs „normales", nous nous sommes servis du calcul des probabilités. On a établi pour chaque station la courbe de fréquence d'écoulement annuel selon la méthode de Dębski[2]. La superficie entre la courbe et l'abscisse, divisée par la base, nous donne la valeur du module probable. Il est évident que les valeurs ainsi obtenues dépendent des matériaux de départ, c'est-à-dire de la série — point de départ du calcul. Elles donnent cependant une plus grande probabilité d'obtenir une valeur moyenne approchée de la valeur „normale". Même de brèves séries — si elles n'offrent pas d'anomalies extrêmes — permettent d'établir de cette manière une valeur qui ne sera guère trop éloignée de la valeur moyenne établie à partir d'une période de plusieurs années. A titre d'exemple on a calculé le module dans le profil d'embouchure du R. Colorado, et ceci pour deux séries — pour les 39 années pour lesquelles il a été établi des valeurs annuelles du débit puis, pour les 14 années successives de 1939 à 1952 (Tabl. 3).

[2] Dębski, K., Prawdopodobieństwo zjawisk hydrologicznych i meteorologicznych (Probabilité des phénomènes hydrologiques et météorologiques), PIHM, *Instrukcje i podręczniki*, 30 (1954), Warszawa.
A titre d'exemple nous avons utilisé dans le calcul, la méthode universellement connue de Foster pour Chacabuquito. Les résultats obtenus par les deux méthodes ne divergent guère.

TABLEAU 3. Débit annuel moyen en m³/s du R. Colorado

Nombre d'années	% de probabilité															Moyenne à partir de la courbe de fréquence	Moyenne arithmétique
	0,1	1	5	10	20	30	40	50	60	70	80	90	95	99	99,9		
39	49,6	39,0	25,0	20,6	16,2	13,5	11,6	10,1	8,8	7,8	6,9	6,2	5,7	5,2	5,0	12,1	11,9
14	45,3	33,1	24,3	20,3	16,3	13,8	12,0	10,4	9,1	7,9	6,7	5,6	4,9	4,1	3,8	12,0	11,5

Comme le montre le tableau, les moyennes calculées à partir des courbes de fréquence sont presque identiques, bien que les moyennes arithmétiques divergent.

Le tableau 4 présente les valeurs du module moyen obtenues de différentes façons.

La différenciation spatiale de l'écoulement spécifique dans le bassin du R. Aconcagua est présentée sur une carte (Fig. 6), qui fait voir une régularité bien nette de ce phénomène. Les valeurs maximales s'observent dans le bassin du haut R. Juncal, recevant les plus abondantes précipitations (plus de 1000 mm). Vers le Nord et vers l'Ouest, le module va en diminuant. Vers le Nord, la diminuation est progressive, conforme à la précipitation de plus en plus réduite qui, dans la partie nord du bassin, n'atteint pas 500 mm. Du côté ouest, par contre, on observe un gradient du module trés accusé en bordure de la haute chaîne andine. Le long du R. Aconcagua, la diminution de l'écoulement spécifique progresse en aval, au fur et à mesure que le fleuve reçoit des affluents de moins en moins riches en eau, et qu'il perd d'importantes quantités d'eau au profit de l'agriculture.

3. VARIATIONS DU DÉBIT MOYEN D'UNE ANNÉE A L'AUTRE

Les matériaux statistiques sont insuffisants pour caractériser la variabilité du débit moyen annuel. Les séries de données sont courtes et peuvent, de ce fait, ne pas comporter d'années à débits moyens exceptionnellement faibles ou fortes. Elles ne constituent pas non plus une base suffisamment solide pour l'établissement des courbes de fréquence. C'est pourquoi il faut traiter avec réserve les valeurs extrême que fournit le calcul des probabilités.

Les séries de données ne se rapportent pas aux mêmes périodes, ce qui rend difficile une comparaison des variabilités du débit moyen annuel. Cependant, pour pouvoir comparer des données, il faut qu'elles soient du même temps, car le débit varie probablement d'une année à l'autre — malgré la diversité du bassin — d'une façon analogue sur l'ensemble du territoire en question. Ceci paraît notamment résulter de la comparaison des débits moyens

TABLEAU 4. Débit moyen annuel en m^3/s

Cours d'eau et station	Débit moyen annuel calculé			Superficie du bassin en km^2	Ecoulement spécifique en l/s, km^2
	à partir de toutes les années d'observation	à partir de la période continue d'observation	à partir de la courbe de fréquence		
R. Juncal à Juncal	6,2	5,8	**6,1**	246,9	24,7
E. Juncalillo à l'embouchure		1,48	1,48	88,8	16,7
R. Juncal à Rio Blanco	**11,7**	11,2	12,0	500,1	23,4
R. Blanco à Rio Blanco	10,2	**8,8**	10,5	385,0	22,9
R. Aconcagua à Rio Blanco	**20,5**	20,4	20,5	885,1	23,2
E. Riecillos à l'embouchure		2,7	**3,0**	161,9	18,5
R. Colorado à l'embouchure	11,9	11,5	**12,1**	818,8	14,8
R. Aconcagua à Chacabuquito		32,4	**32,9**	2 075,2	15,9
E. Pocuro à Sifon		1,04	**1,03**	181,3	5,7
R. Putaendo à Los Patos		8,55	**9,4**	848,8	11,1

Les valeurs adoptées sont soulignées

annuels pour la même période 1943—63 dans trois profils dont deux — R. Aconcagua à Rio Blanco et R. Putaendo à Los Patos — sont situés loin l'un de l'autre et dans des conditions fort différentes (Fig. 7).

La confrontation des valeurs extrêmes du débit annuel aux stations particulières (Tabl. 5) permet, malgré l'imperfection des données, de tirer certaines conclusions. Le fait que le coefficient d'irrégularité présente une si vaste gamme, ne résulte pas uniquement du caractère non-homogène des séries statistiques, mais reflète la diversité des conditions d'écoulement. La brièveté des séries est sans doute compensée par une grande variabilité du module d'une année à l'autre; ce qui fait que, même pendant de courtes périodes, il arrive d'enregistrer des années présentant des débits moyens radicalement divergents. C'est le R. Colorado qui peut ici servir d'exemple. Au cours de 14 années (entre 1915 et 1930), le débit annuel varia dans les limites de 3,5 m^3/s — 22,4 m^3/s, ce qui donne comme coefficient d'irrégularité 6,4. Au cours d'une période de 1939 à 1952, on a enregistré les va-

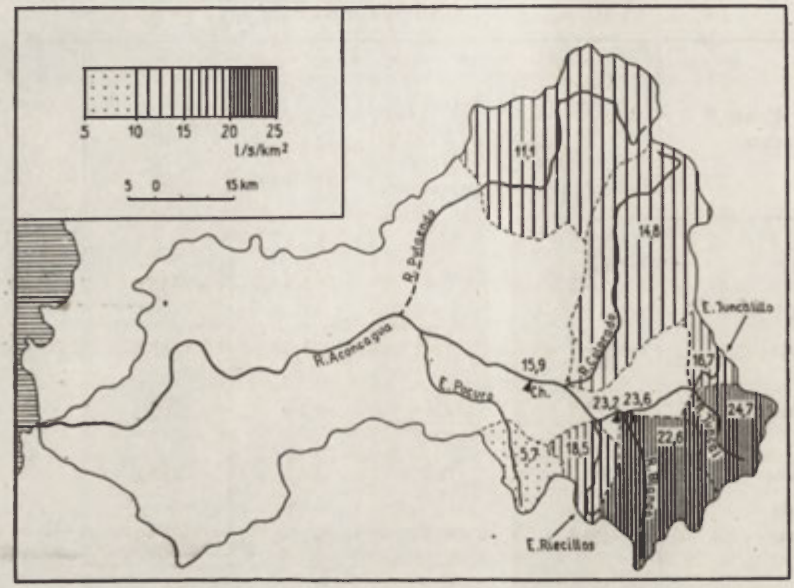

Fig. 6. Écoulement spécifique dans la partie haute du bassin du R. Aconcagua

TABLEAU 5. Variabilité de débit moyen annuel

Cours d'eau et station	Nombre d'années	Débit moyen annuel max	Débit moyen annuel min	Coefficient d'irrégularité
Juncal à Juncal	26	10,45	3,9	2,7
Juncalillo à l'embouchure	18	1,89	1,14	1,7
Juncal à Rio Blanco	27	15,8	8,0	2,0
Blanco à Rio Blanco	21	18,6	4,8	3,9
Aconcagua à Rio Blanco	27	32,4	13,0	2,5
Riecillos à l'embouchure	11	5,9	0,8	7,4
Colorado à l'embouchure	28	23,1	3,5	6,6
Aconcagua à Chacabuquito	27	61,4	20,8	3,0
Pocuro à Sifon	19	3,02	0,14	21,6
Putaendo à Los Patos	26	17,7	3,4	5,2

leurs suivantes: de 4,6 m^3/s à 23,1 m^3/s, ce qui donne un coefficient de variabilité de 5,0. Pour les 38 années, entre 1915 et 1963, dont on a établi ou estimé les débits moyens annuels, les limites de variabilité ne se sont guère élargies et le coefficient d'irrégularité n'a que légèrement augmenté (23,1 : 3,5 = 6,6).

De petits coefficients d'irrégularité s'observent dans la partie supérieure du bassin, jusqu'au R. Blanco y compris, et en ce qui concerne le cours d'eau principal. L' E. Juncalillo présente une variabilité du module exceptionnellement réduite. La cause doit être probablement cherchée dans le rôle régulateur du lac Laguna del Inca et dans la fuite souterraine de l'eau vers le bassin voisin. L'insignifiante variabilité du module de l'E. Juncalillo en comparaison avec le R. Juncal voisin, est mise en évidence par le graphique où les débits moyens annuels sont exprimés, afin de faciliter la comparaison, par le coefficient $Q : Q_m$ (débit moyen d'une année donnée par rapport au débit moyen de plusieurs années) (Fig. 8).

Les coefficient d'irrégularité beaucoup plus importants sont notés pour les affluents en aval du R. Blanco. C'est surtout l'E. Pocuro au profil de Sifon qui, malgré une courte série de 19 ans, présente un coefficient particulièrement élevé.

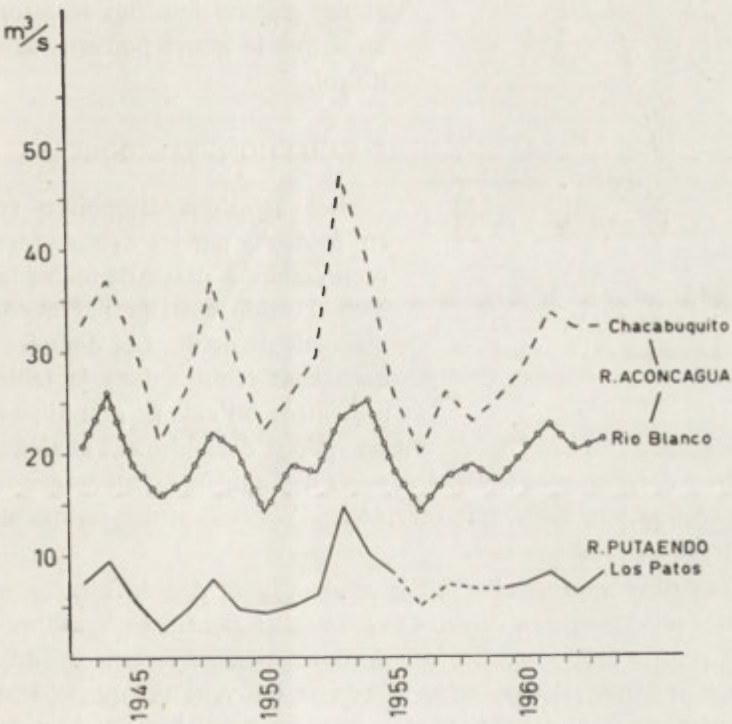

Fig. 7. Variabilité de moyennes annuelles de débit dans trois stations

Ce profil ferme un bassin peu étendu, situé dans la partie extérieure, relativement sèche, des montagnes.

La différenciation spatiale du coefficient d'irrégularité est fonction de nombreux facteurs, principalement de l'importance et de la variabilité de précipitations annuelles, de la glaciation du bassin et de la rétention des nappes d'eau souterraine. Les bassins présentant une moyenne des précipitations annuelles plus élevée ont un écoulement moins variable d'une année à l'autre. Une grande quantité de glaciers influe, elle aussi, sur la diminution des oscillations en ce qui concerne le débit moyen annuel, car la fonte est un phénomène plus régulier que les précipitations. C'est pourquoi les bassins situés le plus haut ont l'écoulement le plus régulier.

Vu la situation du bassin du R. Aconcagua dans la zone du climat méditerranéen, où les précipitations varient énormément d'une année à l'autre, on ne s'étonnera pas de ce que le coefficient soit tellement grand. Précisons d'ailleurs que pour cette zone les valeurs en cause sont plutôt modérées. C'est qu'une influence adoucissante est exercée par le caractère de l'alimentation, où la fonte des neiges et des glaciers joue un rôle fort grand, ainsi que le grand pouvoir de rétention du sol.

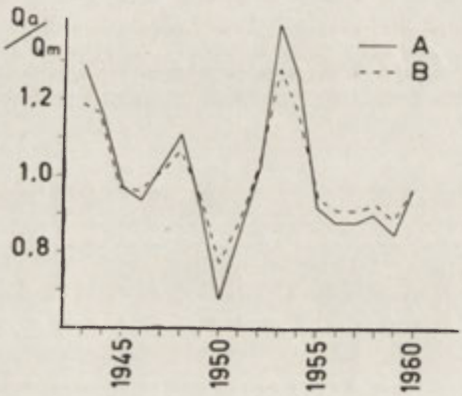

Fig. 8. Variabilité relative de débit moyen annuel du R. Juncal (A) et de l'E. Juncalillo (B)

4. VARIATIONS SAISONNIÈRES

Les variations saisonnières sont mises en évidence par les débits moyens mensuels établis à partir de toutes les années d'observation, ainsi que par les coefficients mensuels de débit. Les données numériques sont réunies dans le tableau 6 et présentées à l'aide de graphiques.

Toutes les stations du haut bassin ont un rythme d'écoulement analogue: abondance d'eau en été, pénurie en hiver. Les cours d'eau de haute montagne sont donc soumis à un régime semblable, que caractérise l'opposition des saisons de hautes eaux et de précipitations intenses.

Une analyse plus approfondie fait cependant voir des différences caractéristiques entre les profils mis en cause. Cinq stations: Juncal, embouchure du Juncalillo et trois profils à Rio Blanco, ont des coefficients mensuels de débit supérieurs à 1 pendant 5 mois, de novembre à mars, ce qui veut dire que le débit moyen mensuel s'y avère plus grand que le module annuel, et ceci à partir du dernier mois du printemps (XI) durant l'été (XII-II) jusqu'au premier mois de l'automne y compris (III).

TABLEAU 6. Variations saisonnières des débits

Cours d'eau et station	Débits moyens en m³/s												Année	Coefficients mensuels de débits											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
E. Juncal à Juncal	14,0	10,7	7,2	4,8	3,2	2,3	1,9	1,8	2,2	3,8	8,4	13,6	6,2	2,27	1,74	1,17	0,78	0,52	0,37	0,31	0,29	0,36	0,62	1,36	2,21
E. Juncalillo à l'embouchure	2,80	2,17	1,62	1,15	0,91	0,81	0,77	0,74	0,82	1,08	1,90	2,94	1,48	1,89	1,46	1,09	0,78	0,62	0,55	0,52	0,50	0,55	0,73	1,28	1,99
E. Juncal à Rio Blanco	23,6	17,5	12,3	8,3	6,3	5,6	5,2	5,2	6,1	8,9	17,3	24,6	11,7	2,02	1,50	1,05	0,71	0,54	0,48	0,44	0,44	0,52	0,77	1,48	2,10
R. Blanco à Rio Blanco [1]	24,6	17,9	11,1	5,0	3,7	3,3	3,3	3,5	4,2	6,9	15,9	23,0	10,2	2,41	1,75	1,09	0,49	0,39	0,32	0,32	0,34	0,41	0,68	1,56	2,25
R. Aconcagua à Rio Blanco	42,8	33,4	21,9	12,6	8,4	7,2	7,1	7,2	9,2	15,6	33,3	47,4	20,5	2,09	1,63	1,07	0,61	0,41	0,35	0,34	0,35	0,45	0,76	1,62	2,31
R. Colorado à l'embouchure	20,2	13,45	8,1	5,1	5,0	4,5	4,7	5,6	8,3	13,8	24,7	29,7	11,9	1,70	1,13	0,68	0,43	0,42	0,38	0,40	0,47	0,69	1,16	2,07	2,50
E. Riecilos à l'embouchure	2,91	1,05	0,5	0,3	0,9	1,3	1,3	1,8	2,6	5,1	7,25	7,6	2,7	1,08	0,39	0,17	0,11	0,32	0,47	0,49	0,66	0,96	1,87	2,68	2,82
R. Aconcagua à Chacabuquito	58,2	39,5	25,3	16,8	14,3	13,7	13,7	15,9	21,0	33,3	58,9	78,6	32,4	1,80	1,22	0,78	0,52	0,44	0,42	0,42	0 49	0,65	1,03	1,82	2,43
E. Pocuro à Sifon	0,87	0,64	0,45	0,46	0,92	1,05	1,13	1,59	1,63	1,50	1,26	1,0	1,04	0,84	0,62	0,43	0,44	0,88	1,01	1,09	1,53	1,57	1,44	1,21	0,96
R. Putaendo à Los Patos	9,7	6,2	4,85	3,95	3,9	4,3	4,5	5,9	7,7	12,95	20,0	18,7	8,6	1,14	0,73	0,57	0,46	0,46	0,50	0,52	0,69	0,90	1,51	2,34	2,18
R. Blanco à Saladillo	24,5	17,4	8,3	3,75	2,1	1,55	1,63	2,35	3,25	6,0	13,9	21,7	8,9	2,76	1,96	0,93	0,42	0,24	0,17	0,18	0,26	0,37	0,67	1,56	2,44
E. Hualtatos à l'embouchure	0,64	0,28	0,21	0,15	0,47	0,51	0,64	0,62	1,41	1,44	2,55	1,83	0,9	0,72	0,31	0,23	0,17	0,53	0,57	0,72	0,69	1,58	1,60	2,85	2,04
E. Rabuco à l'embouchure	0,46	0,47	0,61	0,66	0,62	0,63	0,59	0,58	0,72	0,45	0,47	0,5	0,56	0,82	0,84	1,09	1,18	1,10	1,13	1,04	1,04	1,28	0,80	0,83	0,89

[1] Les moyennes mensuelles ont été établies à partir de 21 années d'observations

Les différences entre ces graphiques se manifestent dans l'ordre des mois à coefficients décroissants et dans la grandeur des coefficients. Seuls le R. Juncal (Fig. 9a) et le R. Blanco à Rio Blanco (Fig. 10b) ont leurs maximums en janvier. Le coefficient y est moindre en décembre, et encore plus petit en février et en novembre. Cet ordre — I, XII, II, XI — correspond aux mois suivants dans notre hémisphère: VII, VI, VIII, V. C'est un ordre typique pour le régime glaciaire, influencé par la fonte des neiges. En effet, dans les deux bassins les glaciers et les neiges éternelles occupent une superficie supérieure à celles des autres bassins du territoire en cause.

Les maximums se produisent en hiver. A Juncal pendant quatre mois (juin--octobre), et à Rio Blanco même pendant six mois (avril-novembre) les coefficients n'atteignent pas 0,5. Pour les deux profils, malgré une assez considérable

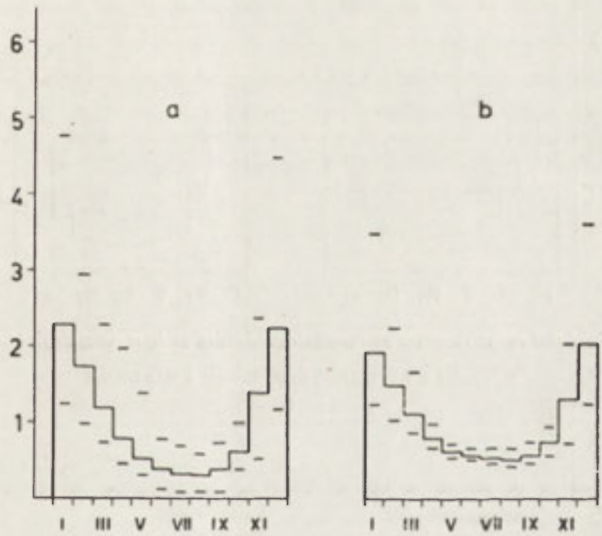

Fig. 9. Coefficients mensuels des débits et leur variabilité

a. R. Juncal à Juncal; b. E. Juncalillo

différence du module, on constate des coefficients du débit mensuel oscillant dans des limites sensiblement identiques: à Juncal de 2,27 à 0,29 et à Rio Blanco de 2,47 à 0,32. Ceci donne des coefficients d' irrégularité presque semblables: 7,8 et 7,5.

L'échelle des coefficients mensuels est, pour un régime glaciaire, assez petite. La cause de cette situation doit être recherchée dans le role régulateur du sol. Par conséquent, le haut Juncal et le R. Blanco ont un régime glaciaire doublement tempéré, par l'action nivale et par l'influence du sol.

Pour les trois autres profils: E. Juncalillo à l'embouchure (Fig. 9b), R. Juncal à Rio Blanco (Fig. 10a) et R. Aconcagua à Rio Blanco (Fig. 11a) la succession des mois selon leurs débits moyens est autre. Décembre l'emporte un peu sur le mois de janvier. L'augmentation du coefficient s'observe plus tot, à savoir, déjà au début de l'été, ce qui met en évidence le rôle accru de la neige estompant un peu l'influence des glaciers. L'ordre des mois: XII, I, II, XI (qui correspondent chez nous aux mois: VI, VII, VIII, V) permet de considérer le régime comme nivo--glaciaire. Ce qui le distingue, ce sont les coefficients encore moins diversifiés. Cette

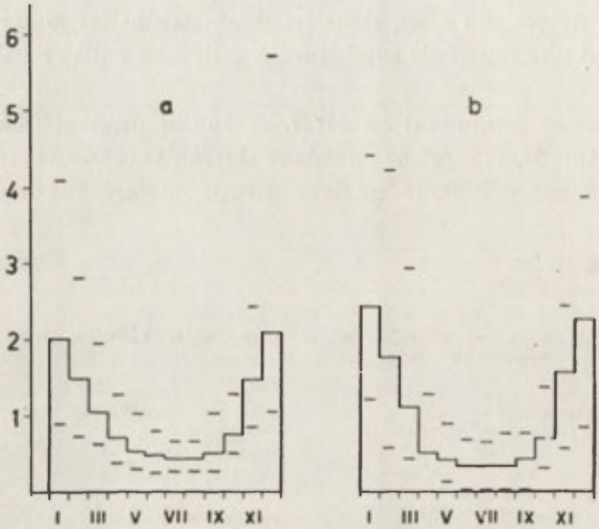

Fig. 10. Coefficients mensuels des débits et leur variabilité

a. R. Juncal à Rio Blanco; b. R. Blanco à Rio Blanco

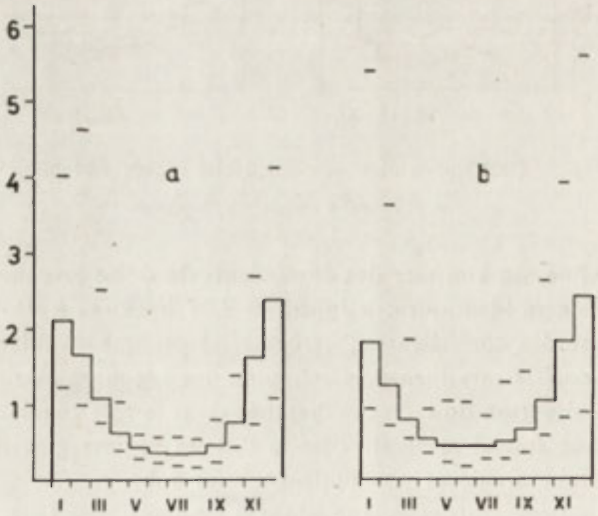

Fig. 11. Coefficients mensuels des débits et leur variabilité

a. R. Aconcagua à Rio Blanco; b. R. Aconcagua à Chacabuquito

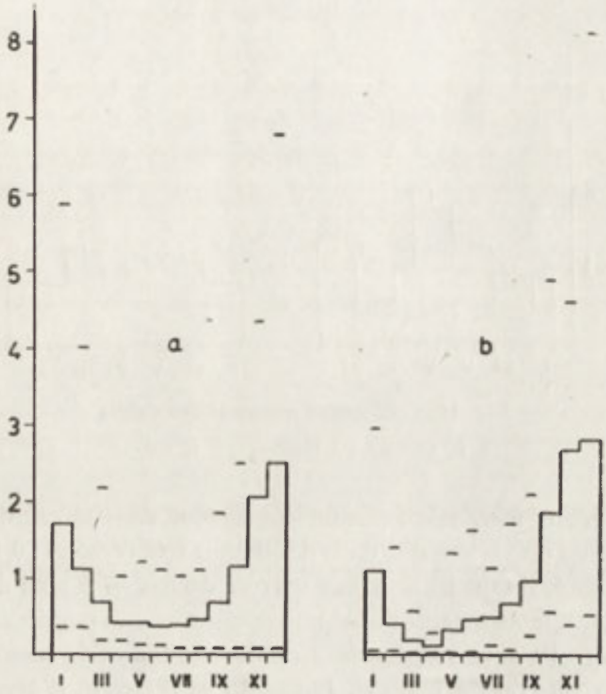

Fig. 12. Coefficients mensuels des débits et leur variabilité

a. R. Colorado; b. E. Riecillos

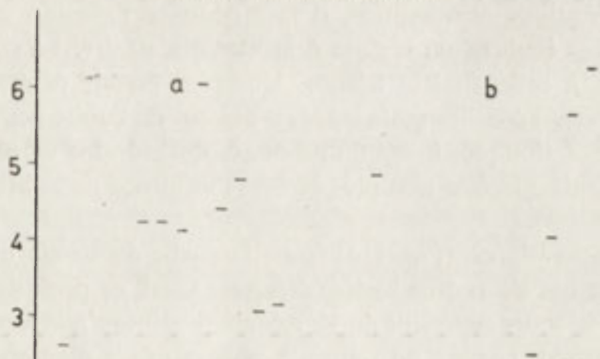

Fig. 13. Coefficients mensuels des débits et leur variabilité

a. E. Pocuro à Sifon; b. R. Putaendo à Los Patos

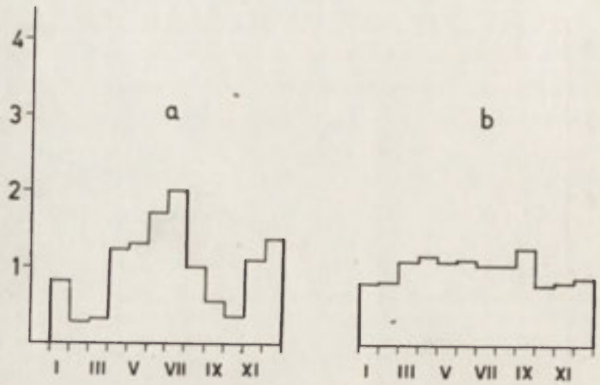

Fig. 14. Coefficients mensuels des débits

a. R. Aconcagua à Tabolango; b. E. Rabuco

uniformité des débits mensuels se manifeste surtout dans le cas de l'E. Juncalillo dont les coefficients ne varient que dans des limites très réduites: 0,5—1,99. Comme on l'a déjà souligné, il faut ici attribuer un rôle décisif — à côté du sol perméable — au lac. Ces deux facteurs entraînent non seulement une pondération de l'écoulement, mais encore ils sont responsables d'un retard de l'écoulement. C'est probablement pour cette raison que l'E. Juncalillo se présente, d'après le graphique, comme une rivière à régime nivo-glaciaire, quoiqu'il n'y ait pas, dans le bassin, de glaciers, mais simplement des lambeaux de neiges éternelles.

A côté des stations mentionnées, il faut compter Saladillo sur le R. Blanco parmi celles qui présentent un régime à influence glaciaire. La courbe des coefficients ressemble à celle du Rio Blanco. Une plus grande divergence de valeurs (de 2,76 à 0,17) et un coefficient de mars au-dessous de l'unité peuvent être la conséquence de la situation plus haute du bassin, ce qui entraîne un rôle accru des glaciers. On ne saurait pourtant non plus exclure l'influence de la brièveté de la série d'observation (6 ans).

Le profil à Rio Blanco (Fig. 11a) ferme la partie du bassin du R. Aconcagua que caractérisent ces six profils hydrométriques. C'est ce profil-là qui nous autorise à envisager le cours supérieur du R. Aconcagua, jusqu'à la jonction du R. Juncal et du R. Blanco, comme un fleuve à régime mixte nivo-glaciaire. L'inégale distribution de l'écoulement entre les saisons se présente comme suit: l'été enregistre 50,2%, le printemps 23,6%, l'automne 17,4% et l'hiver 8,8%. Plus d'un tiers (36,6%) de l'écoulement se concentre pendant deux mois d'été: décembre et janvier. Les écoulements de février (13,6%) et de novembre (13,5%) sont pratiquement identiques. Cette distribution ainsi que la prépondérance de l'écoulement printanier face à celui d'automne mettent en relief la part de la fonte des neiges dans le processus d'écoulement. La brusque décroissance du coefficient mensul en automne (mars 1,07, avril 0,61), donc au commencement de la période des précipitations, prouve que l'écoulement n'est, que dans une très faible mesure, directement redevable aux précipitations. Dans la haute montagne, les chutes se font sous forme de neige et sont dans leur majeure partie retenues jusqu'au printemps, tandis que les pluies d'automne sont absorbées par le manteau détritique et alimentent l'écoulement hivernal. L'étendue et l'épaisseur de ce manteau expliquent les coefficients de débit mensuel relativement forts, ne descendent guère au-dessous de 0,34, donc peu typiques pour les régimes glaciaires, et même pour les régimes nivaux de montagne. Ce qui est par contre typique, c'est la longue période hivernale des basses eaux. Les coefficients mensuels n'atteignent pas la valeur de 0,5 pendant cinq mois (mai-septembre).

Pour illustrer la variabilité des débits moyens mensuels, nous avons porté sur nos graphiques les valeurs des coefficients calculés pour les mois ayant des écoulements maximums et minimums au cours de la période d'observation. Cela permet d'établir une régularité au sein des régimes qui présentent tous les ans des étiages d'hiver et des hautes eaux d'été. Pendant les mois d'hiver, et dans la plupart des stations pendant cinq mois de l'année, le débit moyen n'atteint pas, même pour les années riche en eau, la valeur du module. En décembre et en janvier par contre, le débit moyen n'est jamais inférieur au module. (Seul le bassin du R. Juncal à Rio Blanco constitue une exception: en 1957 le débit de janvier n'y a pas atteint la valeur du module).

Ce n'est qu'en décembre et en janvier que le R. Aconcagua à Rio Blanco débite toujours plus d'eau qu'il ne résulterait de la moyenne. Même le plus faible débit moyen de février, dans le cadre de la période d'observation, s'approche du module. Il convient de voir dans ce fait une influence des glaciers dont la participation à l'alimentation n'est pas soumise à des fluctuations d'une année à l'autre aussi importantes que celles des neiges. Pour les neuf autres mois de l'année, le débit moyen mensuel peut se situer au-dessous du module. Les plus basses valeurs du coefficient ne descendent qu'exceptionnellement au-dessous 0,2 pendant les mois d'hiver ce qui témoigne d'une relative richesse du fleuve en eau pendant l'hiver en comparaison avec les cours d'eau à régime nivo-glaciaire typique. De très forts débits mensuels se produisent exclusivement en été. Le coefficient mensuel maximum a été pour février, 27 ans durant, 4,11. En hiver et pendant les deux mois voisins (V—IX) les débits mensuels moyens n'arrivent jamais à atteindre le module. Ainsi donc, la pénurie d'eau en hiver apparaît, pour ce qui est du haut R. Aconcagua, comme un phénomène plus stable que l'abondance d'été.

Contrairement à ce que suggère le graphique, notamment une grande variabilité interannuelle des débits moyens en été et une petite en hiver, cette variabilité n'apparaît point comme solidaire de la saison. Les écarts par rapport aux valeurs moyennes de nombreuses années, surtout en haut, prennent des valeurs semblables en été aussi bien qu'en hiver. La différenciation des amplitudes, nette s'il s'agit des nombres absolus, s'efface en ce qui concerne les valeurs relatives. La régularité des étiages d'hiver supérieure à celle des hautes eaux d'été se manifeste donc, non pas dans une moindre variabilité du débit moyen au cours de cette période, mais dans la durée de ces périodes, soumise à des changements moins importants d'une année à l'autre.

Le R. Colorado à l'embouchure, l'E. Riecillos, l'E. Hualtatos, le R. Putaendo à Los Patos et le R. Aconcagua à Chacabuquito ont un régime nival de transition où l'influence de la pluie se fait déjà sensible. Les maximums des courbes des coefficients mensuels se situent vers la fin du printemps et au début de l'été (XI, XII). Le débit moyen de décembre, et même celui de novembre, l'emporte nettement sur celui de janvier. D'insignifiantes différences dans la succession des mois reflètent une alimentation un peu différente.

Le R. Colorado (Fig. 12a) et l'E. Riecillos (Fig. 12b) ont des maximums de décembre. Novembre vient en deuxième. Pour le reste des mois, l'ordre peut parfois varier. En ce qui concerne le R. Colorado, dont le bassin est plus haut, le mois de janvier l'emporte sur le mois d'octobre. Dans le cas de l'E. Riecillos, le rôle de janvier est beaucoup plus effacé. Le mois de janvier a une importance encore moindre dans le bassin de l'E. Hualtatos qui occupe le rebord des montagnes. L'altitude moins grande du bassin fait que le maximum se déplace du mois de décembre vers novembre.

Le rythme du R. Aconcagua à Chacabuquito constitue une synthèse d'influences se superposant dans la partie supérieure du bassin (Fig. 11b). La configuration des mois — XII, XI, I, II — est typique pour un régime nival de transition. L'écoulement est distribué de la manière suivante entre les saisons de l'année: été — 45,3%, printemps — 29,1%, automne — 14,5%, hiver — 11,1%. En comparaison avec le profil à Rio Blanco, on remarque à Chacabuquito une influence accrue de l'hiver et du printemps, tandis que l'écoulement diminue en été et en automne. Ceci prouve une importance de la neige plus grande que dans le cours supérieur. Un assez grand coefficient mensuel de février (1,22) supérieur à celui à d'octobre, (1,03), reflète l'influence des glaciers, influence que le rôle prédominant des neiges n'arrive pas à effacer complètement.

Le profil Los Patos ferme le bassin du haut R. Putaendo, issu de la jonction du R. Rocin et de l'E. Chalaco (Fig. 13b). C'est la partie la plus septentrionale du bassin du R. Aconcagua. Elle englobe les parties intérieures et extérieures de la principale chaîne andine. Le R. Putaendo à Los Patos débite 39,6% de l'eau au printemps, 33,7% en été, 14,3% en hiver et 12,4% en automne. Cette distribution de l'écoulement fait penser à une alimentation differente de celle que l'on observe dans la partie du bassin situé en haute montagne, que ferme le profil du R. Aconcagua à Rio Blanco. La part beaucoup plus grande de l'écoulement printanier dans le bassin du R. Putaendo, l'emportant sur l'écoulement d'été, résulte du rôle décisif de la fonte des neiges. La prépondérance de l'écoulement d'hiver, par rapport à celui d'automne, met en évidence le rôle des précipitations pluviales.

Le maximum de débit du R. Putaendo ne se situe pas en décembre ($18{,}7 m^3/s$), mais en novembre (20,0). Le fait est à mettre en rapport avec la latitude géographique moindre de cette partie du bassin ainsi qu'avec l'altitude moins importante du bassin de l'E. Chalaco, qui fournit les eaux de la fonte des neiges plus tôt que le bassin du R. Rocin, situé plus haut. Durant l'été, la courbe des coefficients mensuels de débit du R. Putaendo diminue rapidement, pour atteindre son maximum tard dans l'automne (V). Le minimum de mai est suivi d'une très lente croissance des valeurs. Cette augmentation est due aux pluies. C'est principalement l'E. Chalaco qui fournit l'eau; dans son bassin, les précipitations pluviales jouent un rôle plus considérable que dans le bassin du R. Rocin, recevant avant tout de la neige.

Les bassins du R. Colorado, de l'E. Riecillos et du R. Putaendo se distinguent par une régularité moins grande des débits mensuels que les bassins des plus hautes parties de montagne. Chaque mois peut enregistrer un débit moyen inférieur au module. Même en été, les débits mensuels se réduisent parfois à de très basses valeurs. Et inversement, il arrive même au mois d'hiver d'avoir des débits moyens dépassant largement le module. Ce sont avant tout les mois d'été qui présentent une grande irrégularité. Le débit moyen de décembre du R. Colorado variait, durant une période de 28 ans, de 1,1 m^3/s à 81 m^3/s, avec une moyenne de 29 m^3/s. Dans le même mois, le débit moyen de l'E. Riecillos oscillait, au cours de 11 années, entre 1,4 m^3/s et 22 m^3/s, avec une moyenne 2,8 m^3/s. Pour le R. Putaendo on note respectivement 4,1 m^3/s et 54 m^3/s, avec une moyenne de 28,2 m^3/s.

Le R. Aconcagua à Chacabuquito rappelle ses affluents par la variabilité des débits moyens. Ici les coefficients de débit de n'importe quel mois peuvent descendre au-dessous de l'unité, tandis que les débits moyens mensuels en hiver peuvent s'avérer plus grands qu'au cours de l'été d'une autre année. L'influence des affluents alimentés par la fonte des glaciers se manifeste dans ce que les débits des mois d'été n'atteignent jamais des valeurs aussi basses qu'en hiver. Les valeurs les plus basses se maintiennent en été au niveau des moyennes relatives aux mois d'hiver pour des périodes de plusieurs années.

L'E. Pocuro à Sifon (Fig. 13a) a un rythme foncièrement différent. Il débite le maximum d'eau en août et en septembre, c'est-à-dire vers la fin de l'hiver et au début du printemps. A partir du maximum de septembre, le débit mensuel décroit progressivement, pour atteindre le minimum en automne (III, IV). La saison des pluies amène une augmentation progressive de débit. Une courbe simple, à un seul maximum, masque la complexité de l'alimentation, due à la fonte des neiges aussi bien qu'aux pluies. Le rôle de la neige apparaît dans le terme où se situe le maximum; ce terme est considérablement écarté du maximum des précipitations en juin. L'abondance des eaux au printemps traduit le même fait. S'il s'agit de la part qui revient à la pluie dans l'alimentation, il faut évoquer l'augmentation de l'écoulement en automne (V) et le débit des mois d'hiver, dépassant la moyenne annuelle, au moment où la rétention nivale réduit au minimum le débit des cours d'eau en haute montagne.

Dans le cours moyen et inférieur du R. Aconcagua, le rythme de l'écoulement subit une modification notable. La cause en est le caractère différent d'alimentation dans cette partie du bassin, et l'ingérence humaine en rapport avec l'agriculture.

A l'ouest de la Cordillère Principale, les précipitations d'automne et d'hiver prennent la forme de pluie ou de neige rapidement fondante. Par conséquent, une partie considérable de la chute intervient immédiatement dans l'écoulement. L'abondance et la grande irrégularité des précipitations durant la saison froide, (précipitations sous forme d'averses, tellement typique pour le climat méditerranéen), fait que l'écoulement en automne et en hiver présente une grande variabilité. L'absence de données nous empêche d'en tenter une caractérisation détaillée. Les données les plus nombreuses pour le secteur inférieur du R. Aconcagua se rapportent à la station Tabolango située près de l'embouchure. Elles proviennent de 6 années non successives, et, pour 6 autres années, comportent de grandes lacunes. Ces données nous autorisent cependant à conclure à une très forte variabilité des débits moyens mensuels. Le coefficient d'irrégularité pour le mois d'avril, établi à partir des 10 années pour lesquelles le débit moyen de ce mois est connu, se monte à 38 (100 m^3/s et 2,6 m^3/s). L'écoulement au cours de la saison chaude de l'année est également très variable. Le débit moyen de décembre oscillait, pendant 9 ans, entre 1,3 m^3/s et 82,4 m^3/s (coefficient 63).

Seule la prise en considération de toutes les données accessibles permet de constater que l'écoulement automnal-hivernal à Tabolango dépasse l'écoulement du printemps et de l'été. Le graphique (fig. 14a), élaboré à partir de moyennes de 6 années seulement, montre deux maximums: le maximum principal, d'hiver (VII), d'origine pluviale, et le maximum secondaire, d'été (XII), dû à l'écoulement de l'eau des terrains de haute montagne. Le minimum principal se situe vers la fin de l'été (II), au moment où le rôle de fonte des neiges et des glaciers va déjà diminuant et où l'utilisation de l'eau à des fins d'irrigation est encore considérable. Le minimum secondaire apparaît en octobre. La saison des pluies touche alors à sa fin et les montagnes ne fournissent pas encore beaucoup d'eau.

La courbe de Tabolango n'est guère utilisable dans l'élaboration d'une caractérisation des débits naturels du R. Aconcagua. Même en faisant abstraction de la quantité réduite des données — ce qui, dans un phénomène aussi variable que l'écoulement dans cette région, constitue un appauvrissement de l'analyse — on se trouve encore en présence de l'ingérence humaine. Du tableau 7, qui réunit les valeurs moyennes mensuelles et annuelles de débit du R. Aconcagua à Chacabuquito et à Tabolango, il résulte, que l'utilisation humaine de l'eau efface souvent l'influence de facteurs naturels et modifie radicalement le rythme saisonnier que ces facteurs sont censés imposer.

Les influences humaines se font remarquer, dans une plus forte mesure encore, dans les petits bassins. E. Rabuco (Fig. 14b) en fournit un exemple. Son débit moyen mensuel ne présente aucun rythme saisonnier. La quantité d'eau débitée est ici

TABLEAU 7. Débits moyens mensuels du R. Aconcagua dans deux profils en m^3/s

Année	Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Moyenne annuelle
1943	Ch	89,2	49,1	28,1	21,4	17,8	16,3	15,7	15,5	18,2	28,6	47,9	52,7	33,3
	T	62,5	17,8	23,3	22,7	25,5	32,3	30,6	32,4	10,3	16,8	20,2	29,0	26,9
1946	Ch	39,6	38,7	26,7	14,4	11,2	9,8	11,5	9,5	10,5	18,6	37,2	36,0	22,0
	T	3,6	2,5	4,5	9,4	14,4	23,1	26,5	13,9	7,3	6,0	4,0	1,3	9,7
1947	Ch	36,6	25,9	21,6	11,9	7,6	7,1	11,2	8,6	17,7	26,0	79,5	70,4	27,0
	T	2,6	1,4	1,6	2,6	5,3	13,5	42,4	19,4	10,6	3,3	46,6	24,2	14,5
1950	Ch	32,0	25,9	20,7	11,4	13,2	10,3	8,5	10,4	14,6	23,0	33,8	74,3	23,2
	T	2,8	3,35	3,5	100,0	75,0	40,0	16,6	6,6	12,0	2,5	14,0	44,0	26,7
1951	Ch	44,2	29,8	20,9	14,7	12,0	13,4	18,3	15,8	16,4	22,8	48,4	59,4	26,3
	T	12,6	1,1	1,1	6,4	16,8	45,5	76,0	26,0	8,9	1,8	18,4	22,5	19,8
1952	Ch	45,6	25,3	20,6	14,9	14,4	13,6	13,2	12,6	22,1	39,9	64,5	77,7	30,4
	T	10,4	5,2	2,8	5,4	18,0	47,5	45,0	19,6	16,4	10,8	27,5	43,0	21,0

Ch — Chacabuquito T — Tabolango

fonction non seulement de l'alimentation et de l'utilisation à des fins d'irrigation, mais encore de l'eau déversée par de nombreux canaux à partir du R. Aconcagua.

Etant donné les grands besoins de l'agriculture en ce qui concerne l'eau et le déficit de celle-ci, aggravé par un système d'irrigation désuet, une bonne reconnaissance des régimes fluviaux dans le bassin du R. Aconcagua apparaît comme un problème de toute première importance.

5. DÉBITS MAXIMAUX ET MINIMAUX

Les données ne sont pas suffistantes pour l'analyse de la variabilité du débit. Nous disposons, pour trois profils seulement: R. Aconcagua à Chacabuquito, R. Colorado à l'embouchure et R. Putaendo à Los Patos, des valeurs maximales et minimales des débits journaliers dans les périodes mensuelles s'echelonnant sur plusieurs années (au moins 25 ans). Ces valeurs ne montrent pas l'importance du débit instantané qui, dans les régimes alimentés par la fonte des neiges et glaciers, peut surpasser le débit moyen journaliers.

Les données dont nous disposons n'embrassent pas des périodes continuelles et identiques pour toutes les stations. Elles ne sont donc pas tout à fait comparables et ne constituent pas une bonne base pour l'analyse statistique. Considérant qu'elles caractérisent de façon approximative la variabilité du phénomène, elles nous ont permis de calculer les maximums et les minimums moyens mensuels du débit. Nous nous sommes servi, pour les calculs, de toutes les donnée: dont nous pouvions disposer, même — autant que possible—des années n'ayant pas eu de séries d'observation complètes. Il s'agissait d'obtenir le plus de données de départ, car les débits extrêmes constituent un phénomène à variabilité considérable. Nous n'avons écarté que les valeurs indubitablement fausses. Les maximums et les minimums moyens ont été donc calculés d'après un différent nombre d'années (de 28 à 32), c'est pourquoi on ne peut les considérer que comme des valeurs approximatives.

Les graphiques ci-joints (Fig. 15—17) montrent les maximums (A) et minimums (C) moyens mensuels du débit en m^3/s. Pour la comparaison, on a également inséré les graphiques des débits moyens mensuels (B). Sur chaque graphique, la ligne continue indique les valeurs moyennes de plusieures années. Pendant la période d'observation, les valeurs extrêmes sont indiquécs par des cercles de part et d'autre des lignes continues. C'est ainsi que l'on a caractérisé la variabilité du phénomène dans les années, pour lesquelles nous disposons de données statistiques.

Le profil Chacabuquito, qui ferme la partie supérieure du bassin du R. Aconcagua, débitant le plus d'eau, constitue l'objet principal de nos préoccupations (Fig. 15). Les graphiques des maximums (A) et minimums (C) moyens mensuels du débit dans ce profil, rendent assez fidèlement le graphique des débits moyens mensuels (B). Les mois de printemps et d'été se caractérisent par l'abondance d'eau et les mois d'automne et d'hiver par son insuffisance. Les minimums moyens du débit de novembre à janvier surpassent le module, c'est à dire 32,4 m³/s, par contre les maximums moyens d'avril à août ne l'atteignent pas. Sur tous les graphiques décembre est indiqué comme le mois ayant les débits les plus élevés. Des

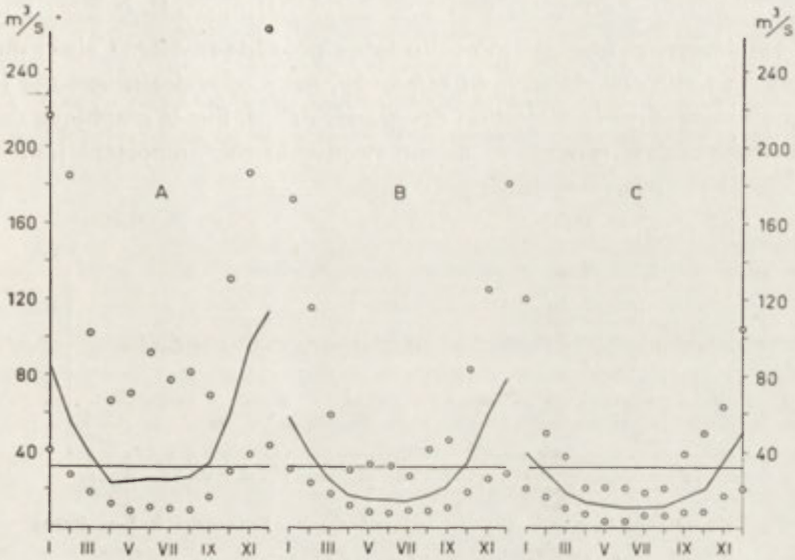

Fig. 15. Débits mensuels caractéristiques du R. Aconcagua à Chacabuquito

A. Maximaux; B. Moyens; C. Minimaux

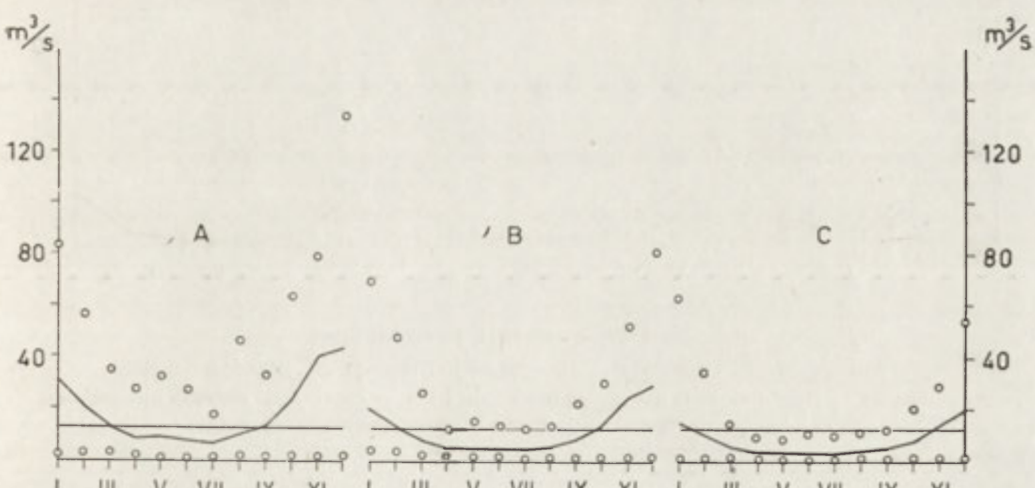

Fig. 16. Débits mensuels caractéristiques du R. Colorado

A. Maximaux; B. Moyens; C. Minimaux

différences insignifiantes, mais pourtant caractéristiques, apparaissent dans la succession des mois à valeurs décroissantes:

débits moyens mensuels	XII, XI, I, II, X
maximums moyens mensuels du débit	XII, XI, I, X, II
minimums moyens mensuels du débit	XII, I, XI, II, X

Dans les maximums moyens, le mois d'octobre préciède février. Cela prouve que ce n'est pas la fonte des glaciers, en été tardif, mais celle des neiges qui joue un rôle plus important dans la formation des grands débits. Sur le graphique des minimums janvier précède novembre, ce qui prouve le rôle important joué par les glaciers dans le maintien des débits en été.

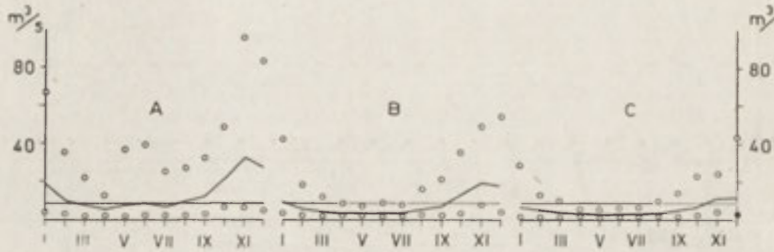

Fig. 17. Débits mensuels caractéristiques du R. Putaendo à Los Patos
A. Maximaux; B. Moyens; C. Minimaux

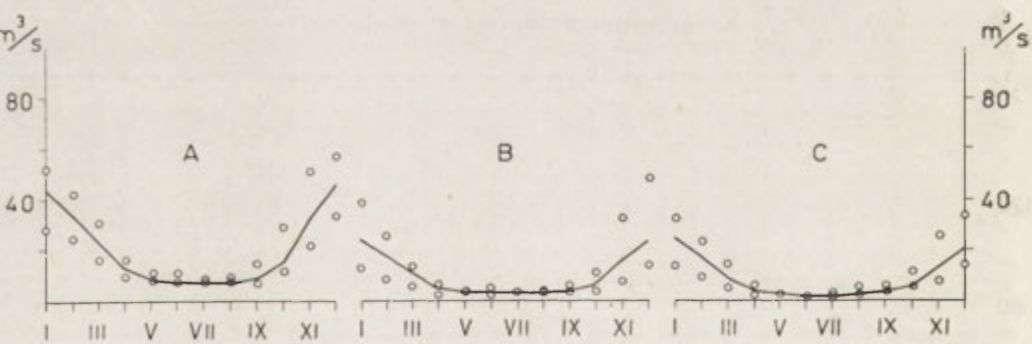

Fig. 18. Débits mensuels caractéristiques
A. R. Aconcagua à Rio Blanco; B. R. Blanco à Rio Blanco; C. R. Blanco à Saladillo
lignes continues — débits moyens mensuels; cercles du haut — maximums moyens mensuels du débit; cercles du bas — minimums moyens mensuels du débit

Les graphiques, illustrant la variabilité des débits maximaux et minimaux mensuels, caractérisent le R. Aconcagua dans le profil Chacabuquito comme un fleuve, dans le bassin duquel le phénomène de l'écoulement se déroule de façon régulière.

C'est un trait typique pour toutes les rivières dont le débit dépend plus des phénomènes thermiques que des précipitations. Nous n'observons une irrégularité que dans la répartition annuelle des maximums mensuels les plus élevés au cours de la période d'observation. Là encore se manifeste un contraste évident entre les grands maximums d'été et ceux, beaucoup moins élevés, d'hiver. Pendant les mois d'hiver cependant, recevant de fortes précipitations, peuvent se produire également d'importantes crues.

Les graphiques du R. Colorado (Fig. 16) et du R. Putaendo (Fig. 17) montrent de grandes analogies avec le graphique de Chacabuquito. Seules les valeurs les plus petites sont nivelées au cours d'une année sur tous les graphiques. Cela prouve la possibilité d'apparition d'étiages en toute saison.

Les graphiques pour trois profils: R. Aconcagua à Rio Blanco, R. Blanco à Rio Blanco et à Saladillo (Fig. 18) confirment le caractère rythmique de l'écou-

TABLEAU 8. Débits minimums et maximums

Rivière et Station	Mesure	Maximums mensuels			Minimums mensuels		
		moyens de à	extrêmes		moyens de à	extrêmes	
R. Aconcagua à Chacabuquito	débit absolu en m^3/s	23,2—114,1	262,0	9,0	10,9—50,8	114,5	3,5
	coefficient du débit	0,71—3,52	8,09	0,28	0,34—1,57	3,53	0,08
	écoulement spécifique l/s, km^2	9,4—51,7	126,3	4,3	4,9—23,9	55,2	1,7
R. Colorado à l'embouchure	débit absolu en m^3/s	6,6—43,2	134,0	0,6	3,4—20,5	64,0	0,6
	coefficient du débit	0,55—3,63	11,26	0,05	0,29—1,72	5,38	0,05
	écoulement spécifique l/s, km^2	8,1—52,8	163,7	0,7	4,2—25,0	78,2	0,7
R. Putaendo à Los Patos	débit absolu en m^3/s	5,6—32,9	96,0	2,0	2,8—11,4	42,8	1,1
	coefficient du débit	0,65—3,83	11,16	0,23	0,33—1,33	4,98	0,13
	écoulement spécifique l/s, km^2	6,6—38,8	113,1	2,4	3,3—13,4	50,4	1,3

lement, bien que les valeurs moyennes aient été calculées à partir de périodes très courtes (7—11 ans). Ce trait est donc typique pour la partie supérieure du bassin du R. Aconcagua.

Au déroulement régulier des phénomènes dans le temps s'oppose la variabilité d'intensité du débit. Le débit maximal de chaque mois peut être sensiblement inférieur au débit minimal du même mois mais d'une autre année. Les maximums du débit du R. Colorado et du R. Putaendo pendant les mois d'été n'atteignent parfois pas les valeurs minimales des débits correspondant aux mois d'hiver, abondant en eau.

Cette irrégularité du débit ne se marque pas aussi rigoureusement dans tous les bassins. Les coefficients du débit (quotient du débit par le module) varient dans les limites 0,08—8,09 à Chacabuquito, 0,13—11,16 à Los Patos, et 0,05—11,26 à l'embouchure du R. Colorado (Tabl. 8). Les coefficients d'irrégularité, calculés à partir des débits extrêmes sont les suivants: R. Aconcagua 75, R. Putaendo 87, et R. Colorado 223.

Chaque mois — même en été — le débit du R. Colorado peut être fortement réduit. Les écoulements spécifiques tombent alors au dessous de 1 l/s, km^2. Des valeurs semblables ne sont notées dans aucune autre station, même pendant les étiages les plus rigoureux. Ces valeurs exceptionnellement basses de l'écoulement du bassin du R. Colorado sont dues aux prises d'eau en amont de la station hydrométrique. Les effets de cette act'vité se font sentir le plus fortement dans les périodes de sécheresse, quand les besoins en eau augmentent particulièrement.

Les courtes périodes d'observation ne favorisent pas l'analyse des débits extrêmes. Cependant, d'après les données existantes, il faut croire que les débits maximaux n'atteignent pas des valeurs importantes. De plus important écoulement spécifique noté fut de 348 l/s, km^2, à l'embouchure du R. Blanco (385 km^2 de surface). Les écoulements spécifiques dus aux crues des autres rivières ne dépassèrent pas, pendant les périodes d'observation, 200 l/s, km^2. Les débits instantanés atteignent certainement des valeurs plus importantes, mais les crues, dans le cours supérieur du R. Aconcagua, sont malgré tout modérées. La faiblesse des crues est due à deux facteurs: faiblesse des précipitations et précipitations hivernales qui, dans les hautes montagnes, n'alimentent pas directement l'écoulement. Par contre, la fonte des neiges et des glaciers s'étend sur une longue période, par suite des grandes différences d'altitude.

L'analyse des matériaux statistiques montre que les phases rythmiques de l'écoulement pendant l'année constituent le trait caractéristique de la partie supérieure du bassin du R. Aconcagua. L'irrégularité du débit, sensible surtout dans les bassins dépourvus de glaciers, se manifeste par la possibilité d'apparition de très faibles debits en toute saison. Les débits les plus importants en comparaison avec ceux des rivières à régime semblable sont faibles. Il faut souligner qu'aucun des profils hydrométriques étudiés ne reflète intégralement les conditions naturelles, car la prise d'eau pour l'activité humaine se fait en amont des stations étudiées.

6. FRÉQUENCE DES DÉBITS MAXIMAUX ET MINIMAUX ANNUELS ET MENSUELS

Afin de compléter l'analyse des débits maximaux, nous en avons calculé la fréquence dans les deux stations suivantes: Chacabuquito sur le R. Aconcagua et Los Patos sur le R. Putaendo. Nous avons adopté deux méthodes: celle de Dębski et la courbe experimentale de fréquence selon la formule

$$p\% = \frac{m - 0,3}{N + 0,4} \cdot 100$$

où m = numero d'ordre d'années classées d'après la valeur progresive des débits et N = nombre d'années.

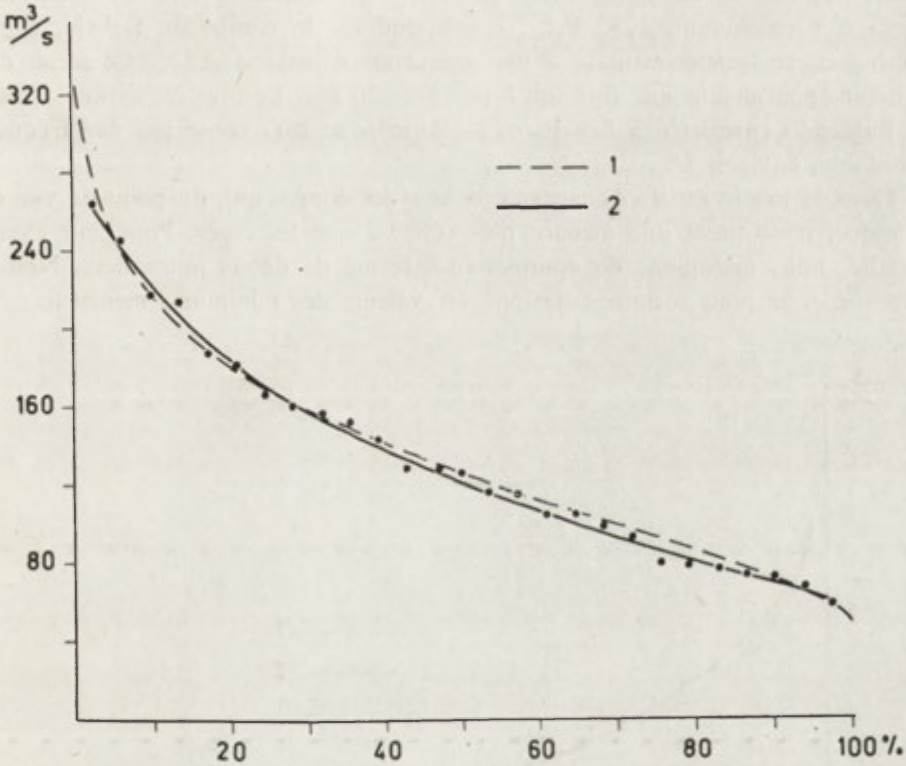

Fig. 19. Distribution statistique des débits maximaux annuels du R. Aconcagua à Chacabuquito
1. Courbe de Dębski; 2. Courbe expérimentale

Les courbes obtenues d'après les deux méthodes se présentent de la même façon (Fig. 19 et 20), et les débits de probabilité donnée ont des valeurs analogues (Tabl. 9).

Nous n'avons pas pris en considération dans le tableau la probabilité inférieure à 1% (eau séculaire), car, compte tenu du petit nombre d'années, l'erreur de calcul augmente considérablement en même temps que diminue la fréquence du phénomène. Les données calculées d'après la méthode de Dębski sont présentées avec une erreur possible évaluée selon la formule:

$$\sigma = \zeta \frac{\bar{Q}_{max} C_v}{\sqrt{N}}$$

où Q_{max} = valeur moyenne des maximums annuels, C_v — coefficient de variabilité, N — nombre d'années, et ζ — valeur dépendant de la fréquence donnée et du coefficient d'asymétrie.

Les résultats obtenus confirment le peu d'importance des crues dans le bassin du R. Aconcagua. Le maximum le plus important du débit noté sur le R. Aconcagua à Chacabuquito, 262 m³/s, correspond sur la courbe de Dębski, comme sur la courbe expérimentale à une fréquence d'environ 3,5%. Ce serait donc le débit apparaîssant une fois sur à peu près 30 ans. Le plus important débit du R. Putaendo enregistré à Los Patos — 96 m³/s se caractérise par une fréquence semblable, environ 3%.

Dans le bassin du R. Aconcagua, ce sont les étiages qui, du point de vue économique, constituent une menace plus sérieuse que les crues. Pour leur examen détaillé, nous manquons de données sous forme de débits journaliers. Nous ne disposons que pour certaines stations des valeurs des minimums mensuels.

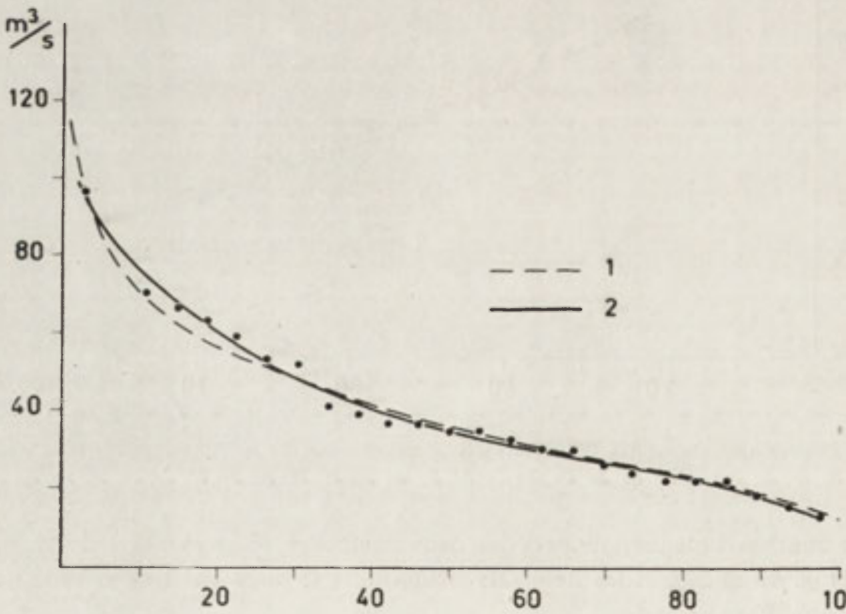

Fig. 20. Distribution statistique des débits maximaux annuels du R. Putaendo à Los Patos
1. Courbe de Dębski; 2. Courbe expérimentale

TABLEAU 9. Débits maximaux annuels en m³/s d'après leur fréquence

Station	Courbe	1	10	50	90	99
		%				
Chacabuquito	de Dębski	325±78	217±29	125±13	72	50
	expérimentale	302	218	122	68	52
Los Patos	de Dębski	115±32	70±12	36±5	18	13
	expérimentale	115	73	34	18	12

La fréquence des débits minimaux annuels est calculée d'après la formule de Gumbel-Kaczmarek[3].

$$Qmin_p = \overline{Q}\,min + AS$$

où $Qmin_p$ = débit minimal à fréquence p, $\overline{Q}$ min = moyenne des débits minimaux annuels observés, A = valeur dépendant de la fréquence p, S — écart type des debits minimaux.

Pour Chacabuquito

$$\overline{Q}min = \frac{\Sigma Qmin}{N} = \frac{235,9}{25} = 9,44 \text{ m}^3/\text{s}$$

et

$$S = \sqrt{\frac{\sum Qmin^2}{N} - (\overline{Q}min)^2} = 2,64 \text{ m}^3/\text{s}$$

La partie gauche du tableau 10 donne les résultats des autres calculs.

TABLEAU 10. Débits min. annuels en m³/s d'après leur fréquence; R. Aconcagua à Chacabuquito

p%	A	$Qmin_p$	B	Δ_p pour $\alpha = 0,8$	Δ_p pour $\alpha = 0,9$	$Qmin_p$ pour $\alpha = 0,8$	$Qmin_p$ pour $\alpha = 0,9$
0,0	—1,912	4,4	1,355	0,92	1,18	3,5—5,3	3,2—5,6
0,5	—1,759	4,8	1,272	0,86	1,11	3,9—5,7	3,7—5,9
1,0	—1,696	5,0	1,240	0,84	1,08	4,2—5,8	3,9—6,1
2,0	—1,606	5,2	1,195	0,81	1,04	4,4—6,0	4,2—6,2
5,0	—1,424	5,7	1,111	0,75	0,97	4,9—6,5	4,7—6,7
10,0	—1,211	6,2	1,027	0,69	0,89	5,5—6,9	5,3—7,1
20,0	—0,893	7,1	0,939	0,64	0,82	6,5—7,7	6,3—7,9
50,0	—0,114	9,1	0,967	0,66	0,84	8,4—9,8	8,3—9,9
80,0	0,824	11,6	1,379	0,93	1,20	10,7—12,5	10,4—13,8
90,0	1,362	13,0	1,702	1,15	1,48	11,8—14,2	11,5—14,5
99,0	2,719	16,6	2,618	1,77	2,27	14,8—18,4	14,3—18,9

[3] Kaczmarek, Z., Częstotliwość przepływów niżówkowych (Frequency of Droughts) *Przegląd Geofizyczny, II (X)*, (1957).

Les valeurs $Q\min_p$, acquises d'après une série de 25 ans, ne déterminent pas de façon stricte l'importance des débits minimaux. Afin d'obtenir des résultats plus sûrs, on a calculé les intervalles, dans lesquelles devraient s'insérer les débits minimauxà fréquence donnée pour les deux seuils de confiance $\alpha = 0,8$ et $\alpha = 0,9$ (c'est à dire avec 80 et 90% de chances). Les calculs sont effectués d'après la formule

$$\Delta p = \pm t \cdot B \frac{S}{N}$$

où t = valeur dépendant du seuil de confiance; pour $\alpha = 0,8$ $t = 1,282$ et pour $\alpha = 0,9$ $t = 1,645$. B dépend de la valeur de p requise. Les résultats acquis sont donnés dans la partie droite du tableau 10.

Il ressort du tableau 10 que le débit du R. Aconcagua à Chacabuquito le plus faible entre, avec une sécurité de 80%, dans les limites 3,5—5,3 m^3/s, et, avec une sécurité de 90%, dans les limites 3,2—5,6 m^3/s. Le débit minimal à fréquence 50%, apparaîssant donc tous les deux ans en moyenne, devrait, avec une sécurité de 90%, tomber au dessous de 9,9 m^3/s.

On a calculé par cette même méthode la fréquence des débits minimaux annuels du R. Putaendo à Los Patos (Tabl. 11).

TABLEAU 11. Débits minimaux annules en m^3/s d'après leur fréquence; R. Putaendo à Los Patos

p%	$Q\min_p$	Δ_p pour $\alpha = 0,9$	$Q\min_p$ pour $\alpha = 0,9$
0,0	1,1	0,26	0,9—1,4
1,0	1,3	0,24	1,0—1,5
5,0	1,45	0,21	1,2—1,7
10,0	1,6	0,20	1,4—1,8
50,0	2,3	0,19	2,1—2,5
90,0	3,3	0,33	3,0—3,7
99,0	4,3	0,51	3,8—4,8

D'après les données dont nous disposons, nous pouvons conclure que les débits minimaux annuels du R. Putaendo à Los Patos devraient, avec une sécurité de 90%, entrer dans les limites 0,9—4,8 m^3/s.

Les débits les plus faibles enregistrés pendant la période d'observation dans les deux stations entrent dans les limites des plus petits débits possibles. La courbe expérimentale de la probabilité des débits minimaux pour le profil de Los Patos (fig. 21) confirme le résultat acquis par les calculs. On ne peut en dire autant de la courbe pour le R. Aconcagua à Chacabuquito. Cette courbe là, tracée à l'échelle normale, se caractérise par des bords extrêmes fortement arqués. A l'échelle de probabilité, les points extrêmes ne sont pas disposés en ligne droite (Fig. 22). Cette irrégularité peut être due, sans compter une série d'observation trop courte, à l'influence humaine sur le débit faible. Cette influence doit se faire sentir le plus fortement dans les années les plus sèches, quand la prise d'eau réduit considérablement les débits déjà extrêmement faibles. Dans les années exceptionnellement abondantes en eau, l'exploitation économique de l'eau influe le moins sur son écoulement naturel. C'est pourquoi les minimums annuels les plus élevés pendant la période d'observation peuvent s'écarter le plus des valeurs moyennes.

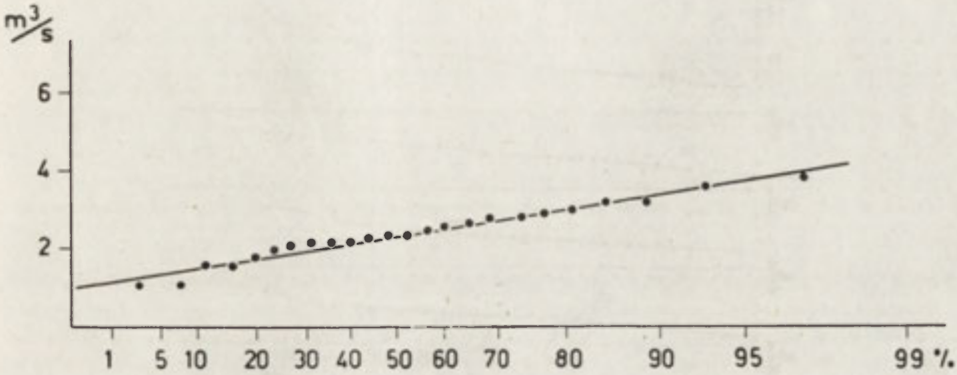

Fig. 21. Distribution statistique des débits minimaux annuels du R. Putaendo à Los Patos

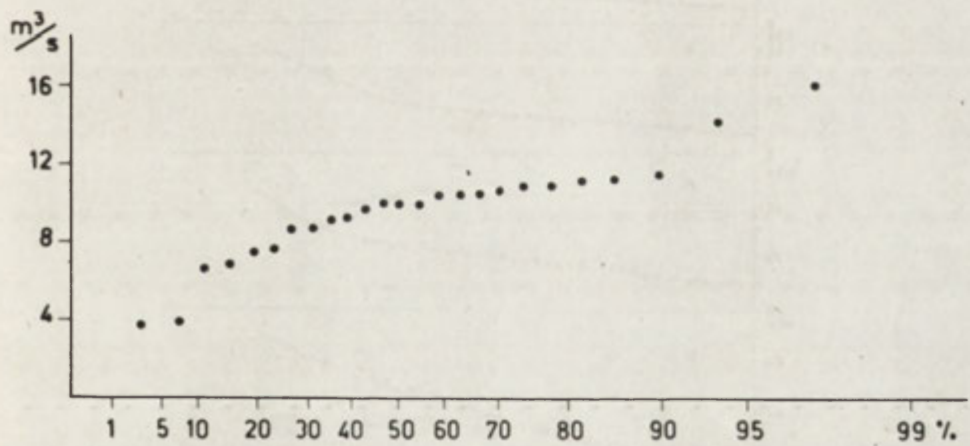

Fig. 22. Distribution statistique des débits minimaux annuels du R. Aconcagua à Chacabuquito

Considérant le problème des minimums annuels dans le bassin du R. Aconcagua, il faudrait donc parler non des débits naturels, mais de ceux qui, dans une période donnée, dépendent de la prise d'eau à des fins économiques.

Les débits minimaux annuels dans le bassin du R. Aconcagua correspondent, en général, à la période d'automne et d'hiver, quand les besoins en eau sont les

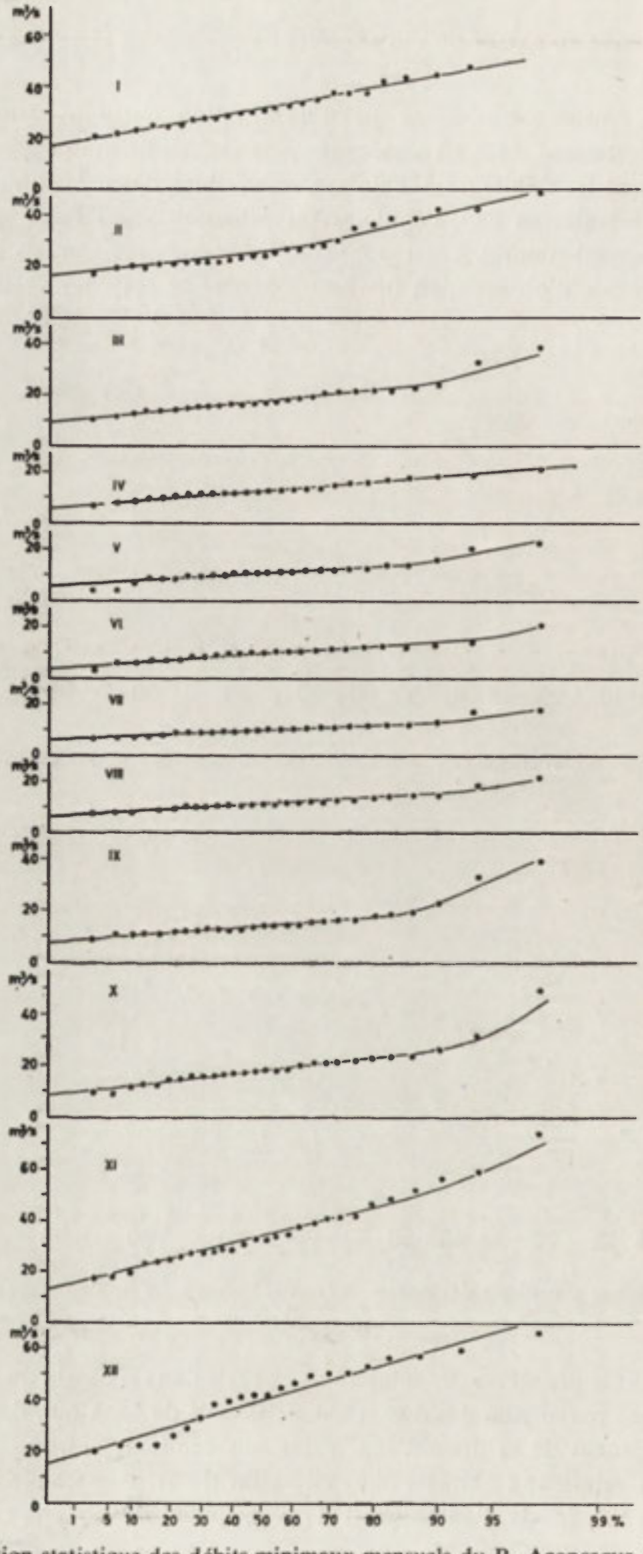

Fig. 23. Distribution statistique des débits minimaux mensuels du R. Aconcagua à Chacabuquito

plus faibles. Infiniment plus pénible est le manque d'eau en été. On a donc également soumis à analyse les débits minimaux mensuels du R. Aconcagua à Chacabuquito.

On a, pour les différents mois, tracé une courbe expérimentale des débits minimaux d'après la formule

$$p\% = \frac{m - 0,3}{N + 0,4} : 100$$

en portant, sur l'axe des abscisses, l'échelle de probabilité (Fig. 23). Sur les graphiques correspondant à cinq mois, d'avril à août, presque tous les points sont disposés en ligne droite. Les courbes empiriques des autres mois (sauf décembre) s'arquent plus ou moins fortement pour une fréquence d'environ 70—90%. Les derniers valeurs sont trop élevés et les points qui leur correspondent sur les graphiques sont placés trop haut. Sur tous ces graphiques on peut lire assez nettement les débits minimaux à petite fréquence. Le rejet des valeurs les plus élevés lors des tracés des courbes influe de façon insignifiante sur l'importance des débits minimaux lus sur le graphique. On a procédé ainsi pour le mois de janvier et nous n'avons obtenu une différence de valeur infime que pour les débits à fréquence 50%.

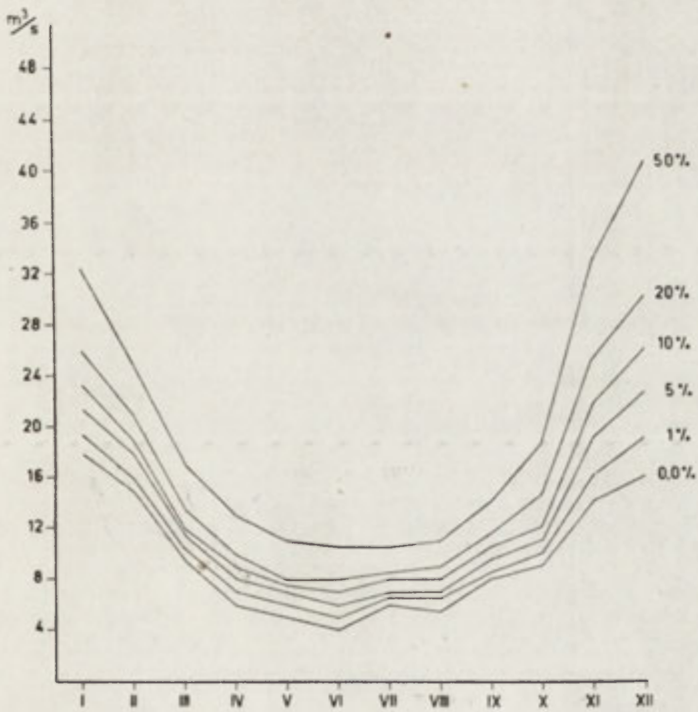

Fig. 24. Débits minimaux mensuels du R. Aconcagua à Chacabuquito d'après leur frequence

Le problème ne se complique qu'en décembre. Les valeurs ne forment pas un ensemble homogène. Les valeurs les plus élevées du débit minimal mensuel correspondent aux années pendant lesquelles les crues duraient tout le mois. C'est pourquoi nous avons tracé une droite pour ce mois, après avoir écarté les données

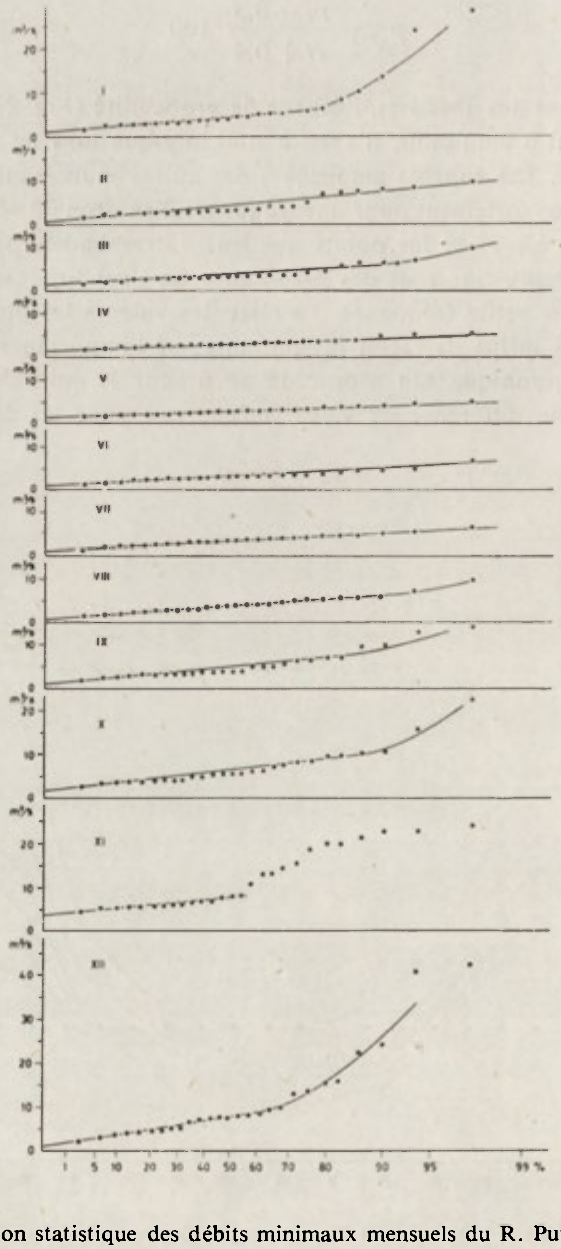

Fig. 25. Distribution statistique des débits minimaux mensuels du R. Putaendo à Los Patos

de six années, pendant lesquelles les minimums avaient une valeur supérieure à celle des maximums de ce mois pendant les années pauvres en eau.

Les débits mensuels d'après leur frequence, lus sur les graphiques sont notés dans le tableau 12 et représentés graphiquement (Fig. 24).

TABLEAU 12. Débits minimaux mensuels en m³/s d'après leur fréquence; R. Aconcagua à Chacabuquito

Mois	Q min$_p$ en m³/s					
	0,0%	1,0%	5,0%	10,0%	20,0%	50,0%
I	18,0	19,5	21,5	23,5	26,0	32,5
II	15,0	16,0	18,0	19,0	21,0	25,0
III	9,5	10,5	11,5	12,0	13,5	17,0
IV	6,0	7,0	8,0	9,0	10,0	13,0
V	5,0	6,0	7,0	7,5	8,0	11,0
VI	4,0	5,0	6,0	7,0	8,0	10,5
VII	5,5	6,5	7,0	8,0	8,5	10,5
VIII	6,0	6,5	7,0	8,0	9,0	11,0
IX	8,0	8,5	9,5	10,5	11,5	14,0
X	9,0	10,0	11,0	12,0	14,5	18,5
XI	14,0	16,0	19,0	21,0	25,0	32,5
XII	16,0	19,0	22,5	26,0	30,0	40,5

Les minimums les plus faibles et en même temps les moins variables apparaîssent pendant les mois d'hiver. Pendant le printemps et l'été, quand les besoins en eau sont les plus pressants, les débits minimaux sont, à vrai dire, plus élevés, mais se distinguent par une plus grande variabilité.

Les débits minimaux mensuels du R. Putaendo à Los Patos, déterminés par les courbes expérimentales (Fig. 25), montrent une variabilité plus faible. Le mois le moins exposé aux étiages est novembre. Les débits très faibles peuvent apparaître au cours de tous les autres mois (Tabl. 13 et Fig. 26).

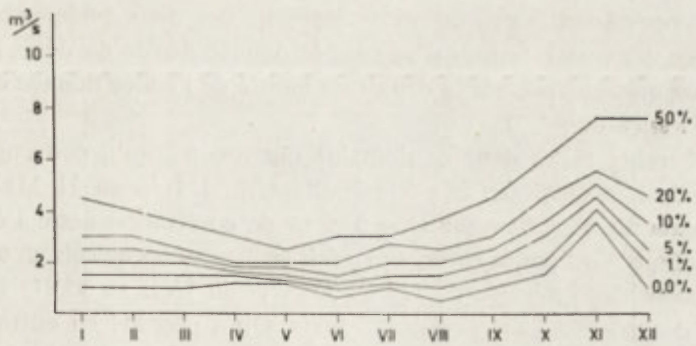

Fig. 26. Débits minimaux mensuels du R. Putaendo à Los Patos d'après leur fréquence

TABLEAU 13. Débits minimaux mensuels en m^3/s d'après leur fréquence; R. Putaendo à Los Patos

Mois	Q min$_p$ en m^3/s					
	0,0%	1,0%	5,0%	10,0%	20,0%	50,0%
I	1,0	1,5	2,0	2,5	3,0	4,5
II	1,0	1,5	2,0	2,5	3,0	4,0
III	1,0	1,5	2,0	2,2	2,5	3,5
IV	1,2	1,5	1,6	1,8	2,0	3,0
V	1,2	1,3	1,5	1,8	2,0	2,5
VI	0,7	1,0	1,2	1,5	2,0	3,0
VII	1,0	1,2	1,5	2,0	2,7	3,0
VIII	0,5	1,0	1,5	2,0	2,5	3,7
IX	1,0	1,5	2,0	2,5	3,0	4,5
X	1,5	2,0	3,0	3,5	4,5	6,0
XI	3,5	4,0	4,5	5,0	5,5	7,5
XII	1,0	2,0	2,5	3,5	4,5	7,5

7. RELATION ENTRE ÉCOULEMENT ET PRÉCIPITATIONS

Dans la partie supérieure du bassin du R. Aconcagua, il n'y a pas de statione météorologiques qui fassent de longues séries d'observation. Cela empêche l'étuds des relations entre l'écoulement et les précipitations se manifestant dans cette même zone. Par suite du manque de données concernant les précipitations des hautes montagnes, nous avons décidé d'étudier les relations entre l'écoulement de la partie supérieure du bassin, limitée par le profil du Chacabuquito, et les précipitations notées dans la zone pré-montagneuse. On a choisi la station Los Andes à cause de sa situation et d'une longue série d'observation.

L'élaboration du graphique des débits moyens mensuels du R. Aconcagua à Chacabuquito et des précipitations annuelles à Los Andes, au cours des années 1936—1951 (pour celles-ci nous possédons des données tant hydrométriques que pluviométriques) nous a servi de premier critère tendant à vérifier l'existence de la relation étudiée. La superposition des graphiques, avec un délai de six mois, permet de constater une concordance frappante des deux phénomènes (Fig 27). L'importance des précipitations d'une année donnée décide du débit pendant l'année hydrologique, embrassant la deuxième moitié de l'année donnée et la première moitié de la suivante.

Les recherches faites dans ce domaine ont montré qu'il convenait d'adopter, comme année hydrologique, la période allant du 1 Juin au 31 Mai. On obtient alors la valeur la plus élevée du coefficient de corrélation entre l'écoulement et les précipitations de l'année civile. On a fait également les calculs en tenant compte de l'écoulement de la période du 1.V au 30.IV et du 1.VII au 30.VI; ils ont donné cependant des résultats un peu moins bons. On a procédé en outre à des essais d'emploi d'autres périodes de précipitations que l'année civile. Ils n'ont cependant pas permis d'obtenir de meilleures corrélations avec l'écoulement.

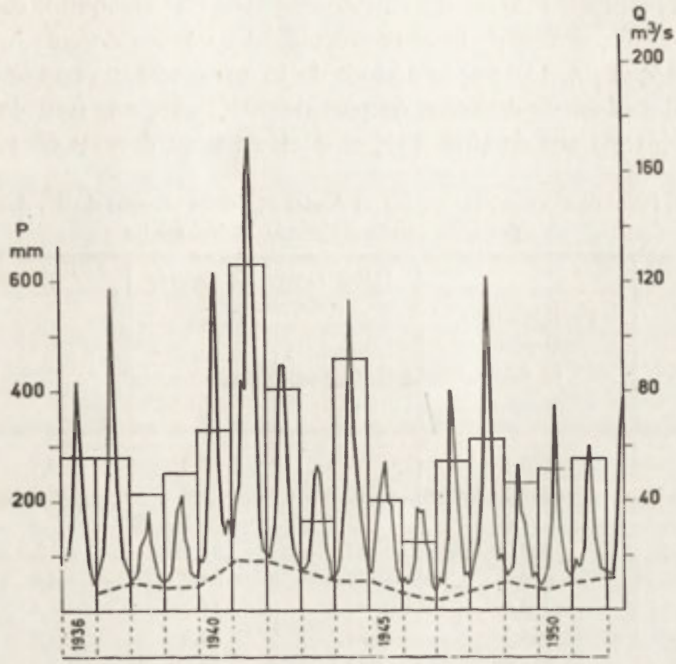

Fig. 27. Précipitations à Los Andes et débits moyens mensuels du R. Aconcagua à Chacabuquito
Le graphique des débits est décalé de 6 mois par rapport à la somme des précipitations

Nous avons porté en coordonnées les données des précipitations et de l'écoulement pour 15 ans (Fig. 28). Le coefficient de corrélation de deux variables est grand, 0,907. L'écart type du coefficient:

$$\sigma r = \frac{1 - r^2}{\sqrt{N-1}}$$

est de 0,047.

La relation entre l'écoulement de l'année hydrologique et les précipitations de l'année civile s'exprime par l'équation suivante

$$Q_{VI-V} = 0{,}1025\, P + 3{,}5$$

ou

$$H_{VI-V} = 1{,}56\, P + 53{,}2$$

où P = précipitations en mm pendant l'année civile, Q_{VI-V} = débit moyen pendant l'année hydrologique en m³/s, et H_{VI-V} = indice de l'écoulement en mm.

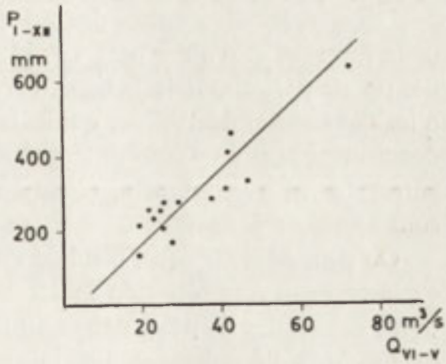

Fig. 28. Corrélation entre somme des précipitations annuelles à Los Andes et débit moyen du R. Aconcagua à Chacabuquito au cours de l'année hyrodlogique

Les débits annuels moyens du R. Aconcagua à Chacabuquito, calculés d'après la formule donée, diffèrent de ceux calculés d'après les donnés hydrometriques de 5,8 à 33,3% (Tabl. 14). Sur la période de 15 ans étudiés, à une seule année correspondent des résultats différant de plus de 30%; cinq ans sont dans les limites de 20 à 30%, trois ans de 10 à 20% et quatre ans au dessous de 10%.

TABLEAU 14. Précipitations annuelles à Los Andes et débits moyens du R. Aconcagua à Chacabuquito pendant l'année hydrologique

Année	Précipitations annuelles en mm	Débit moyen de l'année hydr. en m³/s		$Q' - Q$	$\frac{(Q' - Q)}{Q}$ 100%
		à partir des données hydr. Q	à partir de la formule Q'		
1937	280,1	37,9	32,2	—5,7	15,0
1938	212,3	19,7	25,3	5,6	28,4
1939	251,0	21,9	29,2	7,3	33,3
1940	328,0	47,1	37,1	—10,0	21,2
1941	628,0	72,3	67,9	—4,4	6,1
1942	402,0	42,3	44,7	2,4	5,8
1943	164,2	28,2	20,3	—7,9	28,0
1944	458,0	43,1	50,4	7,3	16,9
1945	202,6	25,8	24,3	—1,5	5,8
1946	127,1	19,7	16,5	—3,2	16,2
1947	272,6	29,5	31,4	1,9	6,4
1948	308,7	41,6	35,1	—6,5	15,6
1949	231,5	23,3	27,2	3,9	16,7
1950	256,7	24,7	29,8	5,1	20,6
1951	276,4	26,3	31,8	5,5	20,9

Les grandes divergences des valeurs du débit moyen calculé d'une part à l'aide de la formule, et d'autre part à l'aide des données hydrométriques, et la dispersion des points par rapport à la ligne de régression — tout cela fait penser à l'existence d'un facteur supplémentaire qui influe de façon systématique sur la relation entre écoulement et précipitations. Parmi les facteurs compliquant cette relation peuvent entrer en jeu avant tout la rétention souterraine et la température. Toutes deux sont soumises à analyse.

On peut admettre que, pendant l'hiver, l'alimentation du fleuve est due presque exclusivement à la rétention souterraine. Bien que ce soit une période de précipitations, des chutes de neige dans les montagnes ne contribuent pas cependant immédiatement à l'écoulement. Les minimums mensuels du débit pendant la période hivernale caractérisent, par conséquent, l'importance de l'alimentation souterraine. Sur la fig. 27 on a dessiné, seulement d'après les minimums des mois d'hiver, l'alimentation par la rétention. En fait, cette alimentation est plus importante, car, pendant les crues d'été, l'écoulement souterrain augmente sans aucun doute.

Cela n'a cependant pas une grande importance pour nos études, étant donné que nous ne nous intéressons qu'à la partie de l'écoulement souterrain qui augmente le module de l'année hydrologique. Cette partie — là est caractérisée par les minimums précédant ou commençant l'année hydrologique.

L'analyse du graphique n'indique pas le rôle décisif de la rétention dans l'écoulement. Donc, parmi les années 1937, 1940, 1941, 1943, et 1948 qui dénotent un excédent de l'écoulement par rapport aux précipitations (Fig. 28), l'année 1940 suit deux années assez pauvres en précipitations, pendant lesquelles les réserves souterraines n'ont pas augmenté. Il en est de même pour l'année 1948. Certaines années, ayant un écoulement trop faible par rapport aux précipitations, par ex. les années 1942 et 1949, suivent des années riches en précipitations et qui ont des réserves souterraines accrues. D'aprés les matériaux que nous possédons, nous ne pouvons pas conclure de la grande influence jouée par la rétention souterraine sur l'importance de l'écoulement et ne pouvons déterminer cette influence.

L'influence de la température n'est pas unidirectionnelle. Les fortes chaleurs de l'été augmentent l'évaporation, mais causent également une augmentation de la fonte des glaciers et des neiges éternelles. Dans les fleuves à régime dépendant des neiges et des glaciers ce deuxième processus semble plus efficace. Les années ayant un écoulement important devraient, par là, se caractériser par de fortes températures correspondant à la période chaude de l'année.

Les matériaux dont nous disposons ne confirment cependant pas nos hypothèses de façon évidente. Autant pour les années se caractérisant par un écoulement plus fort que les précipitations, que pour celles qui connaîssent le phénomène inverse, les températures moyennes des mois d'été sont fortement différenciées. Dans le groupe des années à écoulement trop faible, les températures moyennes de la période estivale (XII—II) à Los Andes oscillent entre 21—22,2^{0}, et, dans le groupe des années à écoulement excessif, entre 21,8—23,0^{0}. Les calculs de corrélation auraient peut-être montré l'existence d'un rapport entre l'importance de l'écoulement et la température de l'été. Nous ne les avons cependant pas faits, car ils n'auraient pas eu de signification pratique pour la prévision de l'écoulement.

Les différences de température pendant la période chaude influent sur la répartition de l'écoulement dans le temps. La plus forte température moyenne mensuelle apparaît d'habitude en janvier, plus rarement en décembre. Ces deux mois se caractérisent également, en général, par les débits moyens le plus grands. Il faut tenir compte du fait qu'il correspond plus souvent à décembre, mais qu'il peut également paraître en novembre. Le rapport entre la répartition de l'écoulement sur les mois et la température est assez évidente. On note un maximum d'écoulement plus précoce pendant les années ayant un printemps relativement chaud. Les fortes températures de novembre décident du fait que c'est pendant ce mois qu'apparaît l'écoulement le plus fort (1946, 1947, et 1949), ou en décembre (1943, 1948), bien que la plus forte chaleur corresponde au mois de janvier. En règle générale, après les chaleurs de novembre et de décembre, l'écoulement de janvier n'atteint pas des valeurs maximales. Il peut cependant se maintenir à un niveau élevé, si les réserves en neige n'ont pas été épuisées. Dans ce cas, l'abondance des précipitations de l'hiver précédent joue un rôle décisif. Après des années à fortes précipitations (1941, 1942 et 1944), un écoulement élevé se prolonge jusqu'en février de l'année suivante. Les écoulements de février s'avèrent donc être en rapport plus étroit avec les précipitations qu'avec la température, qui n'influe sur l'écoulement de ce mois de façon sensible que dans les années, pendant lesquelles les réserves de neige n'ont pas été plus tôt nettement diminuées.

En tenant compte, lors de l'étude du rapport entre écoulement et précipitations, de l'influence modificatrice de deux facteurs: rétention souterraine et température moyenne de la période estivale, nous pouvons expliquer certaines irrégularités de corrélation, mais cependant pas toutes. La difficulté que nous avons à trouver des rapports étroits réside sûrement dans le manque de documents complets et dans le fait que nous nous sommes servi, pour effectuer des calculs, des données concernant les précipitations d'une station, située hors de la partie du bassin envisagée. On peut supposer que l'emploi de données concernant les précipitations d'une station bien choisie dans la zone haut-montagneuse, permettrait de déterminer plus précisément le rapport entre écoulement et précipitations.

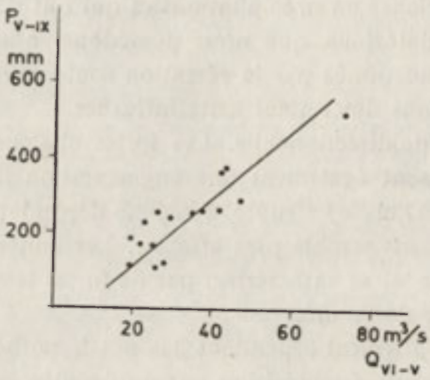

Fig. 29. Corrélation entre somme des précipitations de 5 mois (V—IX) à Los Andes et débit moyen du R. Aconcagua à Chacabuquito au cours de l'année hydrologique

Pour prévoir de façon pratique l'écoulement d'après les précipitations notées, il est plus avantageux de s'appuyer non sur les précipitations de l'année cuivile, mais sur la somme des précipitations d'une période plus courte. On a constaté, d'après les essais, que, pour l'exemple donné, on peut se servir des précipitations de cinq mois, de mai à septembre. La corrélation entre les précipitations de cette période et l'écoulement de l'année hydrologique est sensible (Fig. 29). Le coefficient de corrélation est de 0,880, et l'écart type du coefficient de 0,060. L'équation permettant de calculer le débit annuel moyen se présente comme suit

$$Q_{\mathrm{VI-V}} = 0{,}11\, P_{\mathrm{V-IX}} + 7{,}1$$

où $Q_{\mathrm{VI-V}}$ = débit moyen de l'année hydrologique en m³/s, et $P_{\mathrm{V-IX}}$ = précipitations en mm de cinq mois, durant la période commençant un mois avant l'année hydrologique.

Les débits calculés d'après la formule donnée (Tabl. 15) divergent assez considérablement des données de départ, de 2,5 à 39,6%, (soit en moyenne 18,4%).

TABLEAU 15. Précipitations de 5 mois (V—IX) à Los Andes et débits moyens du R. Aconcagua à Chacabuquito au cours de l'année hydrologique

Année hydrol.	Précipitations V—IX	Débit moyen de l'année hydrol. m³/s		$Q - Q'$	$\frac{(Q-Q')}{Q}$ 100%
		à partir de données hydromètriques Q	à partir de la formule Q'		
1937	275,0	37,9	35,4	—2,5	6,6
1938	185,0	19,7	27,5	7,8	39,6
1939	168,0	21,9	25,6	3,7	16,9
1940	285,0	47,1	38,5	—8,6	18,2
1941	520,0	72,3	64,3	—8,0	11,1
1942	362,0	42,3	46,8	4,5	10,6
1943	113,0	28,2	19,5	—8,7	30,9
1944	373,6	43,1	48,8	5,7	13,2
1945	104,1	25,8	18,6	—7,2	27,9
1946	109,8	19,7	19,2	—0,5	2,5
1947	237,0	29,5	33,2	3,7	12,5
1948	261,5	41,6	35,9	—5,7	13,7
1949	224,5	23,3	31,8	8,5	36,5
1950	165,0	24,7	25,3	0,6	4,3
1951	251,2	26,3	34,7	8,4	31,9

Dans un but pratique, on a procédé à une série d'essais visant à déterminer les rapports entre les précipitations annuelles, ou d'une partie de l'année seulement, et l'écoulement d'une partie de l'année. Ces essais prouvent qu'il est possible, dans une certaine partie de l'année, de prévoir l'écoulement. Deux essais sont particulièrement intéressants. Il existe une corrélation évidente entre les précipitations de toute l'année à Los Andes et l'écoulement du bassin (profil Chacabuquito) pendant une période de six mois les plus riches en eau (Fig. 30). L'écoulement le plus fort correspond presque toujours à la période allant d'octobre à mars, exceptionnellement de septembre à février. Le coefficient de corrélation est de 0,899, l'écart type du coefficient étant de 0,052. L'équation de régression se présente comme suit

$$Q_{6m} = 0{,}162\,P + 2{,}8$$

où Q_{6m} = débit moyen en m³/s des six mois les plus riches en eau pendant l'année hydrologique, P = précipitations de l'année civile en mm.

Les résultats calculés d'après la formule proposée (Tabl. 16) donnent des divergences avec les données hydrométriques allant de 0,2 à 40,9% (en moyenne 19,3%).

Le deuxième essai concerne les précipitations à Los Andes pendant une période de cinq mois, de mai à septembre, et le débit moyen de trois mois, de septembre

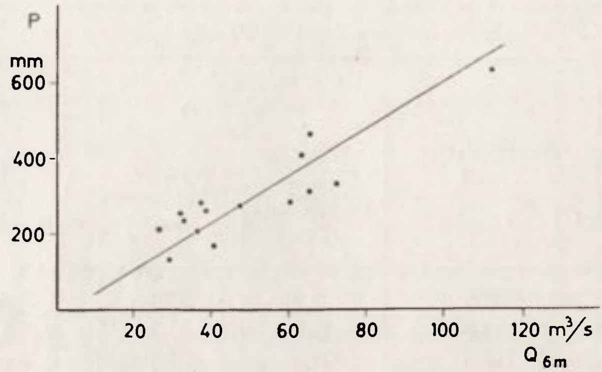

Fig. 30. Corrélation entre somme des précipitations annuelles à Los Andes et débit moyen du R. Aconcagua à Chacabuquito au cours des 6 mois les plus riches en eau

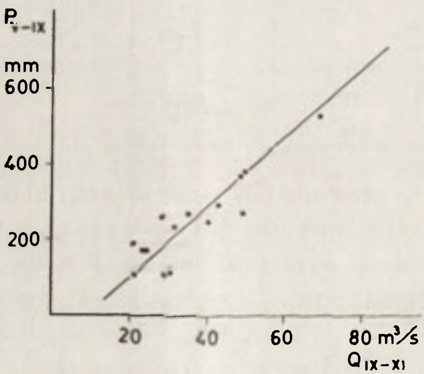

Fig. 31. Corrélation entre somme des précipitations de 5 mois (V—IX) à Los Andes et débit moyen du R. Aconcagua à Chacabuquito au cours de 3 mois (IX—XI)

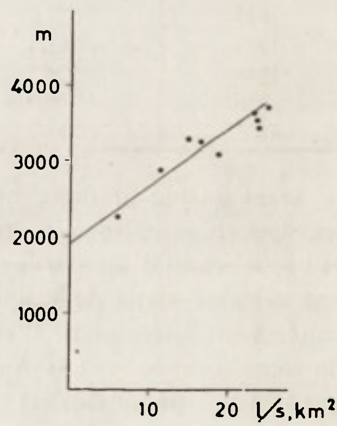

Fig. 32. Corrélation entre hauteur moyenne des bassins partiels et écoulement spécifique

à Novembre (Fig. 31). Le coefficient de corrélation est dans ce cas de 0,896, et l'écart type du coefficient de 0,053. L'équation se présente comme suit

$$Q_{IX-XI} = 0{,}109\, P_{V-IX} + 10{,}75$$

Les valeurs calculées (Tabl. 17) divergent des valeurs de départ de 0,4 à 45,8% (en moyenne 15,5%). Une erreur importante concerne l'année 1938, pendant laquelle de fortes précipitations sont tombées en mai (106 mm). Une partie des pré-

TABLEAU 16. Précipitations annuelles à Los Andes et débit moyen du R. Aconcagua à Chacabuquito en m^3/s au cours des 6 mois les plus riches en eau

Année hydrol.	Précipitations annuelles en mm	Débit moyen de 6 mois en m^3/s		$Q' - Q$	$\frac{(Q'-Q)}{Q}$ 100%
		à partir des données hydrométriques Q	à partir de la formule Q'		
1937	280,1	59,6	48,2	—11,4	19,1
1938	212,3	26,4	37,2	10,8	40,9
1939	251,0	31,6	43,5	11,9	37,7
1940	328,0	72,0	55,9	—16,1	22,4
1941	628,0	111,8	104,5	—7,3	6,5
1942	402,0	62,8	67,9	5,1	8,1
1943	164.2	40,3	29,4	—10,9	27,0
1944	458,0	64,7	77,0	12,3	19,0
1945	202,6	36,1	35,6	—0,5	1,4
1946	127,1	29,3	23,4	—5,9	20,1
1947	272,9	47,1	47,0	0,1	0,2
1948	308,7	64,8	52,8	—12,0	18,5
1949	231,5	32,7	40,3	7,6	23,2
1950	256,7	37,7	44,4	6,7	17,8
1951	276,4	37,1	47,6	10,5	28,3

TABLEAU 17. Somme des précipitations de 5 mois (V—IX) à Los Andes et débit moyen du R. Aconcagua à Chacabuquito au cours de trois mois (IX—XI)

Année	Précipitations de 5 mois en mm	Débit moyen de 3 mois en m^3/s		$Q' - Q$	$\frac{(Q'-Q)}{Q}$ 100%
		à partir des données hydrométriques Q	à partir de la formule Q'		
1937	257,0	35,7	38,8	3,1	8,7
1938	185,0	21,2	30,9	9,7	45,8
1939	168,0	24,4	29,1	4,7	19,3
1940	285,0	44,0	41,8	—2,2	5,0
1941	520,0	70,1	67,4	—2,7	3,9
1942	362,0	50,0	50,2	0,2	0,4
1943	113,0	31,3	23,1	—8,2	26,2
1944	373,6	50,9	51,5	0,6	1,2
1945	104,1	29,7	22,1	—7,6	25,6
1946	109,8	22,1	22,7	0,6	2,7
1947	237,0	41,1	36,6	—4,5	10,9
1948	261,5	50,7	39,3	—11,4	22,5
1949	224,5	32,3	35,2	2,9	9,0
1950	165,0	23,8	28,7	4,9	20,6
1951	251,2	29,2	38,1	8,9	30,5

cipitations a dû s'écouler directement et n'a pas alimenté l'écoulement du printemps. C'est pourquoi le débit moyen des trois mois de printemps, calculé d'après les précipitations, a nettement surpassé la valeur réelle.

Les essais effectués montrent qu'il est possible d'évaluer, d'après les précipitations des cinq mois d'hiver, l'écoulement pendant les mois de printemps, donc pendant la période où les besoins en eau pour l'irrigation sont déjà importants. Les calculs peuvent être erronnés si les précipitations en mai apparaîssent sous forme de pluie ou si la neige, tombée pendant ce mois, fond avant l'hiver.

L'extrême importance que représente la prévision de l'écoulement fluvial pour l'agriculture dans le bassin du R. Aconcagua, justifie la recherche de la corrélation. Même les formules qui, dans certains cas précis, donnent des résultats s'éloignant considérablement des valeurs réelles de l'écoulement, peuvent être utiles. L'analyse des courbes de température et de l'état de la rétention souterraine faite parallèlement aux calculs permet de prévoir si le débit calculé sera en fait surpassé, ou bien s'il ne sera pas atteint.

8. RAPPORT ENTRE ÉCOULEMENT ET ALTITUDE DU BASSIN

Les bassins partiels du R. Aconcagua, offrant les plus grandes altitudes, ont de forts écoulements spécifiques. Ceux situés en aval se caractérisent par des écoulements plus faibles. Cela incite à faire un calcul numérique du rapport entre écoulement et altitudes du bassin partiel. Il est vrai qu'il existe bien peu de bassins partiels à écoulement spécifique connu; cependant, l'évidence du rapport justifie les recherches.

On a pris, afin de calculer le coefficient de corrélation, des données provenant de neuf bassins partiels, dont on avait déterminé au préalable les écoulements spécifiques. On a écarté cependant le bassin du l'E. Juncalillo, dont l'écoulement se fait en partie par voie souterraine. Nous avons calculé les altitudes moyennes des bassins partiels à partir de courbes hypsographiques. Le coefficient de corrélation entre écoulement spécifique et altitude moyenne du bassin partiel est assez élevé — 0.942. La corrélation est, malgré le peu de données, importante. L'écart type du coefficient s'élève à 0,038. La ligne de régression est déterminée par l'équation

$$q = 13{,}46\, H - 26{,}2$$

où q = écoulement spécifique en l/s, km^2 et H = altitude moyenne du bassin partiel en km.

En comparant les écoulements calculés d'après la formule et ceux obtenus d'après les données hydrométriques, nous constatons des différences importantes allant jusqu'à 23,6% (Tabl. 18). Elles peuvent être dues à deux sortes de causes. La première tient sans doute aux matériaux, qui sont loin d'être parfaits. Il faut chercher également une source d'erreur dans les données concernant l'écoulement, comme dans les altitudes moyennes calculées d'après la carte à l'échelle 1 : 250 000, présentant assez peu précisément les rapports hypsométriques.

La seconde cause de divergences se trouve peut-être dans les influences supplémentaires des facteurs, venant modifier les rapports mentionnés ci-dessus. La latitude est le facteur qui devrait exercer une telle influence supplémentaire. Dans cette partie du Chili, l'augmentation des précipitations dans la direction sud se manifeste de façon très nette. Dans cette même direction, la température baisse également — ce qui contribue à la diminution des pertes en évaporation. L'alimentation doit donc augmenter en fonction de la latitude. Le résultat des calculs prouve le rôle joué par la latitude. Les écoulements specifiques calculés pour les bassins nord (R. Putaendo et R. Colorado) montrent les divergences positives, les plus importantes, par rapport aux données hydrométriques. Par contre, les plus importantes divergences négatives sont présentées par les écoulements des bassins sud (E. Pocuro et E. Riecillos).

Nous avons donc procédé au calcul de la corrélation de trois variables: écoulement spécifique, altitude moyenne, et latitude du bassin. Nous avons déterminé cette dernière en tant que latitude du parallèle séparant le bassin à peu près en deux parties égales. Le choix du parallèle a été fait à vue, et la latitude exprimée en degrés et dixièmes de degrés.

Les coefficients de corrélation des variables se montent à $r_{12} = 0{,}9414$, $r_{13} = 0{,}4308$ et $r_{23} = 0{,}2231$, et le coefficient général de corrélation multiple $R = 0{,}9684$. En introduisant la correction du coefficient, conformément à la formule

$$_cR^2 = 1 - (1 - R^2)\frac{N-1}{N-m}$$

où m = nombre de variables de corrélation, on obtient un coefficient corrigé $_cR = 0{,}9577$.

L'equation finale se présente comme suit

$$q = 12{,}747\,H + 7{,}202\,\varphi - 260{,}57$$

où q = écoulement spécifique en l/s, km², H = altitude moyenne du bassin en km, φ — latitude du parallèle partageant le bassin en deux, exprimé en degrés.

Les résultats obtenus d'après cette formule sont plus conformes aux données de départ (Tabl. 18). L'écart maximal atteint 12,8%. Cependant, dans le cas du bassin du R. Blanco, la première formule donne de meilleurs résultats que cette dernière. Cela prouve que le calcul du débit moyen du R. Blanco, d'après l'analyse des données hydrométriques, peut être erroné.

Dans les deux cas, les plus grands écarts concernent les données du R. Colorado. Il en faut chercher partiellement la cause dans la structure du bassin. L'allongement méridien du bassin et la situation de ses parties supérieures dans la zone nord et nord-est provoque une augmentation des résultats obtenus d'après la for-

TABLEAU 18. Écoulements spécifiques, l'altitude moyenne et latitude du bassin

Rivière et profil	Altitude moyenne du bassin en m	Latitude moyenne du bassin	Ecoulement spécifique en l/s. km²			$q_1 - q$	$\frac{q_1 - q}{q}100\%$	$q_2 - q$	$\frac{q_2 - q}{q}100\%$
			à partir des données hydrométriques q	à partir de l'altitude moyenne q_1	à partir de l'altitude moyenne et de la latitude q_2				
E. Juncal à Juncal	3 777	32°,95	24,7	24,7	24,9	0,0	0,0	0,2	0,8
E. Juncal à Rio Blanco	3 475	32°,92	23,4	20,6	20,8	—2,8	12,0	—2,6	11,1
R. Blanco à Rio Blanco	3 665	33°,05	22,9	23,1	24,2	0,2	0,9	1,3	5,7
R. Aconcagua à Rio Blanco	3 568	32°,95	23,2	21,9	22,2	1,4	6,0	—1,0	4,3
E. Riecillos	3 132	33°,02	18,5	16,0	17,1	—2,5	13,5	—1,4	7,6
R. Colorado	3 305	32°,65	14,8	18,3	16,7	3,5	23,6	1,9	12,8
R. Aconcagua à Chacabuquito	3 278	32°,82	15,9	17,9	17,6	2,0	12,6	1,7	10,7
E. Pocuro à Sifon	2 286	32°,98	5,7	4,6	6,1	—1,1	19,3	0,4	7,0
R. Putaendo à Los Patos	2 928	32°,40	11,1	13,2	10,1	2,1	18,9	—1,0	9,0

mule. En effet, le bassin doit sa grande altitude moyenne aux terrains situés à des latitudes plus basses. Les régions méridionales, situées bas, décident également de la latitude convenue.

Il est également très vraisemblable que les données de départ, concernant l'écoulement dans le bassin du R. Colorado, manquent d'exactitude. Cela expliquerait, dans ce cas, la diminution des valeurs de l'écoulement calculées à partir de la formule, par rapport aux donnés de départ, dans presque tous les bassins.

On peut calculer d'après les deux formules pour quelle altitude moyenne l'écoulement du bassin devient nul. D'après la première formule nous obtenons une altitude moyenne de 1947 m. Par contre, d'après la seconde, elle se monte à 2080 m pour une latitude de 2°,5 et à 1798 m pour une latitude de 33°. On pourrait en déduire que l'écoulement ne se fait pas dans la partie basse du bassin du R. Aconcagua — ce qui n'est pas en rapport avec la réalité. Il faut donc constater que les formules ne peuvent pas être appliquées pour les bassins situés en dehors de la chaîne principale des Andes. En effet, là-bas entre en jeu un facteur supplémentaire — l'éloignement de la mer. Par suite de cet éloignement, les bassins situés dans la zone de la Cordillère Littorale reçoivent un peu plus de précipitations que le bassin situé à la même hauteur, mais à l'intérieur des terres. Il est cependant impossible d'évaluer ce facteur, par suite du manque de données hydrométriques provenant de la partie basse du bassin.

Cependant, même pour la partie haut-montagneuse du bassin, la détermination des altitudes moyennes des bassins partiels, où l'écoulement ne se fait plus, ne peut être précise. Dans les matériaux hydrométriques de départ, les écoulements des bassins situés plus bas sont amoindris par suite de la prise d'eau. Cela ne concerne

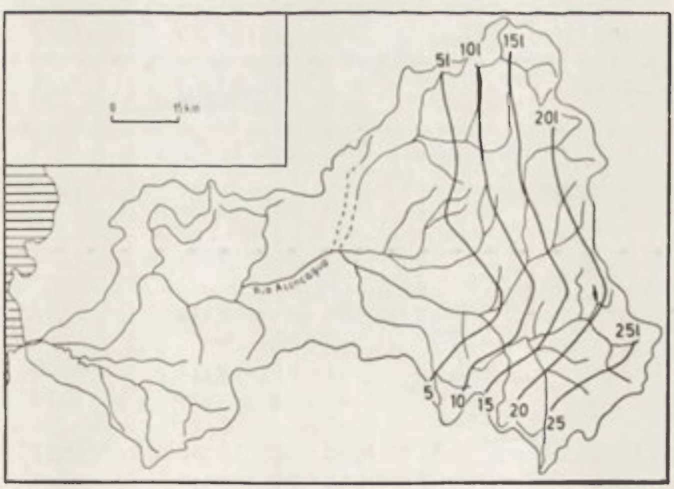

Fig. 33. Différenciation spaciale de l'écoulement spécifique (en l/s, km²) dans le bassin supérieur du R. Aconcagua

pas les bassins situés dans les parties hautes. Le rapport entre le niveau du bassin et l'écoulement est donc un peu modifié par rapport à l'état naturel. Si l'écoulement n'était pas modifié par l'homme, cette dépendance aurait une autre expression numérique. La droite de régression aurait une autre inclinaison et le point

TABLEAU 19. Ecoulements spécifiques calculés d'après l'altitude moyenne et la latitude du bassin

Bassin	Surface du bassin en km²	Altitude moyenne du bassin, en m	Latitude du bassin	Ecoulement spécifique en l/s, km²
E. Juncal à Juncalillo	246,9	3 777	32,95	24,9
E. Juncalillo	88,8	3 459	32,79	19,7
E. Juncal en aval de Juncalillo	164,4	3 050	32,95	14,9
R. Blanco jusqu'à Saladillo	313,1	3 784	33,05	25,7
R. Blanco en aval de Saladillo	71,9	3 296	32,94	18,7
R. Aconcagua de R. Blanco au Rio Colorado	88,1	2 357	32,90	6,4
E. Riecillos jusqu'au R. Aconcagua, sans E. Hualtatos	122,5	3 294	33,02	19,2
l'E. Hualtatos	39,4	2 735	32,97	11,7
E. Colorado jusqu'à l'E. Riecillos	441,9	3 586	32,57	19,7
E. Riecillos, affl. du R. Colorado	235,6	3 456	32,69	18,9
R. Colorado en aval de l'E. Riecillos	141,3	2 362	32,81	5,8
E. Pocuro jusqu'à Sifon	181,3	2 286	32,98	6,1
E. S. Francisco (Quilpué)	193,8	2 509	32,69	6,8
E. El Cobre (Quilpué)	127,5	2 416	32,65	5,4
E. Jahuel et E. del Solino (Quilpué)	55,6	2 126	32,61	1,4
R. Rocin jusqu'au R. Hidalgo	396,3	3 331	32,36	14,7
R. Hidalgo	156,9	3 065	32,50	12,6
R. Rocin en aval du R. Hidalgo	105,6	2 271	32,51	2,5
E. Chalaco	190,0	2 339	32,40	2,6
Q. El Espino (Putaendo)	48,1	2 410	32,54	4,5

de l'écoulement nul correspondrait à une altitude moyenne du bassin plus petite. Cependant, les formules, et surtout la seconde, peuvent être utilisées pour déterminer l'écoulement de n'importe quel bassin haut-montagneux, sans risque de commettre une erreur importante.

On a calculé, d'après la seconde formule, l'écoulement spécifique de 24 bassins partiels, situés dans les hautes Andes, et à leur limite (Tabl. 19). Nous pouvons affirmer, d'après les données obtenues, que la répartition de l'écoulement spécifique dans la partie haut-montagneuse du bassin du R. Aconcagua montre nettement l'ordre spatial. Si la valeur de l'écoulement spécifique du bassin est référeé au point situé à peu près au centre de gravité de la surface du bassin, on peut alors obtenir une image isarythmique, illustrant la tendance de différentiaion spaciale du phénomène (Fig. 33). L'écoulement spécifique augmente depuis le bord de la chaîne principale vers l'est et simultanément du nord au sud. C'est pourquoi le gradient dans la direction parallèle varie avec la latitude. Dans la partie nord du bassin, la différence de valeur de l'écoulement spécifique entre les parties littorales et l'intérieur des montagnes ne se monte sans doute pas à plus de 15 l/s, km^2, tandisque, dans la partie sud, elle atteint plus de 25 l/s, km^2.

D'après les données hydrométriques et la formule empirique déterminant l'écoulement, on peut évaluer la quantité d'eau s'écoulant de la partie haut-montagneuse du bassin du R. Aconcagua. Les débits annuels moyens de plusieurs années, se présentent comme suit:

R. Putaendo en aval de Los Patos	9,6 m^3/s
parties montagneuses des rivières dans le bassin de l'E. Quilpué	2,1 ,,
R. Aconcagua à Chacabuquito	32,9 ,,
E. Pocuro en aval de Sifon	1,1 ,,
au total	45,7 ,,

On peut considérer la valeur obtenue comme réserves d'eau moyennes, fournies par les terrains haut-montagneux, constituant la source principale d'alimentation du bassin du R. Aconcagua. Il faut ajouter à ces réserves de la zone haut-montagneuse les quantités d'eau s'écoulant du bassin par le canal Chacabuquito (environ 1 m^3/s en moyenne), ainsi que celles utilisées pour l'irrigation dans les montagnes (difficiles à évaluer).

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- Łupki ilaste i margliste, iłołupki z cienką pokrywą zwietrzelinową
- Torfy

MOKRADŁA I WODY STOJĄCE
- Mokradła stałe
- Mokradła okresowe
- Teren zdrenowany
- Jezioro
- Oczka
- Staw stale wypełniony wodą
- Starorzecze okresowo wypełnione wodą

NATURALNE WYPŁYWY WÓD PODZIEMNYCH
- Wylew
- Źródło stałe z odpływem
- Źródło okresowe z odpływem
- Źródło bez odpływu

WODY PODZIEMNE

GŁĘBOKOŚĆ DO ZWIERCIADŁA WODY W POMIERZONYCH STUDNIACH (KOPANYCH)
- 0–1 m
- 1–2 m
- 2–5 m
- 5–10 m
- 10–20 m

Źródło o wydajności
- do 0,1 l/sek
- 0,1–0,5 l/sek
- 0,5–1,0 l/sek
- 1,0–5,0 l/sek
- 5,0–10,0 l/sek
- 10,0–100,0 l/sek
- powyżej 100 l/sek

- Źródło mineralne
- Linia źródeł
- Źródło użytkowane przez ludność
- Młaka
- Wyciek
- Wysięki

SIEĆ RZECZNA

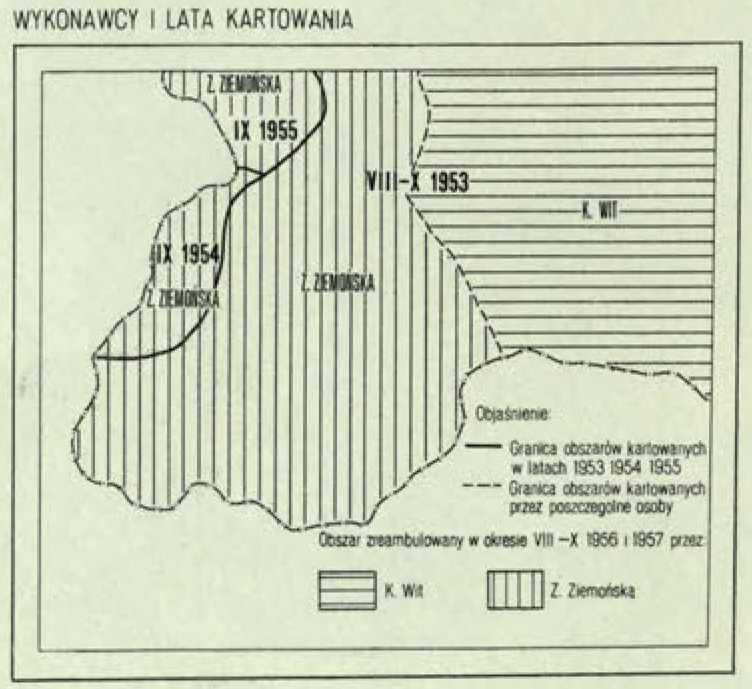
CIEKI NATURALNE
- o szer. koryta do 1 m
- 〃 〃 1–3 m
- 〃 〃 3–10 m
- 〃 〃 10–30 m

- Ciek odcinkami ginący w osadach
- Ciek o stałych odcinkach ginięcia wody
- Ciek okresowy
- Miejsce pomiaru przepływu jednorazowego
- Kierunek płynięcia wody
- Szypoty i bystrza w korycie
- Wodospady
- Podcięcia brzegu
- Obszary zalewów katastrofalnych

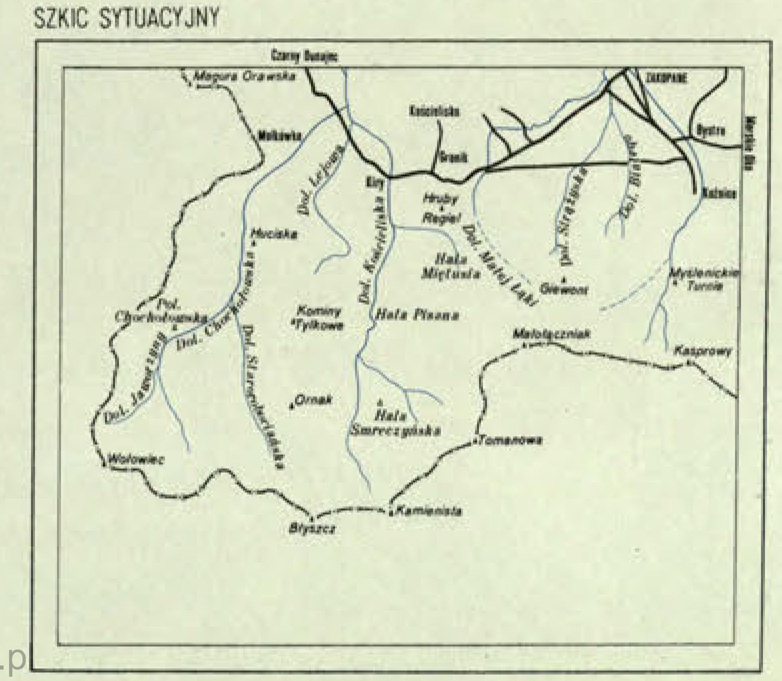
ZAGOSPODAROWANIE CIEKÓW
- Opaski brzegowe
- Ostrogi
- Zapory szutrowe
- Obudowa szczelna koryta (żłób kamienny)
- Wpust pod ziemię i wylot cieku na powierzchnię
- Przepływ wody w przewodach zamkniętych
- Ciek zanieczyszczony
- Rów odwadniający czynny stale
- Młynówka

PUNKTY OBSERWACYJNE
- Stacja opadowa PIHM
- Stacja klimatologiczna i synoptyczna PIHM
- Stacja wodowskazowa PIHM z pomierzonymi przepływami
- Miejsce pomiaru przepływów powtarzanych

WYKONAWCY I LATA KARTOWANIA



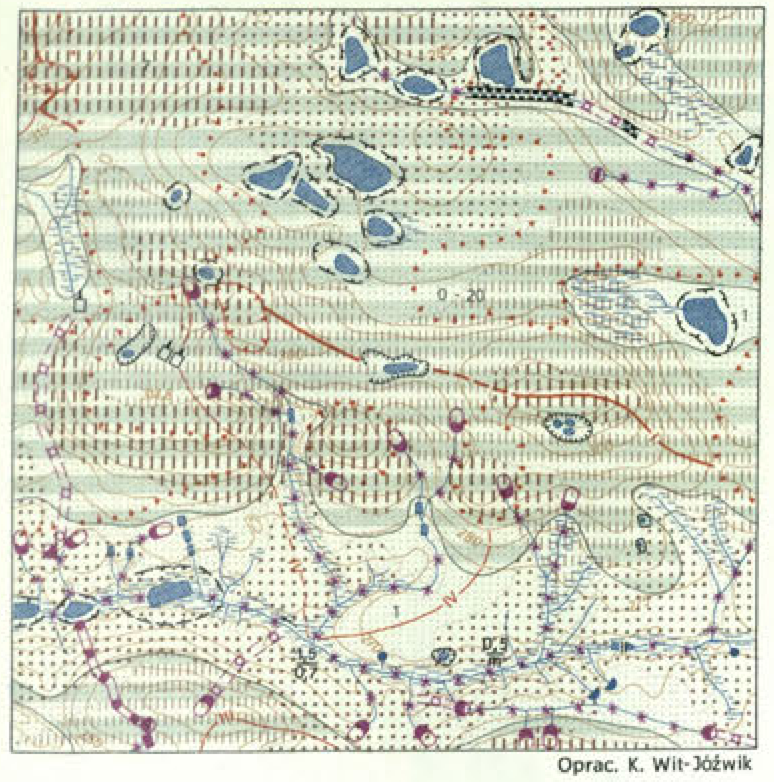
SZKIC SYTUACYJNY



Skala szkiców 1:200 000

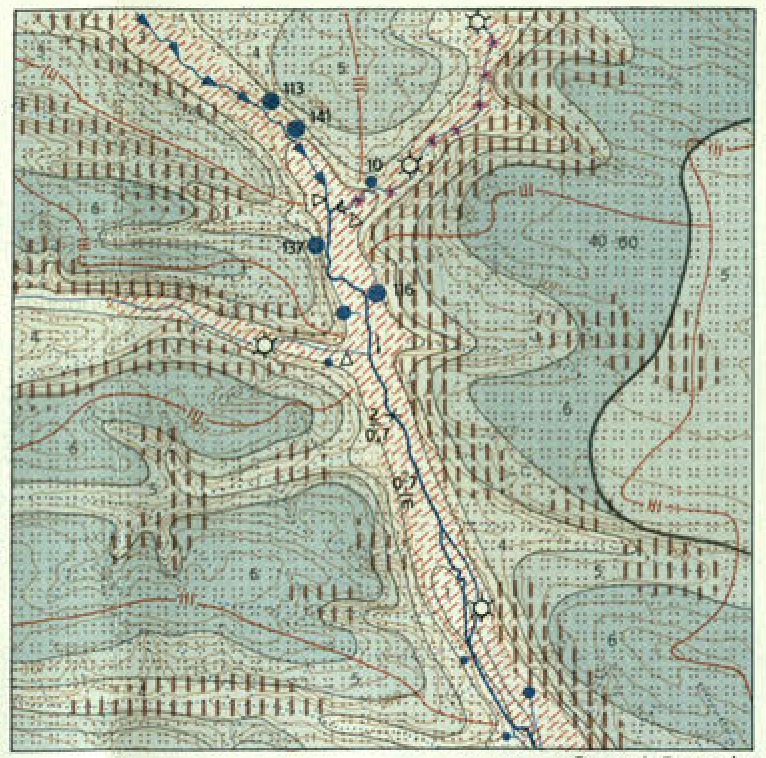
PRZYKŁADY MAP HYDROGRAFICZNYCH Z POLSKI POŁUDNIOWEJ
EXAMPLES OF HYDROGRAPHIC MAPS FROM SOUTHERN POLAND

A



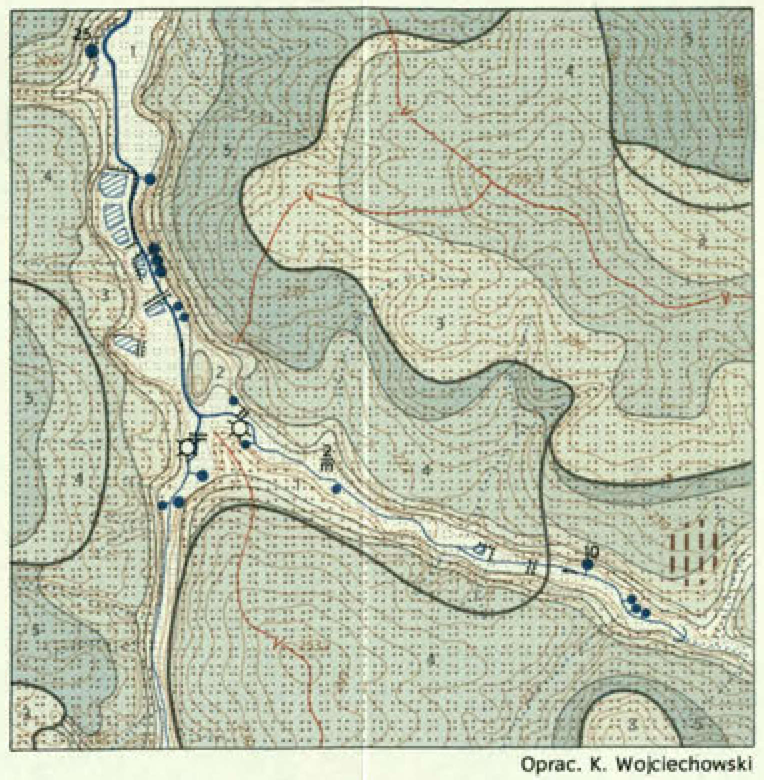
Oprac. K. Wit-Jóźwik

B



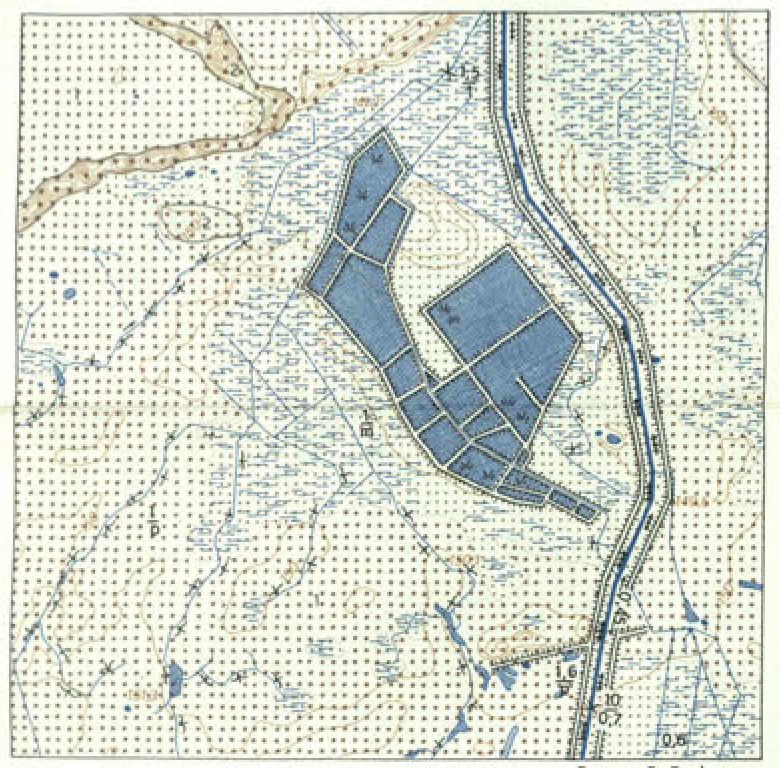
Oprac. I. Dynowska

C



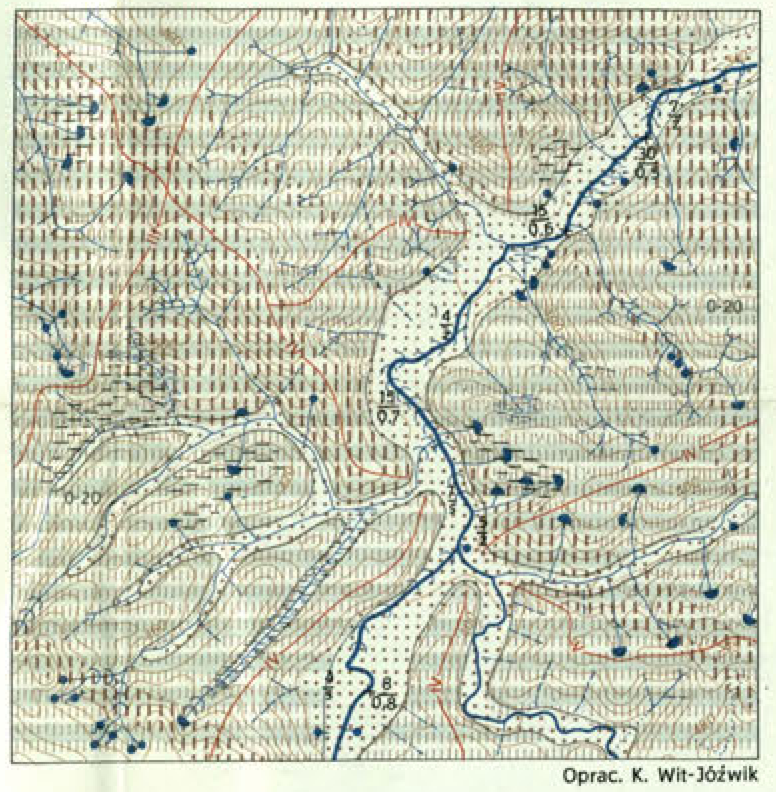
Oprac. K. Wojciechowski

D



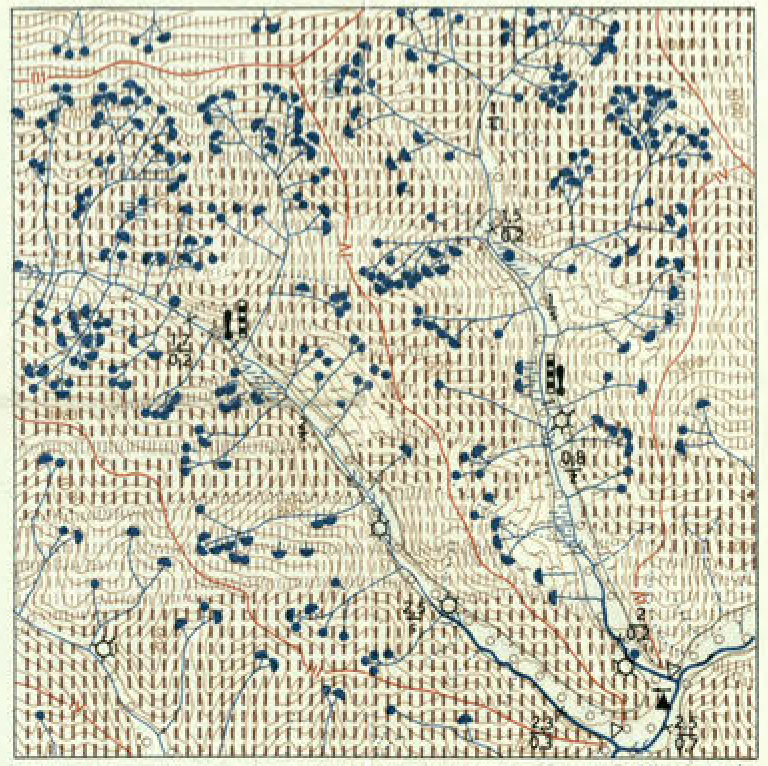
Oprac. E. Rederowa

E



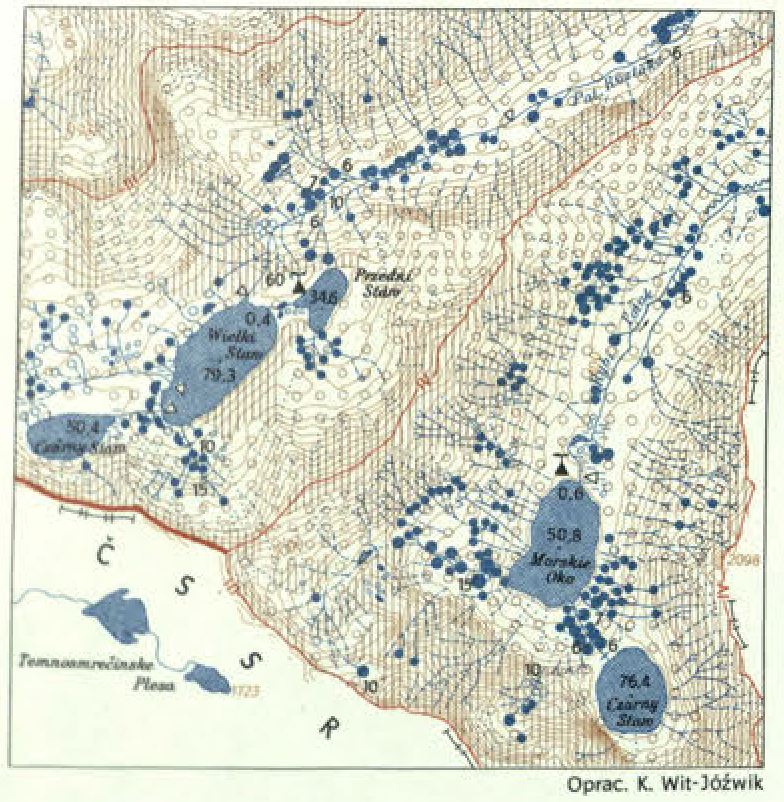
Oprac. K. Wit-Jóźwik

F



Oprac. J. Niemirowska

G



Oprac. K. Wit-Jóźwik

ZDJĘCIA HYDROGRAFICZNE (ROK) - WYKONAWCA
Wyc. A (1955) - J. Bzikot, M. Krasoń
B (1957) - I. Dynowska
C (1955) - St. Niedbała

Wyc. D (1962) - E. Rederowa, B. Szalkiewicz
E (1954) - M. Małaszyńska, U. Tucholska, M. Klimek
F (1965) - J. Niemirowska
G (1960-62) - A. Rajwa, K. Wit-Jóźwik

Redakcja: K. Wit-Jóźwik
Rysunek: M. Klimek

m 1000 500 0 1 2 km

OBJAŚNIENIE ZNAKÓW
EXPLANATORY NOTES

SPŁYW POWIERZCHNIOWY I WSIĄKANIE
SURFACE FLOW AND INFILTRATION

DZIAŁY WÓD POWIERZCHNIOWYCH
SURFACE WATER DIVIDES

- Dział główny europejski / European Main divide — a) wyraźny distinct b) niepewny uncertain
- Dział wodny I rzędu / Divide of the I-st order — wyraźny distinct
- Dział wodny III rzędu / Divide of the III-rd order — wyraźny distinct
- Dział wodny IV rzędu i rzędów niższych / Divide of the IV-th order and lower orders — a) wyraźny distinct b) niepewny uncertain
- Dział wodny obszaru bezodpływowego / Divide of an endoreic area
- Granica obszaru kanalizacji miejskiej / Limit of the communal sewerage

UTWORY POWIERZCHNIOWE
SURFACE ROCKS

PRZEPUSZCZALNOŚĆ UTWORÓW / PERMEABILITY OF ROCKS	RODZAJ UTWORÓW POWIERZCHNIOWYCH / ROCK TYPE: Skały luźne / Loose rocks: rumoszowe i żwirowe / Rock-debris and gravelly	piaszczyste / Sandy	pyłowe / Dust-like	ilaste / Clayey	Skały lite / Solid rocks: osadowe / Sedimentary	magmowe i zmetamorf. / Igneous and metamorphic
Duża / High						
Średnia / Median						
Mała / Little						
Praktycznie żadna / Essentially none						

MOKRADŁA I WODY STOJĄCE
SWAMP AND STAGNANT WATER

- Mokradło okresowe / Swamp temporary
- 0,6 — Mokradło stałe (liczba oznacza głębokość mokradła w m) / Swamp permanent (the figure shows the depth of the swamp in m.)
- Jezioro i starorzecze stale wypełnione wodą (liczba oznacza głębokość w m) / Lake or ox-bow lake permanently filled with water (maximum depth in m. shown by a number)
- Amplituda lustra wody (liczba oznacza wielkość amplitudy w m) / Amplitude of the fluctuations of the lake's level
- Jezioro i starorzecze zarastające / Overgrown lake or ox-bow lake
- Jezioro i starorzecze okresowo wypełnione wodą / Lake or ox-bow lake temporarily filled with water
- Oczka i sadzawki stale wypełnione wodą / Kettle-lake (sölle) and pool
- Staw stale wypełniony wodą / Pond permanently filled
- Staw okresowo wypełniony wodą / Pond filled temporarily
- Wyrobisko z wodą / Water filled pit
- Zapadlisko z wodą / Subsidence hollow with water
- Osadnik / Slime-pit
- Zbiornik przemysłowy / Industrial water reservoir

WODY PODZIEMNE
UNDERGROUND WATER

- 1 — Głębokość do zwierciadła wody w metrach w dniu pomiaru / Depth of the water table at the time of measurement in m. 0 - 2
- 2 — 2 - 5
- 3 — 5 - 10
- 4 — 10 - 20
- 5 — 20 - 40
- 40 - 60 / 6 — ponad 40 (liczby 40 - 60 oznaczają przypuszczalną głębokość do wody gruntowej w m) / above 40 (numbers show the probable depth of the water table in m.)
- 0-20 — Głębokość do zwierciadła wody zróżnicowana (liczby ozn. głęb. skrajne w m) / Various depths of the water table (numbers show the extreme depth in m.)
- Wody wierzchówkowe / Subcutaneous water
- Głębokość do zwierciadła wody nieznana / Depth of the water table unknown
- Granica różnych poziomów wodonośnych / Border between different water horizons

NATURALNE WYPŁYWY WÓD PODZIEMNYCH
NATURAL OUTFLOWS OF UNDERGROUND WATER

- Źródło stałe / Permanent spring
- Źródło okresowe / Intermittent spring

Wydajność źródła
Discharge of the spring

- do 1,0 l/sek. / up to 1,0 l/sec.
- 9 — 1-10 l/sek. (cyfra oznacza wydajność źródła w dniu pomiaru powyżej 5 l/sek.) / (number shows discharge at the day of measurement for the springs over 5 l/sec.)
- 58 — 10 - 100 l/sek. (liczba oznacza wydajność źródła w dniu pomiaru powyżej 50 l/ sek.) / (number shows discharge at the day of measurement for springs over 50 l/sec.)
- 141 — ponad 100 l/sek. (liczba oznacza wydajność źródła w dniu pomiaru) / over 100 l/sec. (number shows discharge of the spring at the day of measurement)
- Linia źródeł i wylewów (wydajność według klas jak wyżej) / Line of springs (discharge in classes given above)
- Młaka / Bog-spring
- Wyciek / Leakage
- Wysięk / Trickling outflow

SIEĆ RZECZNA
RIVER NET

CIEKI NATURALNE I SZTUCZNE
NATURAL AND ARTIFICIAL STREAMS

- Ciek stały o szerokości koryta w metrach / Permanent stream with the width of bed in m. 0 - 2
- 2 - 5
- 5 - 10
- 10 - 30
- Odcinek cieku o całkowitym, stałym lub okresowym zaniku wody / Segment of stream where water completely disappears (permanently or periodically)
- Miejsce zaobserwowanego zmniejszenia przepływu / Segment of the stream where the flow discernibly decreases
- Ciek okresowy / Seasonal stream
- Ciek epizodyczny / Episodic stream
- Ciek o korycie zarastającym / Stream with overgrown bed
- Szypoty i bystrza w korycie / Rapids and steps in river bed
- 10 — Wodospad (cyfra oznacza wysokość wodospadu w m) / Waterfall (number shows the height in m.)
- 14/2 — Opis cieku i kanału: / Description of a stream or canal: a) w liczniku szerokość w m w mianowniku głębokość w m / numerator - width in m. denominator - depth in m.
- b) prędkość wody w m/sek / velocity of water flow in m/sec.
- 4/ż — c) w liczniku wysokość brzegu w m w mianowniku rodzaj dna (m-muliste, p-piaszczyste, ż-żwirowe, sk-skaliste) / numerator - height of the river bank / denominator - character of the bottom: m-muddy, p-sandy, ż-gravelly, sk-rocky
- Kanał o szerokości koryta w m / Canal width in m. 0 - 2
- Obszar zalewu katastrofalnego / Area covered by catastrophic floods

ZAGOSPODAROWANIE CIEKÓW
REGULATION AND UTILIZATION OF STREAMS

- Ciek uregulowany / Regulated stream
- Szczelna obudowa koryta - żłob kamienny / Watertight casing of the river-bed
- Zastawka na ciekach / Water level regulator
- Zapora szutrowa / Gravel scereen
- Młyn i tartak wodny / Water-mill and saw-mill
- Wał ochronny lub grobla / Embankment and dike

ZRZUTY I PRZERZUTY
REMOVAL OF POLLUTED WATER AND OTHER TRANSFERS OF WATER

- Przewód zamknięty nadziemny z wodą zanieczyszczoną / Closed collector above ground with polluted water
- Przewód zamknięty podziemny z wodą zanieczyszczoną / Closed collector underground with polluted water
- Wypływ wody zanieczyszczonej z kopalni / Outflow of polluted water from a mine
- Wypływ ścieków z hut i innych zakładów przemysłowych / Outflow of refuse from foundries and other industrial establishments
- Wypływ ścieków komunalnych / Outflow of communal sewage
- Ciek zanieczyszczony / Polluted stream

PUNKTY HYDROMETRYCZNE
HYDROMETRICAL STATIONS

- Stacja meteorologiczna / Meteorological station
- Stacja opadowa / Precipitation gauging station
- Limnigraf / Limnograph
- Miejsce pomiarów przepływów powtarzanych / Location of repeated measurements of discharge

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Załącznik do artykułu: "Przykłady map hydrograficznych z Południowej Polski"

Cena zł 44.—