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REPORT ON THE

NIGER WATER RESOURCES SURVEY

CONTRACT AID/afr-452

PIO/T 683-026-3-6666021

PIO/T 683-026-3-6675140

An Economic and Hydrogeological Review of the
Government of Niger Request for
200 Dug Wells and 15 Drilled Wells

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August 17, 1967

Mr. Kenneth Jeffries
Code AA/AFR/CS
AID/Department of State
Washington, D. C. 20523

Subject: Submission of Final Report
Niger Water Resources Survey
Contract No. AID/afr-452
P10/T 683-026-3-6666021
P10/T 683-026-3-6675140

Dear Mr. Jeffries:

We enclose with pleasure 30 copies of this report in English. (An advance shipment of several copies is contemplated).

The Aero Service Economic/Hydrogeological team assigned to this task fulfilled all objectives of the program:

a) Overall appraisal of the GON's request to AID for a 215 well program, including national and third party development undertakings.

b) Cost-benefit relationships.

c) Recommendations for both action and study programs.

Statistics of existing conditions and recommendations for future activity will enable government to develop logical forward planning for domestic and agricultural water in areas of interest.

Dr. Michel Herve and Dr. Ruthven W. Pike are especially grateful for constant support received from AID-Washington and AID-Niamey. Their success in the program is significantly related to this guidance and cooperation.

Faithfully yours,

AERO SERVICE CORPORATION

Harold F. Flynn

Harold F. Flynn, Director
Resources Development

HFF/bcw
encl.

cc: Mr. Albert P. Disdier
Mr. Robert Delemarre
Mr. Joseph Guardiano

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We wish to acknowledge gratefully the many courtesies and assistance rendered by M. Hamani Diori, President of the Republic; M. L. Kaziende, Minister of Public Works and numerous members of the GON concerned with water resources development. Numerous data were offered for on-site reference and some statistics donated for use in preparing reports. Thanks are due to BRGM for permission to obtain information in Paris and Dakar not available elsewhere.

Special thanks are also extended to Ambassador Robert J. Ryan; Mr. Donald B. Easum, DCM - Consul; Mr. Joseph C. Guardiano, AID affairs officer; Mr. Nelson Anderson, N.E.F. and other members of the Mission staff in Niamey.

Valuable guidance, support and counsel were freely given by AID/Washington members concerned with Niger including Mr. Harry J. Petrequin; Mr. Robert Delemarre; Mr. Solomon G. Sherman; Mr. John C. Gotschal; Mr. Thomas Leahy; Mr. K. Jeffries and Mr. Robert G. Rose.

SUMMARY

A. PURPOSE AND SCOPE OF STUDY

The Government of Niger requested US AID to consider financing a water resource project in Niger involving the development of 200 dug wells and fifteen drilled wells in five different areas of the sedentary and nomad zones between Niamey and Tanout (plate 15).

Prior to making a detailed appraisal of this project, AID desired that a preliminary investigation of the GON overall water resources program be undertaken for the purpose of placing the proposal in proper perspective. Points needing clarification included: 1) the relation of the 215 shallow and deep wells to other GON water resources programs including those being undertaken by other donors; 2) the integration of water resource programs with other GON development effort, particularly those related to agriculture, livestock and kindred sectors; 3) the timing and planned phasing of water resource development projects to establish their consistency with priority needs.

An Aero Service - Pitt Resources Development Institute team (See Appendix V) of one hydrogeologist and one development economist were selected to fulfill these requirements and specifically to develop information including:

1. A brief examination into Niger's needs for water, both animal and human and the resources available.
2. An evaluation of GON plans for the development of water resources together with an explanation of the rationale employed in selection of individual projects.
3. On-site inspection of three to ten wells in each area of interest including a review of all available data.
4. End products of the study should include:
    a. a detailed project description.
    b. an evaluation of the project in relation to foregoing statements.
    c. conclusions as to the desirability of proceeding with a full-length study of the proposed project from the standpoint of contribution to both long and short-range GON water development programs.
5. The identification, priority rating and description of additional possible water resources projects of strategic value which appear to warrant further investigation and study to determine their justification so as to maximize the U.S. contribution to this important sector of Niger economic development.

B. CONCLUSIONS ON THE WELLS PROGRAM PROPOSED BY THE GON

1. Changes in the composition of the proposed program

The high operating costs of the pumping stations and the problems of overgrazing in their vicinity have led the Nigerien authorities to modify the original program proposed for AID financing. Deep bore-holes with pumping stations are no longer part of the program. The totality of the AID loan would be used for the construction of hand-dug, cement-lined shallow wells.

2. General objections to the proposed hand-dug wells

a. Technology - While Niger has had considerable experience in building such wells the present technology leaves much to be desired:

- Only the top of the aquifer is being tapped.
- The wells are not "developed" i.e. brought to a maximum production status.
- Their maintenance and rehabilitation is expensive.
- They are easily if not invariably polluted.

b. Benefit-Cost -

- Construction costs are very high.
- Direct economic benefits would be forthcoming only if a complementary program in improvement of animal husbandry were undertaken.

3. Objections to US AID financing of the proposed program -

a. Local costs represent about 60% of total costs.

b. The program is very similar to and overlaps a much larger program throughout the sedentary zone financed by the European Development Fund (FED). AID has already cautioned against possible interference with third party interests. But besides the objections already listed, it should be noted that FED has already developed the administrative machinery for implementation and control of its program. Undoubtedly, administrative duplication by US AID would be an added waste. Furthermore, FED is in a better position to contract with local contractors or with contractors from its member nations who are often already engaged in construction in West Africa.

4. Need for water resources development -

In spite of the foregoing objections to the proposed program, a water resources development program in Niger is entirely justified on the following grounds:

a. Health and Human benefits: The indirect benefits accruing in health cannot be measured. They are both an end of, and a means toward, development.

b. Economically, in the short-run, provided that complementary measures to improve animal husbandry are taken.

It seems that small and inexpensive changes in animal husbandry methods should bring relatively high gains in meat production. In the wake of extension work this might occur even in the absence of a large scale national program such as the establishment of regional markets and control of the number of cattle at the optimum level -- which could only be ascertained by an extensive survey.

c. Economically, in the long run, Niger, which still has a land surplus, will face a problem of land shortage if the present population growth rate continues. Present work by international agencies and foreign donors to introduce better seed and farming practices will not solve the looming unemployment problem even if they succeed in increasing food production. Agricultural unemployment can be prevented either 1) by the introduction of labor-intensive practices with a risk of higher costs or 2) by increasing the supply of land. Irrigation belongs to method 1); unfortunately the irrigable areas in Niger are negligible in relation to the population and the original capital cost per hectare is extremely high. Better farming practices increase the productivity of agricultural workers but do not create employment. When, as is often the case, better farming practices mean mostly the introduction of ox-drawn plows they may, ironically, speed up the advent of the land limit by enabling each farmer to cultivate more land than he did before.

For these reasons we feel that government should foster new wells in areas where the land could be cultivated in dry farming, if only water for human needs were available.

C. SUMMARY OF RECOMMENDATIONS

1. Pilot Percussion Drilling - Sedentary Zone

Introduction of established American technology and percussion drilling of large diameter wells lined with metal casing appropriately perforated opposite water-bearing zones is recommended.

The key elements of this undertaking are (a) to determine the total thickness of phreatic aquifers; (b) estimate therefrom water reserves and safe yield; (c) demonstrate the advantages of modern American mechanized techniques; (d) compile and develop hydrogeological paramaters essential for locating areas of maximum water producing potential including places suitable for developing unused arable land; (e) mapping the ground water table; (f) control of subsurface stratigraphy, lithology and structure; (g) analyze water quality and applicability in all instances; (h) train up to 10 people selected and supported by Government in the fields of drilling, production, well testing, elementary hydrogeology and photogeology.

Utilization of this technology will mean the entire aquifer will be penetrated (this is not practical using present Nigerien methodology). This will increase the available amount of water per well two to ten times and will reduce cost per cubic foot for construction. In addition, maintenance and rehabilitation will be facilitated (today both are often impossible). The program planned at a demonstration scale would require 36 man months of American professional activity and 288 man months of Nigerien personnel.

2. Surface Catchment Basins - Nomad Zone (9 months)

Conservation of scanty rainfall, in an area where precipitation is the limiting factor in land use, may be accomplished by mechanically enlarging the reservoir capacity of numerous suitable, topographic depressions or catchment basins. A Nigerien, operating a front end loader and back hoe under the direction of a hydrogeologist, would excavate and/or dam selected places of concentric drainage. Both the AID affairs officer and international technicians agree the concept is constructive and does not entail the possibility of overgrazing and land destruction.

This program would require the services of an American hydrogeologist for 9 months and 72 man months of Nigerien personnel.

3. RECOMMENDED FUTURE PROGRAMS

In addition to the pilot percussion program and the surface catchment basin program two study programs are recommended for Niger. First, a study of areas in, or at the limit of the sedentary zone where wells would open new land to agriculture. This program would require the services of one hydrogeologist and one agricultural expert for 9 man months each. They would require support from the Government of Niger for logistics. Second, study of a well program in the nomadic zone north of Maradi including soil configuration, quality of pastures and depth in which water is to be found. This program could be undertaken in conjunction with the program previously mentioned and would require the same staffing for a period of approximately six months.

4. ECONOMIC EVALUATION OF RECOMMENDED ACTION PROGRAMS:

Pilot Percussion Drilling: Total costs would be considerably lower for these wells than for the hand-dug cement lined wells now built in Niger.

Surface Catchment Basins: Would make water available at a cost lower than present water hole costs. Also, the proposed equipment is a marked improvement over presently utilized equipment.

CHAPTER I. INTRODUCTION

The Niger Republic, the second biggest country of West Africa, is mainly desert or semi-desert, so that within its 458,874 square miles (much more than Texas and California combined) there are only 3.1 million inhabitants or 6.5 persons per square mile. The country extends 650 miles from south to north, into the poorest desert, and 1,000 miles from southwest to northeast, again into desert. The region reviewed forms a triangle bounded by Niamey on the west (Lat. 13° 45'N - Long. 2°05'E); Zinder on the east (Lat. 14°N - Long 9°E) and Agades in the north (Lat. 17°N - Long. 8°E). It has an area of approximately 50,000 square miles.

The single most important problem of Niger is water. According to official figures from the Ministry of Economy, 8 per cent only has an annual rainfall of over 21 inches; 16 per cent has between 14 and 21 inches; 28 per cent has between 4 and 14 inches; and 48 per cent has under 4 inches. Much of the country has as little rain as Arizona and New Mexico, and this very low rainfall is also highly variable in amount, times of onset and cessation, and pattern of falls from year to year. Usually, Niamey receives its 21.6 inches of annual rainfall in four and a half months, and Agades its 6.9 inches in two and a half months.

Agricultural production is only theoretically possible in one-quarter of the country; in fact, only about two per cent is cultivated. Crops are grown in certain areas along the southern fringes of the country, notably rice near the Niger River in the southwest; and peanuts, millet, beans and cotton in the south-center near the boundary with Nigeria, especially around Maradi and Zinder.

Livestock are more widespread, since they are found both in the areas intermittently cropped and in the semi-arid quarter of the country to the north which has over four inches of rain. Cattle are raised both for export and subsistence. They are owned by some 300,000 Peul and 250,000 Touareg who are necessarily nomadic, since their cattle must move constantly in search of the always poor pastures and rare water supplies.

Industry scarcely exists, and there are no other assets such as transit trade, strategic position, or even a tradition of migrant labor as in the equally poor Upper Volta.

The Niger is also landlocked, and Niamey, with some 40,000 inhabitants only, is 650 miles from the nearest port at Cotonou in Dahomey. Only three other towns, Tahoua, Maradi, and Zinder have over 10,000 people.

CHAPTER II. ECONOMICS

Section 1. Economic Background

1.1 An economy in low-level equilibrium[1]

With a per capital gross national product estimated at about $70. and with 94% of the population in agriculture or animal husbandry, it is obvious that the major part of the economic activity in Niger takes place in the subsistence sector. In spite of the low income level, food consumption, while not satisfactory, is not as insufficient or as unbalanced as in many other parts of the underdeveloped world. Even among the Peul nomads, the daily caloric intake reaches an average of 1800 units, covering 91% of their needs. With over 73 grams

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[1]For brief descriptions in English of the geographical, political, human and economic conditions of the country, see: 1) M. H. Kassem, Animal Husbandry. Production and Health, F.A.O., 1966 (Mimeographed); 2) The Economy of Niger, I·M.F., 1966 (Mimeographed); and 3) The Economy of Niger, International Bank for Reconstruction and Development, Report No. AF-16a, 1964 (Mimeographed)..

of proteins, mostly from dairy products, their daily ration is in excess of requirements. The main deficiencies are vitamins A and C.[2] As in any subsistence economy, however, the equilibrium is precarious and serious deficiencies can always appear following a year of unfavorable rainfall. In any case the period preceding the rainy season presents serious problems every year when food stocks are depleted and prices rise on local markets.

The colonial period brought few changes to Niger. Even the introduction of commercial crops, ground nuts and cotton, in the Central-South area of the country did not affect significantly the traditional structures in agriculture. There was no agricultural colonization in the wake of political colonization.

The government sector, representing about 15% of G.N.P., is also in low level equilibrium. Receipts of the order of $36 million now cover current expenditures. The bulk of the

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[2] Etude Demographique et Economique en Milieu Nomade. Société d'Etudes pour le Développement Economique et Social, Paris, 1966, Part I, p. 177. (Mimeographed).

public investment program has to be financed by foreign aid, which fills the savings gap.

1.2 The existence of a land surplus explains the present equilibrium.

In spite of the low productivity of land, its availability has allowed the population to grow at a rate now probably in excess of 2.5% per year without disturbing alarmingly the existing equilibrium between available water resources, land in use, human population and livestock. In the last few years the amount of agricultural land in use has increased annually by about 2.5%. Problems, however, have begun to emerge in the nomadic zone where an increase in the number of animals appears to be straining the pastures in the areas where water is available.

1.3 The interplay of four forces, population growth, livestock growth, water resources, land resources, could eventually lead to a serious crisis and to a deterioration of the present standard of living.

There is at present no program of population control and not even a discussion of the need or possibility of such program. It is therefore necessary for us to assume that the population growth will continue at least at the present rate in the foreseeable future. In any case, even if such a program should soon be implemented, the effect would not be felt for a long time.

On the other hand, with the present attitudes of the animal raisers, the eradication of rinderpest and the planned increase in the quantity of water at their disposal will probably result, at least for a while, in an increase in the number of animals which will complete with humans for the use of the land. Unless better husbandry methods are introduced and accepted, the herds will continue to be more consumers than producers -- the meat consumption of the local population is very low; even the animal raisers consume less than 10 kilograms of meat per capita per year.[3] The magnitude of this problem is well recognized and measures are envisaged to remedy it.

Eventually all usable land will be used and the land limit reached. However, until this inevitable event occurs the quantity of land available will depend primarily on the existence of water for human and animal needs. It is believed that sizable amounts of land could be brought under cultiva-

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[3] *Ibid.*, p. 185

tion if the farmers could find water within reasonable distance. In the same vein pastures which are at present grazed only as long as the nearby ponds contain water could be used longer if their capacity were increased. The problem of postponement of the land limit is therefore mainly a problem of water supply. The need for water is not only recognized, but, to some extent, misinterpreted, in Niger. It seems that increasing the supply of water is too often viewed as good *per se*, with only lip service being paid to the economic effects and without realizing that water provided in the wrong place or in excessive quantities can even have detrimental effects for the land.

1.4 Problems to be faced when the land limit is reached

As long as a land surplus is available, the introduction of better seeds, of animal traction, of plows, etc., will increase per capita output. In the present state of education of the peasant population, one should have modest expectations concerning the progress in agricultural output per land unit. Increase in output can only be slow and may even be absolutely limited until a breakthrough becomes possible with the use of fertilizers, for instance. The land surplus, on the other hand, tends to shrink rapidly since only limited amounts of uncultivated arable land are located in areas where water for human needs is available or can easily be made available by digging wells in a traditional way, i.e., digging by the local population without outside help, wood lining of the wells, which can only be done safely in certain soils and if water is to be found at relatively shallow depth, 100 to 150 feet -- although at least one African well of over 300 feet depth is known to exist in Niger.

The situation which will gradually emerge when the land limit is eventually reached can easily be seen from what is already starting to happen: reduction of the surface of fallow land in the sedentary zone, entailing a decrease in grazing possibilities both for animals owned by the sedentary peasants and for animals owned by the nomads - mainly Peuls -- who come south during the dry season. At the same time planting of millet and sorghum crops will tend to progress northward, thus further reducing the grazing areas. When the land limit is reached not only will the agricultural output per capita decrease, or, at best remain stationary if there are enough technological improvements, but also the traditionally common conflicts between sedentary farmers and nomads will become even more acute.

1.5 Need to postpone the advent of the land limit problem and measures to be taken.

Niger is presently embarking on a program of economic development under extremely difficult natural circumstances: among them let us cite the size of the country, the fact that it is land-locked, the low level of literacy, the lack of mineral resources, the poverty of the land and the small level of rainfall, the absence of rivers for irrigation, with the exception of the Niger River in the western region of the country. There are, however, positive factors, such as the seriousness and dedication of the administration, the absence of a class of large landowners resisting change, the existence of valuable cattle and, among the most important, the breathing spell provided by the existence of a land surplus. In spite of the adverse conditions, this respite may permit the various undertakings envisaged in the plan to improve the situation. It is therefore of the utmost importance to the whole development program that measures should be taken to postpone the day when the land limit is reached. Providing water for human needs where the sedentary population cannot obtain any with traditional well-digging methods is a way to increase the quantity of land available. To provide water to the nomads also means that their forced migration to the South during the dry season will decline, that they will have less use for land there and that conflicts will be less numerous.

Obviously the limitation of the human population increase through family planning education and the limitation of the size of the herds, while improving their quality, through animal husbandry education, would be alternative methods. Both of these unfortunately, take more time and their effect would not be sufficiently felt in the short run.

1.6 A narrow Cost-Benefit study of a Government well program is inappropriate, even if it were possible.

The foregoing considerations suggest that the outcome of the whole development effort of Niger may depend upon increasing the supply of water, particularly in uninhabited parts of the Southern area. The expected direct benefits from the projected Government wells and boreholes are difficult to measure; furthermore, when estimates are presented they are, as we shall see, of very dubious value since the computations assume changes in livestock quantity and quality, which are most unlikely to occur in the short run. The benefits for the whole economy must also be taken into account. They are impossible to measure but, if our analysis of future events in the subsistence sector is correct, they may well be considerable, the sine qua non for economic progress in the country, since they will provide the indispensable respite needed to undertake other projects. The contrast between the limited direct benefits, which can at best be reckoned as the opening of unused land for cultivation, and the importance of the indirect benefits is great. Both direct and indirect economic benefits are forthcoming only for wells dug in areas where the population is unable to dig wells by itself. If wells are to be dug near existing villages, primarily in order to improve the quality of the water supply or to decrease the effort necessary nowadays to extract the water, the benefits to be expected, although not negligible, belong purely to the domain of social improvement. With limited resources available, such wells have naturally a lower priority.

1.7 Livestock improvement associated with Government well projects.

We cannot accept the benefits computation presented by the Government of Niger for its well projects since they assume that livestock improvement will result automatically from a larger water supply. Undoubtedly the stock-raising potential of Niger is important and well understood at present: with more than 4 million heads of cattle, the present annual output does not exceed 7-8%. Possible improvements could bring it over 11%. At present, livestock is the leading export, even before groundnuts; it is estimated that animal products represent over 54% of total exports, for a value of nearly $15 million. In the long run, the annual output of the herds could be considerably improved, providing a better diet for the people of Niger as well as export receipts.

Section 2. Foreign Aid to Niger

2.1 The role of foreign assistance

Foreign aid to Niger averaged $12 million annually during the period 1961-64. Although this represented less than $4 per capita, it was more than one-third of the government receipts. Until 1963 Niger received from France direct subsidies to the budget for current expenses. Since 1964 the direct subsidy was allocated to the equipment budget. Foreign aid now fills the savings gap; it is needed for any investment program. Its magnitude in relation to the modern sector of the economy and to total public expenditures suggests that the donors should exercise great caution in giving aid. Mistakes, such as burdening the government budget with heavy recurrent costs or destroying the present balance in the subsistence sector, would have serious consequences in a country still far from the take-off point. There is a scarcity of apparently feasible projects. Another way to describe the present situation would be to say that the absorptive capacity of Niger for foreign capital is low. Aside from budgetary aid, foreign aid is given for:

1. Technical Assistance, obviously greatly needed.
2. Industrial projects, of which the cement factory

at Malbaza is an example. It is difficult to find viable projects of this kind.

3. <u>Gifts of equipment</u>, particularly heavy equipment for public works and agriculture. Such aid is easy to give; there is no problem of generating funds for local costs. The local public authorities are anxious to obtain as much equipment as possible and the technical assistance personnel encourages them to ask for it since, as technicians, they generally fail to consider the economic wisdom of the use of labor-saving machinery in a country where there is a large supply of unemployed labor during the dry season, from October to May.[1]

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[1]From the national point of view labor is a free commodity during the dry season, in the sense that its opportunity cost is zero. This should not, however, hide the fact that actual mobilization of this untapped source of potential savings is extremely difficult. Although there are instances of community work at the village level -- the existence of thousands of African wells is the best proof -- there seems to be great resistance to undertake unpaid work under the direction of the administration even when the local community is to benefit from it.

Furthermore, the recurring costs are high. The choice open to the government is then either to bear the heavy burden of maintenance and replacement costs or to neglect maintenance. A large part of maintenance costs consists of imports of spare parts and these represent a drain on the scarce foreign resources of the country -- a problem at present less recognized in Niger than the preceding one, and yet more crucial.

Beneficiaries of irrigation projects along the Niger River are known to have refused to repair the government's dams! Local participation will probably be easier to obtain for the digging of wells, for which there is a tradition. This is shown in the experiment of the Upper Volta program of well construction in human investment. For other projects, such as those for which heavy equipment is used at present, the government would have to pay wages. In view of the tax base and considering that tax receipts are not likely to be increased by the amount necessary to finance a sizable program of human investment, the government would have to run a budget deficit or turn to foreign aid. The first part of the alternative is closed because of the membership of Niger in the African Financial Community which offers too many other advantages, the most important

4. <u>Construction</u>, such as roads, bridges, wells, irrigation projects, etc. The advantage of these projects for the donor is the relative easiness with which they are undertaken and the fact that they minimize post-project involvement. Undoubtedly the country gains by adding to its infra-structure and also by the employment provided during the building period. Too often, however, the recurring costs, as low as they are, are too high in relation to the economic benefits derived from

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being naturally the flow of French aid, to be abandoned. As for financing human investment projects through foreign aid, it would require a different attitude from the donors who would have to accept a program rather than a project approach. The objection is that the country is ill-equipped for receiving program aid which requires a higher degree of administrative ability and sophistication by the recipient than project aid. It may be added that, even if the foregoing conditions were fulfilled, there would still be paramount problems in staffing the work projects, particularly at the lower levels. It is much easier to bring in a foreign technician to supervise mechanics, drivers, and equipment, then to train local foremen or team leaders.

the projects. To provide a cement-lined well to a village with already operating wells certainly improves the standard of living. But, in the present conditions, the villagers will not maintain the administration's well, although they used to maintain their own wells, and the annual cost of maintenance for the government will be between $140. and $400. per well, exclusive of depreciation. Should such a program be extended to several thousand wells located near villages of 300 persons or more, the budget would bear a heavy annual burden indeed. (It is here that pilot demonstration program of cheaper, low maintenance cost wells would, if adopted, assist the economy.) The same reasoning applies even more to projects such as deep bore-holes with a pumping station which combine the characters of 3 and 4. Annual costs of operating a pumping station are estimated at about $17,000. including depreciation. It is therefore imperative that construction should be undertaken mostly where an economic need exists. Obviously there are cases where the social need may be so important that it has to be satisfied. But this should be the exception rather than the rule.

5. <u>Institution Building</u>. We shall take the liberty of extending the meaning of the term from a narrow interpretation

which includes only establishing institutions such as a development bank or a semi-independent authority like the OFEDES for well maintenance to a broader one encompassing the launching of all projects whose future role will depend less on the original material investment than on the existence of an active organization. In the latter category, projects such as cattle-fattening ranges, cattle and meat markets, and export channels are included. Interpreted in such a broad fashion, institution building offers a highly promising field of activity for foreign donors. Unfortunately the donors' active participation in such projects has to be greater than in most other projects and the involvement normally lasts over an extended period, if only to continue providing the technical assistance personnel needed until the institution is ready to operate with a purely local staff.

Needless to say, the projects considered generally encompass several of the characteristics that we have described independently.

2.2 The role of U. S. foreign assistance

During the period 1961-64 France provided nearly $36 million of aid, the EEC nearly $10 million, the Solidarity Fund of the Entente $6 million and the United States approximately

$2.5 million. For the period of the Four-year plan, 1965-68, Niger had already obtained commitment for $35 million of aid at the time of the drafting of the Plan and was hoping to receive public foreign financing for a total amount of $80 million, of which $26 million would come from France, over $30 million from the European Development Fund and the balance from various sources including the U. S. whose contribution was to be about $8.5 million, assuming the loan request for wells to be granted. The U. S. aid program would then be third in importance. It seems that, after making the decision to provide aid to Niger for reasons which are beyond the scope of the present report, it is in the best interest of both the recipient and the donor to use U.S. aid in projects where its impact may be most beneficial. Aside from single large undertakings such as the bridge over the Niger River in Niamey, most projects in Niger tend to be scattered, both geographically and technically, alongside projects financed by other donors.

Section 3. The Supply of Water, existing and planned.

3.1 Existing supply

It is estimated that there are about 12,000 dug wells in Niger. Of these about 8,000 are listed in the inventory of wells at the Bureau d'Inventaire des Ressources Hydrauliques. Most of the wells are traditional wells, lined with branches. Over 1,600, however, are "modern", cement-lined, built according to the administration norms, with a diameter of 1.80 meter or 1.40 meter. Nearly 400 were recently built with financing from the FED and 150 more are now being built in a 1000 well undertaking. A map of the distribution of wells shows that - aside from the western area of the Liptako and a small area near the Nigerian border, south of Maradi, where there are few wells - the wells, which are more numerous in the South where the rainfall is highest, are concentrated in the lower parts of the country, the dallols, or dried river beds. The sedentary population is also concentrated around those wells.

As one goes north, the number of wells decreases. In the nomadic zone the animal raisers in some cases only, use first the ponds left at the end of the rainy season and turn to the existing wells when the ponds are exhausted, starting with the shallower wells first. It is in the nomadic zone that most of the deep-bore holes are located. According to the BIRH, there are 51 drilled wells, 17 of which are equipped with a pumping station. Among the 17, 3 are providing water for human uses in small towns and one for industrial use at the cement factory of Malbaza. The 13 others are for the use of nomadic herds (11 in the area north of Tahoua) and the responsibility for their operation lies with the OFEDES. There are also 4 drilled wells equipped with a shallow well for the extraction of water and 30 more are drilled but not yet equipped (6 of the latter having been drilled at the occasion of the building of the road Niamey-Zinder). Artesian wells are mostly located in the department of Diffa, in the East: 17 mainly for livestock use and 6 for human use. One also finds 3 artesian wells for human use in the region of Dosso. Finally there are 9 subartesian wells (combined with shallow dug wells). The total yield potential of these wells is not available.

3.2 The targets of the Ten-Year Perspective, 1965-74

The target set for supplying water for human needs is a well for each village and at least one per 400 inhabitants in the larger villages. In order to reach this target, the perspective envisaged that the government should provide a cement-lined well in cases where water is to be found at a depth greater than 60 feet or when local soil conditions (sand) makes the construction of traditional wells impractical or impossible. Toward this aim it was estimated that 1000 wells would have to be built by the administration and 700 more in areas where the water is to be found at less than 60 feet by improved local means (human investment program).

For animal needs the total annual consumption of water was estimated at 75 million cubic meters, meaning that sources of supply of 25 million more per year had to be built. The program broadly envisaged 50 drilled wells with pumping stations, 30 artesian wells, 100 dams, 150 ponds and 300 dug wells.

3.3 The Four-Year Plan 1965-68 and foreign financing

During the four year period, the plan's target for wells was the construction of 889 wells, 450 financed by FED (of which 150 are being now built), 13 by the national budget, 136 financed by a US AID loan and 290 built in human investment by the local population with the Peace Corps and U.S. financing of equipment. The total cost was expected to be about $8 million, $6 million by FED, $200,000. by the Budget, $1 million by US AID for the construction of wells and $1 million also by US AID for the self-help wells. The 136 wells suggested for financing by US AID were located in the Niamey-Dosso area (96) and the Tahoua area (40). The original loan request to US AID was for 200 dug wells but the number was increased to 236, 36 dug wells substituting for 6 boreholes deemed unnecessary by the planners. Of the 236, 136 would be undertaken during the 1966-68 period: 50 in 1966, 50 in 1967 and 36 in 1968. While such a program, together with the program planned by FED, seems attainable, given the building capacity of the existing contractors, and also the possibility of bringing in more contractors, the program of self-help wells, 40 in 1966, 100 in 1967 and 150 in 1968, appears to be overly optimistic. In October 1966 four Peace Corps volunteers assigned to the self-help wells program had arrived but were waiting for the equipment ordered with the first U.S. gift of $87,000. for that project.

The plan's target for deep boreholes with pumping stations seems to have undergone considerable changes following the failure of the state-financed Société Nationale d'Etudes et de Travaux Hydrauliques (SNETHA); furthermore it was found that some boreholes drilled by SNETHA would require considerable rebuilding before they could be equipped and put to use. Finally a comparison of the original program with the realized program and the now planned program is made difficult by the lack of a consistent method for naming the boreholes so that the same station appears under different names in various documents and even appears twice under two names in the same list by mistake. Broadly speaking the French Fonds d'Aide et de Coopération (FAC) is financing a few drilled wells with pumping stations in the nomadic zone; these stations are planned (or already undertaken) in the area north of Tahoua and also on the location of the FAC-financed cattle-fattening ranch in the area north of Sanam. FED finances drilled wells and pumping stations exclusively for human use, near small towns. The German Federal Republic is to finance 6 boreholes in the rural sedentary zone, plus 5 in small towns. In the eastern part of the country, where artesian wells are possible near Lake Chad, more artesian wells are to be drilled, financed with a loan from the BALAKHANY CHAD CO., LTD. The loan request to US AID was for 15 equipped, drilled wells distributed around a line extending from Dakoro to Tanout. The plan envisaged only 9 drilled wells, all located north of the line Dakoro-Tanout, 7 for livestock use and 2 primarily for human use. The other 6 drilled wells, which were to be for human use, asked for in the loan request, are to be replaced, according to the plan, by 36 dug wells in the same area.

3.4 Purpose of the program proposed to US AID

The program proposed by Government for US AID financing can be divided into three main parts, according to economic purpose:

1. The dug wells located in the sedentary zone. There are 102 in the Niamey- Dosso area, 27 in the Filingue area and 39 plus 36 in the Maradi-Dakoro-Tanout area. The purpose of these wells is essentially the same as those built by FED, either to provide water to deprived villages or to improve the quality of water to villages using polluted water. Both the FED and the US AID program would be part of a more general program of water supply in the sedentary zone. As we shall see, the proposed areas for the dug wells are quite flexible since FED is committed to a program extending progressively to the whole sedentary zone anyway.

2. The 32 dug wells located in the nomadic area north of Tahoua. This is also the area where most of the pumping stations (11) for animal use are located. Wells in this area were planned in order to decrease the distance that the cattle would have to walk between water points.

3. The boreholes in the area north of the line Dakoro-Tanout. Until now there has been no government

intervention to improve the water supply for the nomads and their herds in that area. The program was destined to fill the gap.

3.5 Recent change in the attitude of the authorities of Niger towards the pumping stations in the nomadic zone.

Soon after our arrival in Niger, it became evident that the authorities were becoming increasingly critical of the whole planned program of drilled wells with pumping stations. The objections they raised were essentially of two kinds:

1. The high operating cost of the pumping stations. After pumping stations had been in operation for three years (9 in 1963-64, 10 in 1964-65, 13 in 1965-66), the OFEDES was able to provide a fairly accurate estimate of costs: excluding depreciation charges, water cost, about 42 CFA per cubic meter, amounting to an annual cost of $8,000. per station. Including the depreciation charges, the annual cost was close to $17,000. The latter was computed on the basis of an average life of 10 years for the drilled well, of 20 years for the buidings, of 7 years for the pumps and of 14 years for the 2 motors. In fact the average life of the first drilled wells is expected not to exceed 7 years; but improvement in the quality of materials used for future wells should bring the life expectancy to 10 years. It also seems that 14 years may be overoptimistic for

the life expectancy of the motors. With that information the authorities began to realize that the implementation of the total program for human and animal needs which would bring the number of pumping stations close to 100 at the end of the ten-year period would saddle the annual current budget with a burden of the order of $1.5-$2 million, including depreciation.

2. The deterioration of pastures around the pumping stations in the nomadic zone. Originally the pumping stations in the nomadic zone had been conceived to provide emergency relief during the period March-June when, at the end of the dry season the other sources of water in the nomadic zone, ponds and shallow wells, are exhausted. In fact, under local pressure, the stations begin to operate earlier every year. Already several were open at the end of October, at a time when surface waters are still to be found in the nomadic zone. As a result, the grazing land in many areas is under-utilized and the problem of overgrazing around the stations begins to assume ominous proportions. The problem is compounded by the fact that the large number of animals grouped around the stations trample the pasture. Greater and greater distances must be covered to find grazing away from the pumping stations. The improvement in livestock expected from the availability of

water is nullified by the deterioration of the food supply. The situation is in fact absurd because the herds go early in the season to the pumping stations, eating and trampling the pasture there. When the pasture has deteriorated completely, it is too late for them to take advantage of the rest of the grazing land, because both the ponds and the shallow wells have dried before they were used. Even the animal raisers who are still willing to undertake the hard work of extracting water from the wells for their herds suffer from the general misuse of the stations since they find the area around the station overgrazed when they really need to go there at the end of the dry season.

For the sake of completeness, it should be mentioned that the Director of Animal Husbandry still favors strongly a program of drilled wells with pumping stations, provided that the stations are opened only when really needed. Unfortunately, the condition is not likely to be met in the near future in Niger.

3.6 The Nedeco report and the reactions it aroused.

Water needs in the sedentary zone were studied during the first few months of 1965 by the Nedeco with financing from FED. The report was submitted to the Government of Niger in May 1966. Apparently the reactions of the local officials were less than favorable.[1] In spite of these opinions, the FED seems determined to go ahead and use the order of priorities drawn by Nedeco to decide the location of its next program of wells in the sedentary zone. From an economic viewpoint, it seems that while the Nedeco report could be used in planning wells for villages presenting extreme cases of hardship, the priorities cannot be used for what we consider the economically significant roles of a wells program, the opening up of new land. Indeed the enquiry was led by sociologists using questionnaires and the results naturally showed needs for water where there were settlements, omitting the potential needs where there is at present no water supply and no settlement. On the other hand the report presents a number of suggestions for building wells which are well worth investigating, instead of carrying on blindly with the present well proven but very expensive method.

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[1]For a presentation of these criticisms, see: Jacques Vadon, Compte-Rendu Critique du Rapport Medeco, September 1966 (Mimeographed).

3.7 The Meeting of November 14, 1966

In order to clarify the uncertainties now surrounding the program that the authorities of Niger wanted US AID to finance, a meeting with officials most concerned with the wells program was held at the Ministry of Public Works on November 14.[2] From the discussion that took place, it appeared that:

1. There was no preference on the side of the officials as to the area (or areas) where U.S. financed wells in the sedentary zone should be located. Our impression is that, should the U.S. display a preference for having the wells in a specific area of the sedentary zone, it will be readily accepted by the authorities. The only qualification is that a decision should be taken as soon as possible in order to avoid overlapping with the new FED program, the implementation of which may be decided soon.

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[2] The participants of the meeting were: Mr. Briot, Director of the Bureau of Mines, Messrs. Galland and Ninin from the Ministry of Public Works, Mr. Regnault from the Ministry of Saharian Affairs, Mr. Vadon from the BIRH, and Mr. Greigert from the Bureau de Recherches Géologiques et Minières (a private consulting firm). On the U.S. side: Mr. Guardiano, US AID Operations Officer and the two members of the survey team.

2. There seemed to be an agreement that the proposed 32 dug wells in the area north of Tahoua were not needed at present. Those wells were meant to relieve the overgrazing of the areas around the pumping stations. But the existence of unused ponds and shallow traditional wells suggests that dug wells would not be used by the nomads who would have to extract water laboriously using traditional methods while water is flowing freely at the pumping stations.

3. For the reasons explained in 3-5 none of the participants looked favorably at the remaining proposed program of 9 boreholes with pumping stations in the area north of the line Dakoro-Tanout.

4. There was a feeling, however, that a sizable part of the program should be devoted to the nomadic zone both because of the importance of animal husbandry in the economy of the country and because of the past relative neglect for the nomads. Several areas for implementing a dug wells program financed by the US AID were suggested.

a. <u>An area near Tillia, along the border of Mali</u>. This area is just north of the FAC-financed cattle-fattening ranch. The purpose in providing water near the ranch would be to attract nomads from whom cattle could be bought for fattening on the ranch. A secondary purpose would apparently be to relieve forthcoming pressures caused by a poorly timed implementation of the various elements of the ranch: boreholes were drilled before the ranch area was enclosed. As a result, nomads were attracted to the drilled wells, even though the pumping stations are not yet built, in the expectation of an abundant supply of water. Driving them off the ranch area might create some serious difficulties unless they are offered some water in the vicinity. We recommend against financing wells in this proposed area. The need for wells there has such a high priority that they will in any case be built, either with FAC financing, in order to secure the successful completion of the ranch project, or with GON funds. To provide US AID for a project which would be undertaken in any case, and soon, would release GON resources for another project. It is in fact this other project that the US AID loan would really finance without having any voice in its implementation.

b. The nomadic area north of the line Dakoro-Tanout where drilled wells and pumping stations were originally envisaged in the loan request to US AID. This area is included in the suggested area for the pilot action program (plate 1).

Section 4. Problems affecting well construction in Niger

4.1 Introduction

The type of wells built by the administration in Niger is fairly standardized; 1.80 meter or 1.40 meter in diameter and with 0.10 meter of cement. Their cost is very high: about 60,000 CFA per meter, or $240. It is therefore reasonable to ask whether other cheaper types of wells could not be built.

4.2 The extraction of water

There seems to be general agreement that no change in the traditional way of extracting water is possible in the foreseeable future, at least on a large scale. At present water for human uses is extracted mostly by women, who each bring their own rope and dalou (a collapsible bucket made of animal skin) to the well. In any case, the water lifting method is very primitive. Attempts have been made at changing it, both in order to avoid pollution and sand clogging and to decrease the hard work required for extracting the water. Unfortunately most of the systems tried have failed because of the lack of sophistication of the population; roundabouts pulled by oxen or donkeys, aeolian, even pulleys are not maintained if they are communal property. The animals are not even fed. Only one kind of implement can be used at a time and no one is willing to draw water for a neighbor, even taking turns. Using the traditional method, several women or several teams of oxen can work simultaneously. When the water is to be found near the surface, shallow, drilled wells, sealed and equipped with a hand pump, would be the obvious answer. Unfortunately, experience shows that the pump is soon out of order and the village deprived of water. Combined with education, more hand pumps might be introduced in the more advanced areas, near cities, but the number of pumps which could soon be used is probably small.

The present system of extracting water forces the adoption of a very simple type of open well with a very low edge. On the other hand, the present dimensions adopted for wells and the building techniques may be varied more than is generally assumed among officials in Niger.

4.3 The diameter of the wells

Several reasons are given for the adoption of a large (1.40 or 1.80 meters) diameter.

1. The circumference of a well with a large diameter is needed to allow several women (generally 8) or several teams of oxen (6 at most) to be able to work simultaneously.

In places where the well must accommodate many people simultaneously, the cost of building one large well should be compared with the cost of building several smaller ones. Although the quantity of raw materials for the lining would seem to be proportional to the radius, a well of a smaller radius would need a thinner lining, so the total raw material expenditure for lining two wells would be smaller. Also, in the case of a cement-lined well, molds of a smaller radius appear to be considerably cheaper. Another saving, of less consequence because of the cheapness of local labor, arises from the fact that the amount of earth to be dug is proportional to the square of the radius, whereas the circumference is proportional to the radius. On the other hand, the fixed construction costs for each small well would be proportionately higher than the fixed costs of a larger well.

2. The present size is adopted in order to satisfy the requirements of the OFEDES for maintenance. It seems that the existing equipment of the OFEDES for well maintenance requires a minimum diameter of 1.40 meters. Since we have been told that the equipment of the OFEDES for extracting the sand from the bottom of the wells without pumping is in need of replacement, such a reason does not have much value if another type of equipment could be used for smaller wells.

3. When well screens admitting water entry become clogged, the well has to be dug further and the supplementary lining is added telescopically, thereby decreasing the original diameter. This method would be radically altered if different building techniques were introduced.

4.4 The problem of maintenance

Although the local populations used to maintain their own wells, they are extremely reluctant to participate in the maintenance of the administration's wells. An effort to encourage them to take care of the routine aspects of cement-lined wells' maintenance is being undertaken in order to prevent the burden on the OFEDES from becoming a task beyond the human and financial ability of that organization, which should specialize in effecting major repairs only. The obstacles are formidable but if one considered that the average annual cost of maintenance of a well by the OFEDES is about $280., the maintenance cost saved when a well is maintained locally corresponds to the interest (at 6%) of capital amounting to $4,666. This compares favorably with the saving obtained by building a well less than 60 feet deep using voluntary village labor.

4.5 Government and Third Party Wells

It had been hoped to tabulate the number and types of existing wells, well projects proposed in the four and ten year plans, wells requested from AID, etc. Unfortunately these statistics are not assembled in Government files and a very long time would have been required to ferret out the data. The pressure of daily work is such that many wells have not been posted on large scale army maps for which additional clerical staff would be needed.

FED, the chief doner of new wells at this time, has completed about half of a 1,000 well program. Costs have been so high that the commitment is now being considered in the light of capital investment totals rather than the number of wells made.

Section 5. Cost-Benefit Analysis

5.1 Introduction

We have already, in Section 1.6 of this Chapter, stressed the limitations of a cost-benefit analysis of the Government wells program in Niger. The direct benefits estimated in the project proposal will be forthcoming only if changes in animal husbandry are made. Other direct benefits are purely social or impossible to estimate with any reasonable degree of accuracy. The indirect benefits of wells, such as the cultivation of virgin land, would be important since, in our opinion, such a program would give Niger a respite in the race between population growth and its development program but these benefits cannot be accurately estimated either. The costs of construction of wells with the present methods are fairly well known. Two qualifications are, however, in order:

First, these costs are obtained by using the current prices of labor and equipment. These prices do not reflect the relative scarcities of the production factors. The true costs, from an economic viewpoint, distinct from a narrow accounting approach, could only be estimated using shadow prices. It was not possible to determine a set of shadow prices within the scope of this study. Current prices for labor naturally tend to overvalue labor, particularly during the dry season when agricultural labor is unemployed. On the other hand, if heavy equipment is financed by foreign aid which would not be granted for another purpose, the opportunity cost of the equipment (excluding the recurrent charges) becomes also nil.

Second, since it is recommended that other construction methods be explored and used if their real costs are more favorable, the main usefulness of an analysis of present costs will be to provide a basis for comparing the costs of other methods with the costs of the present cement-lined wells.

5.2 <u>High costs of projects in Niger</u>

The cost of drilled wells is 60,000 CFA per meter, i.e. 9 million CFA for a 150-meter well, plus the cost of buildings and equipment, 13 million CFA. The total is approximately $88,000. Dug wells cost about 60,000 CFA per meter or $240. For a well 40 meters deep total cost is $9,600.

In the next subsections we shall examine the components of these costs in greater detail. At this point we would like to emphasize that high prices for building are the rule in Niger, a reflection of the high transportation costs due not only to distances but also to the lack of transportation facilities. The cost of transporting personnel, equipment and raw materials should be carefully considered in any alternative method envisaged for wells construction.

High costs are also found in other projects.[1] In particular we found that the cost of irrigation projects along the Niger River, close to Niamey, is estimated to be over $1000. per hectare when effected by the administration. This figure does not include any expenditure for land purchase. Furthermore we suspect that the real figure is somewhat higher. Public accounting does not provide for the depreciation of equipment, which is probably underestimated. A study of the irrigation project at Kolo[2] undertaken from 1951 to 1960 shows that the cost of the main irrigation work amounted to 125 million CFA

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[1]A benefit-cost analysis of planned irrigation projects is presented in Appendix II-4

[2]Compagnie Générale d'Etudes et Recherches pour l'Afrique, L'Amenagement Hydro-Agricole de Kolo, Décembre, 1961 (Mimeographed)

(at 1960 prices.) Pumping stations and secondary projects amounted to a further 28 million CFA. The capital output ratio was 6.7. The cost per hectare of the main irrigation work (500 hectares irrigated) was exactly $1,000. Whereas past irrigation projects had costs comparable to the new irrigation projects, they cannot serve as a basis for a cost-benefit ratio because the overall conception of the new projects seems superior and one may hope that output on the new projects will justify them. Much of the outcome will depend on the annual yields that the local peasants will obtain on the new projects. They are charged the recurrent costs of the pumping stations or $60. per year per hectare. If a man, cultivating one hectare, produces 2 crops of 2.5 tons of rice each, he will have, after seeds and irrigation costs, about $240. Furthermore, he will obtain about $30. worth of millet on one hectare of non-irrigated dunes. By comparison a family of Touareg nomads consumes about $216. per year and a family of Peul nomads about $140. However, if the interest on the irrigation investment ($60. at 6%) -- a public subsidy to the farmer -- is deducted, the project becomes marginal. The outcome entirely depends on the yield per hectare and will be known only in a few years. The most promising project is probably the one at Kirkissoye where annual yields of 40 tons of vegetable per hectare are expected.

5.3 A study of the costs of dug wells in the Maradi area.

At the Ministry of Public Works, we found the records of the bids submitted by several contractors for the FED program of wells in the Maradi area. The breakdown was not sufficient to allocate the costs to the various factors of production. Fortunately, it appeared that, reacting to the high prices of the bids, the FED had requested from the bidders a more detailed breakdown. Among the eight contractors who complied, we found that the information supplied by three could be used to prepare a comparative summary table, which we present in Table 1.

Caution is needed in the interpretation of the table. First, it is doubtful that the contractors were willing to reveal their true costs and their accounting methods to the administration, especially before they received a contract. It is therefore quite possible that the detailed prices they submitted may have been computed for the use of the administration. Second, the methods used were widely different and we have had to exercise our judgment in the attempt to make them comparable. On the other hand, some of the seeming discrepancies can be explained by the fact that they are percentages

TABLE 1

FOREIGN AND LOCAL COSTS IN THE CONSTRUCTION OF DUG WELLS IN NIGER

Contractors' Costs (in percentages)

Items	A		B		C	
	Local Costs	Foreign Costs	Local Costs	Foreign Costs	Local Costs	Foreign Costs
Labor	16	12	24	7	22	10
Raw Materials and Supplies	9	3	8	6	10	12
Motor-fuel	-	7	-	8	-	6
Equipment	-	8	-	7	-	6
Taxes	16	-	16	-	16	-
Overhead	13	12	14	6	12	2
Profit	-	4	-	4	-	4
TOTAL	54	46	62	38	60	40

Notes: 1) Foreign labor has some local content since the foreign technicians spend part of their salaries in Niger.

2) Some local labor is included in the local expenditures for raw materials, e.g. costs of extracting sand and gravel.

3) Taxes amount to exactly 15.8%: 9% for indirect taxes, 5% for Enregistrement tax, and 1.8% for Patente.

4) Overhead expenditures include expenses for unforeseen contingencies: 6% for A and B, 1% for C. If no such contingencies arise, profit is higher.

5) Profit is considered as a foreign cost since all the bidding contractors but one were foreign firms.

6) Expenses for transportation of raw materials, supplies, etc. are allocated according to their components, labor, fuel, depreciation. They amounted to 9% for A, 6% for B and C.

and that the total costs vary considerably: for a well 60 meters deep, A charged $16,000., B $14,000., and C $10,800.

With these qualifications in mind it can, however, be safely concluded that with the present method of building the wells through contractors, about 40% of the costs are foreign costs and about 60% local costs.

The foregoing breakdown of costs has some implications for the savings which can be effected by building wells in a human investment program. First, it should be noted that out of $240. per meter paid to contractors, 15% or $38. represent taxes which are not a true cost to the government since they come back to it. Second, local, unskilled labor represents only about half the total local labor cost. It is this share that could be contributed by the village population, a saving of about $24. per meter. To this should be added a further saving of about $8. per meter when sand and gravel can be provided locally by the village population. Third, and contrary to what one might have expected, no saving is at first to be found under the heading, foreign labor costs; the experience of Upper Volta shows that in such a program a foreign supervisor is needed for the construction of about 400 meters of wells per year; its cost is well above $40. per meter, about $15. above the foreign labor costs per meter of wells built by a contractor. The explanation is to be found in the economies of scale obtained by contractors. However, after 2 years, the foreign supervisor could probably be replaced by a local supervisor whom he would have trained; the latter would, from then on, cost only about $10. per meter. Finally, if administrative expenses can be kept to a low level, probably about 15% more could be saved from the overhead costs and the profit of the contractor. One can see that, during the first two years when a supervisor is needed, the saving per meter (including taxes) would be only $90., but it would reach $120 in the third year, which represents about half the present price. The result is consistent with the results obtained in Upper Volta where such wells cost 26,000 CFA per meter while wells built by contractors cost about 50,000 CFA.

In fact, comparisons between wells built in a human investment program and wells built by contractors are even more difficult because several other factors should be taken into account. The villagers can only work at small depths -- the average depth in the Upper Volta program is 45 feet -- and the equipment needed is then less important.

Finally, the quality of village wells is certainly lower than the quality of wells built by contractors whose materials have to conform to the specifications set by the Ministry of Public Works.

The cost of building shallow wells could be further reduced by decreasing the amount of raw materials required. Mr. R. Koegel has proposed for village wells built in a human investment program a type of well, 1.25 meters in diameter, 0.05 meters in thickness, with a 2 to 3 meter tube at the bottom.[3] Several objections have been made in Niger to this type of well. The most serious objection arises from the problem created by the dirt, brought into the well by the ropes, which eventually fills the tube which cannot be cleaned. We believe, however, that the possibility suggested by Mr. Koegel should be further explored. On the other hand, we express some doubts about the price of $24. per meter quoted for such a well. Such a price seems to cover only the raw materials and probably excludes the cost of qualified labor, supervisors, equipment, transportation, and overhead administrative expenses.

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[3]Richard Koegel, "Puits 'Self-Help'", US AID, Niamey, Niger, 8 Février, 1966. (Mimeographed).

5.4 Costs of borehole-dug wells combinations and the boreholes with pumping stations.

It has not been possible to obtain a detailed breakdown of the costs for boreholes flanked by dug wells, a solution which is to be recommended because of the low recurrent costs in cases when there is subartesian water, or for boreholes with pumping stations.

In 1964, the average cost per meter of a 320-meter borehole in the area north of Tahoua was 41,000 CFA or $164. The average borehole then cost over $52,500. In this sum was included the cost of assembling and disassembling the equipment at the site of drilling, about $10,000. The cost of a 150 meter borehole in the GON proposal for the US AID loan was estimated at $36,000. or $240. per meter. The higher cost is explained by the higher fixed cost for shallower boreholes and also by changes in costs during the time period elapsed.

Building and equipping a pumping station is estimated to cost $52,000. On the other hand, the building of a complementary dug well would cost slightly more than building an ordinary well since a connection has to be made between the well and the borehole, about $1,200. more.

In the absence of a cost breakdown, we do not know the exact share of local and foreign cost in the case of a borehole. We presume that the foreign costs would represent a considerably larger share than in the case of dug wells.

5.5 Summary of costs of water for human and animal uses

TABLE 2

In US $ per cubic meter

	Investment Cost	Annual Cost		
		Mainten. Cost only	Mainten. + Deprec. Costs[a]	Mainten. + Depre. + Amortiz. Costs[b]
I) Water Holes				
1) Human investment program excl. administra. overhead	0.32[c]	0.01[c]	*	*
2) Built by the administration	0.56[c]	*	0.06[d]	0.08[c]
3) Built by private contractor	1.68[c]	0.05[c]	0.12[d]	0.16[c]
4) Built by private contractor with coating (clay, cement or plastic)	2.96[c]	*	0.13[d]	0.24[c]
5) Built by private contractor with plastic coating and filled with gravel to decrease evaporation	5.28[c]	*	*	*
6) Experimental water hole near Niamey: digging only	1.20[e]	*	*	*
with fence & cover	5.40[e]	*	*	*
II) Dams				
1) In Niger	0.68[c]	*	*	0.08 to 0.16[f]
2) In Upper-Volta	0.16 to 0.48[g]	*	*	*
III) Artesian drilled wells	*	*	*	0.09[h]
IV) Drilled wells with pumping stations	1.87[i]	0.17[i]	0.29[dj]	0.36[ij]
V) Dug wells in the sedentary zone by private contractor [m]	0.80[k]	0.02[k]	0.05[k]	0.08[k]
VI) Dug wells in the nomadic zone by private contractor [m]	1.10[l]	0.03[l]	0.07[l]	0.11[l]

* Information not available

Footnotes to Table 2

a. Expected life for wells and water holes: 25 years. In fact, they could last much longer if properly maintained. For depreciation of drilled wells with pumping stations see footnote (j).

b. Includes the amortization of the original financial investment during the period of repayment of the loan (40 years, 0.75% per year interest).

c. Estimate by the Génie Rural

d. My estimate

e. By Mr. Orev, an Israeli expert. The cost is high, probably because of the small size of the water hole (500 cubic meters). Digging costs could be considerably reduced in a human investment program. The rubber cover is very expensive. Other means of preventing evaporation could be found. These costs do not include the building of an overflow, filter, and troughs.

f. Depending on the speed of silting.

g. For retinue dams holding about 2 million cubic meters. No overflow, filter or trough included. The losses by evaporation are considerable because of the large surface due to the flatness of the country.

h. Estimate by the Génie Rural. This is obviously the best solution wherever possible.

i. Estimate by OFEDES.

j. Expected lives: borehole, 10 years; buildings, 20 years; pumps, 7 years; motors, 14 years. In fact the first boreholes lasted less than 7 years. It is now believed that the more recent ones will last longer because better screens are used.

k. My estimate for a 60-meter dug well producing 50 cubic meters of water per day, built by a private contractor at an average cost of $240 per meter. Maintenance by OFEDES estimated at a maximum of $400. per year. Maintenance costs could be reduced by education of the population.

l. Same basis as (k) but higher building and maintenance costs in the nomadic zone.

m. In a human investment program, costs would be slightly over one half of the costs of wells built by private contractors, assuming again that the present technique is retained. However, it would be difficult to implement such a program in the nomadic zone. The same remark naturally applies to water holes which can be built in a human investment program in the sedentary zone only.

Water holes and retinue dams.

The cost estimates are for water retained. Because of the unknown but certainly considerable evaporation losses, the costs per cubic meter of available water would be much higher. Moreover, when a permanent supply of water is created, it is necessary, for health reasons, to equip the hole or the dam with a sand filter and troughs which increase the cost. When the hole dries up completely every year, the health hazard is lessened, but then there is no water supply when it is most needed, at the end of the dry season.

In order to prevent the evaporation losses several methods have been proposed (Table 2, lines I-5 & I-6). In both cases the costs are prohibitive.

Dug wells

The cost estimates are for available water. Carefully located wells of adequate aquifer penetration provide water all year round.

On the other hand the cost to the users is high since they have to lift up the water--a very hard task. However, from the national point of view, considering that there is a labor surplus during the dry season, the opportunity cost of labor is zero.

In the nomadic zone, the limitations imposed by the difficulties of lifting water from the wells act as a constraint on the number of cattle units which can be watered. Such a constraint provides a built-in protection for the pastures in the vicinity of the well (See Appendix II-5).

5.6 The benefits of the project

We shall mention only briefly the benefits expected by the GON from the deep boreholes with pumping stations in the nomadic zone. We have seen that these drilled wells were no longer to be considered as part of the loan request. One more reason to object to them is that, even with the use of the most favorable assumptions, the loan proposal showed only a slight excess of the benefits over the costs during the 10-year grace period and after the repayment of the loan. During the 40 years of repayment, the costs would slightly exceed the benefits. It is also important to note that the costs taken into account already seem lower than the true costs, because the boreholes have only a useful life of 10 years at most (and not 15 as expected in the proposal) and because annual maintenance and operating costs with unforeseen contingencies will probably exceed the $4,000 now expected by the OFEDES. On the other hand, the expected benefits are considerably inflated since they are computed under the assumption that livestock will directly gain from the boreholes. We have seen that, at present, the effects of the increased water supply were balanced by a deterioration of the pastures. Even if this had not taken place, it would be a bold step indeed to assume that water alone would increase the annual output of the livestock.

The benefits to be expected from dug wells in the nomadic zone would certainly be smaller than the ones presented by the GON. The method used by the GON consists first in assuming that the capital value of the livestock using the wells will increase. Whereas we rejected this assumption in the case of boreholes, it could be a legitimate one for dug wells, if enough dug wells were constructed to allow an even distribution of the animals over the grazing area. According to the GON proposal, the capital value would increase by approximately 20%, 3% representing an increase in number and the balance an increase in weight. Under present conditions, the increase in number is likely to be somewhat larger and the increase in weight somewhat smaller. We shall retain this figure of 20% increase in capital value. Then the benefit computation presented by the GON proceeds by assuming that annual output will increase from 7% to 10% of the capital value for cattle and from 25% to 35% for sheep and goats. Unless changes are made in livestock quality, such a hypothesis is absolutely unwarranted for the near future. We can thus assume only that, in the case of a dug well servicing 1,200 livestock units, the capital value would increase from $42,000 to nearly $52,000. Annual gross income would then increase from $4,200 to $5,000 or by $800. Costs computation provided by the GON show that the annual cost (depreciation over 30 years, maintenance reckoned at $280 per year, interest on loan at 0.75% and repayment of the loan after a 10-year grace period) would be $680 during the first ten years, $880 during the following 40 years, and $600 thereafter, for a 40 meter well. In the nomadic zone, the average depth of the wells is probably greater, at least 50 meters. The building costs will also be higher. In such a case, the project would be considered sound according to strict acounting criteria only when a greater financial return on stock were achieved. We shall therefore recommend that a parallel action be taken to spread animal husbandry education by extension work in the nomadic zone. The results of such action take a long time to mature. However, no improvement of the living conditions of the nomads is possible unless both extension work and water projects are undertaken. On the other hand, as we have seen there is an indirect benefit to be obtained by providing permanent water to the Peul nomads and thus encouraging them not to migrate to the sedentary zone during the dry season.

The benefits to be expected from dug wells in the sedentary zone are presented by the GON, assuming that the number of livestock units in a village is 650 and that the benefits are to be entirely derived from the livestock. In cases of already existing villages, it seems that better yields could be obtained from the livestock but that this would be the consequence of extension work more than from the construction of wells.

In cases where a village de culture exists, i.e. a temporary village, inhabited only during the rainy season, while the peasants cultivate the surrounding fields but deserted during the dry season for lack of a well, the benefits from a well would be greater since the peasants could start farm work earlier, before the rains and the livestock could remain in the area during the dry season if a well were provided. In the most favorable cases, where the land is uncultivated at present, the direct benefits would come from the output of that land brought into culture. The indirect benefits which are the most significant arise from the postponement of the time when the land limit is reached.

CHAPTER III. PROPOSED ACTION PROGRAMS

Action programs, rather than undertakings involving additional study and analysis would seem advantageous from the viewpoint of early initiation of sound benefits to the Republic of Niger. In making a selection there are two important governing factors: (a) provide a show-case for American technology; (b) demonstrate techniques that will greatly reduce the cost of finding a cubic foot of water.

Choice of Central Area

The area in which we believe the program should be concentrated is shown on the map presented overleaf. Maradi is the center of the sedentary zone and Zinder is located just outside its eastern limit. It includes the nomadic zone north of the line, Dakoro-Tanout, in which no important water supply program has so far been undertaken.

Section 1. Drilled Wells

Pilot Percussion Drilling-Sedentary Zone

There is an excellent opportunity to demonstrate American water well construction technology and associated hydrogeological control which, in combination, will penetrate the complete thickness of a surface aquifer and discover the maximum volume of available water per foot of subsurface penetration. This practice is not followed in Niger today. Alternatively, large diameter (1.8 to 1.4 m.) hand-dug wells with hand-cemented side walls are laboriously carried only to and slightly below the top surface of the underground water zone. Holes are terminated at the bottom by 1.4 to 1.0 m. cement rings containing stainless steel insets of uniform mesh occupying only 4% of the well opposite the producing formation compared to a range of 8 to 24% screen face in American practice. Since the bottom of the aquifer is not reached by this method ten to twenty times the amount of water found remains out of reach to drain away down the hydraulic gradient. This procedure raises the cubic foot cost of water finding considerably above what it would be if all of the fluid occurring at each well site were made available. Under favorable conditions cost per foot is $73.20 and the rate of penetration not over 3 feet daily. Although the diameter of FED wells is say 1.40 m. the Nigeriens for their own account, often use a 0.80 m. diameter or 31.5 inches. Even then the access opening is reduced by rectangularly-placed logs across the well mouth (photo-2). The pilot drilling program here favored would involve rapid percussion drilling at a minimum rate of 15 feet per day of a 36 inch diameter hole to be lined with 30-32 inch diameter metal casing, appropriately perforated opposite the full thickness of the water saturated interval. Given availability of gravel the well would be gravel packed behind the permanent casing.

After a well has been drilled it must be "developed" which we understand FED wells are not. Well development provides for ready entry of ground water with minimum resistance in and around the casing.

In consolidated formations water may be allowed to move directly into an uncased hole although we do not recommend this practice in Niger. In unconsolidated formations, however, casing is necessary. It must serve the dual purpose of freely admitting water and supporting the outside material. The casing must either contain perforations or be replaced by a well screen. Water should be allowed to enter along portions of a well penetrating permeable aquifers. Other sections of the well should contain blank casing and be sealed by puddled clay or cement grout to prevent vertical water movement along the exterior of the casing.

Perforations may be made in the field; otherwise machine-perforated casing can be secured. Field perforating can be done before placement by punching or cutting with an acetylene torch. In-place performation are also made with a well knife or well perforator. Generally a horizontal-louvered opening gives a better control of unconsolidated materials than does a vertical slot. Opening should be large enough to allow 50 to 80 percent of the surrounding grains to pass into the well. The coarse, remaining fraction will then form a highly-permeable zone around the well.

A gravel-packed well is one containing a gravel "screen" or envelope surrounding the perforated portions of the casing. The gravel increases effective well diameter, acts as a strainer to keep fine material out of the well and protects the casing from caving of surrounding formations. A gravel-packed well, properly constructed in an unconsolidated formation, usually will have a greater specific capacity than one of the same diameter not surrounded by gravel. In aquifers possessing a large proportion of fine sand, a gravel screen is necessary to avoid sand pumping.

The thickness of the gravel layer should vary with the type of formation. However a minimum of six inches is usually required to be entirely effective. Experience favors a gravel pack comprising a range of sizes ranging from sand up to ¼ inch gravel.

Following completion a well should be "developed" to increase specific capacity, prevent sanding and obtain maximum economic life. Construction methods used by FED do not permit this procedure. The importance of "developing" wells cannot be underestimated. All too often development is not carried out adequately to give full potential yields.

"Development" by pumping requires a pump with a suction pipe extending to near the center of the perforations or screens. The pump is operated at low discharge until the water clears, following which the process should be repeated in a step-wise manner at successively higher discharges until the maximum pump or well capacity is reached. Irregular and non-continuous pumping agitates the fine material surrounding the well so that it can be carried into the hole and pumped out. The coarse fraction entering the well is removed by a bailer or sand pump. A more effective method of developing a well is surging created by the rapid up-and-down motion of a plunger. The plunger is operated above the perforations or screen in wells penetrating unconsolidated aquifers and in the casing above open holes in rock aquifers.

Calgon is often added to the well water. As the plunger rises it draws water into the well while lowering forces water out into the aquifer. The flow reversal overcomes sand bridging and transports fine material into the hole. Surging may be performed with a bailer or a circular surge block. Surging should be continued until no more sand or mud enters the well.

Equipment suggested for this operation is a Speedstar percussion rig, Model M 81 or equivalent, mounted on a 4 x 4 truck with sand tires, using a 36 inch bit, to insure a sufficiently large diamter hole for continuous water withdrawal by several individuals operating simultaneously. The equipment will operate within rated limits to a depth of 600 feet. This range will provide for a strategic deep test, should this be warranted, in search of artesian production and stratigraphic exploration.

Proposed American personnel are one very experienced driller-mechanic-welder and one versatile hydrogeologist-photogeologist, both fluent in French and accustomed to overseas operations.

In passing it should be noted that a bailer is not only applicable to "developing" a well (i.e. conditioning it for maximum utility) but also for approximately determining the producing potential. During each round trip of the bailer up and down the hole, a part of the water is removed and a record kept of the total amount produced per unit of time. This is, indeed, a considerable improvement over prevailing practice, since the procedure followed by others does not provide for gravel packing opposite the producing interval, well "development", production testing and rehabilitation i.e. thorough cleaning out sedimenting well and well screens. Whenever a cement-lined FED well clogs and production drops, sediment found in the bottom of the well must be removed by hand or mechanical grab but there is no way of unclogging the well screens to reinstate the volume of water entry.

During field trips with a government engineer it was observed that new cement-lined wells were recommended to villagers rather than undertaking a difficult, if not wholly insoluble task of proper reconditioning. In the long run water finding costs are elevated far beyond the amount required through failure to apply American technology.

During 18 months suggested for the pilot and educational program about 5000 feet of hole would be drilled. Mechanical drilling will accomplish this footage for a reduced price including time out for training and instruction.

The key elements of this undertaking being (a) to determine the total thickness of phreatic aquifers; (b) estimate therefrom water reserves and safe yield; (c) demonstrate the advantages of modern American mechanized techniques; (d) compile and develop hydrogeological parameters essential for locating areas of maximum water producing potential including places suitable for developing unused arable land; (e) mapping the ground water table; (f) control of subsurface stratigraphy, lithology and structure; (g) analyze water quality and applicability in all instances; (h) train up to 10 people selected and supported by Government in the fields of drilling, production, well testing, elementary hydrogeology and photogeology - it is recommended that this program be offered to the GON for a period of 18 months.

We would envisage both on-the-job and lecture instruction, including examinations; as soon as practicable, responsible assignments would be given to develop reliability and confidence.

In cable tool drilling the falling bit crushes hard rock into small fragments and loosens material of unconsolidated sediments. Reciprocating action of the tools produces a sludge or slurry which is removed to the surface by a bailer. A bailer is a section of pipe with a plunger and check valve at the bottom which opens upon impact with the bottom of the hole.

Water rushing into the empty bailer on a vacuum created by movement of the plunger sucks debris from the bottom of the hole into the bailer for removal to the surface. In the same manner sand entering the well from ropes, buckets or otherwise may be quickly and inexpensively removed through a few trips of a bailer whenever required. This is called "cleaning out" or rehabilitating.

Well maintenance is different. There is no single workable formula for every geological, hydrogeological, water-quality and/or well construction type condition. A careful study of the well in question and histories of surrounding boreholes will reveal logical steps in devising maintenance procedures.

Most commonly the cause of decrease in well capacity is a clogging of the water-bearing formation and clogging of opening in the well screen as controlled by water quality. The kinds and amounts of dissolved gasses and minerals in natural waters determine the tendency to either corrode metals or to deposit some of the mineral matter as incrustation.

The degree of attention required to keep a well functioning properly varies with the quality of water in the aquifer. The second problem is that of maintaining good records of well operation. Corrosion may be limited by using a screen tailored to the type of well water involved. Incrustation cannot be prevented. Incrusting materials should be analyzed from which the best method of treatment may be ascertained, such as acid, chlorine, glassy phosphate and physical agitation.

We would envisage both on-the-job and lecture instruction as mentioned previously.

The loan request of the GON includes the cost of hydrogeological control (20 million CFA or $81,632). It is imperative to supply a hydrogeologist to predict well locations of maximum potential. At present, neither the Bureau of Mines nor the BIRH has the necessary staff to do this. In the most recent program financed by FED, contractors were often delayed, with all their equipment ready in the general area of the site of the well, waiting for the exact location to be decided.

Section 1.2

Estimated costs for the pilot drilling program are presented in the following table. These are based on averages used for Aero overseas operations in 1967 and do not reflect future changes in monetary value or purchasing power.

DRILLING PROGRAM COSTS

EQUIPMENT

1	Speedstar M-81 drilling rig (200 m. cap - truck mounted)	$42,000	
2	3/4 ton pick-up	6,800	
1	G.M.C. 4 x 4 truck	18,000	
1	Lincoln Weldan power unit - #225	625	
			$67,425

MATERIALS

Drill casing	$35,000	
Drills	5,000	
Camping equipment	1,500	
Vehicle spares	5,000	
		$46,500

FREIGHT

$20,000

EXPATRIATE PERSONNEL

Hydrogeologist	18 mos. @ 3000/mo.	$54,000	
Driller	18 mos. @ 2500/mo.	45,000	
(Rate includes salary, overhead and per diem)			$99,000

TRAVEL PERSONNEL

Air fares	4 ea. @ $950/ea.	$ 3,800	
Excess Baggage	4 ea. @ $1100/ea.	4,400	
Hydrogeologist	10 days @ 100/day	1,000	
Driller	10 days @ $85/day	850	
			$10,050

$242, 975

DRILLING PROGRAM COSTS, cont'd

			$242,975
ADDITIONAL TRAVEL EXPENSE			
Replacement - 1			
Air Fare		$ 950	
Per diem	10 days @ $25/day	250	
Contractor's Principles			
Air Fare	3 ea. @ $950/ea.	$2,850	
Expenses	21 days @ $50/day	1,050	$5,100
TELEPHONE-TELEGRAPH			
18 mos. @ $200/mo.			$3,600
LOCAL PERSONNEL			
Assistant Drillers	2 x 18 mos.		
Drivers	4 x 18 mos.		
Laborers	10 x 18 mos.		
	16 x 18 mos. @ $100/mo. (average)		$28,800
LOCAL MATERIAL			
Diesel fuel	18 mos. @ $300/mo	$5,400	
Gasoline & oil	18 mos. @ $400/mo.	7,200	
Lubrication & Maintenance	18 mos. @ $50/mo.	900	
Maps & Photos		1,000	$14,500
PROCUREMENT			
Purchasing	60 days @ $100/day	$6,000	
Advertising		500	
Telephone-Telegraph		200	$ 6,700
REPORT			
Final Report			$5,000
			$306,675

	$306,675
Wells superstructure	
35 wells @ $600 each	21,000
	$327,675
General Administrative overhead and Management fees	114,700
TOTAL	$442,375

Section 1.3 Cost Analysis of the Drilling Program

In order to compare the cost of wells drilled with the proposed method with the cost of wells as presently hand-dug and cement-lined, we present below the drilling costs in a different way from the Program Costs to AID. The main differences are:

1) The cost of equipment is now entered for only part of its total since the equipment is expected to last 3 to 5 years.

2) The cost of the hydrogeologist and of other field overhead is not included in the direct construction cost; according to the method generally followed by present contractors in Niger they are added *in fine*.

Part 1: Cost during 18-month pilot program, in U. S. dollars

	3-Year Depreciation			5-Year Depreciation		
	Total	Local	Foreign	Total	Local	Foreign
Equipment[a/]	35700		35700	21450		21450
Maintenance[b/]	11900	5950	5950	7150	3575	3575
Casing and Drills c.i.f. Niger	56500		56500	56500		56500
Fuel, Gas, Lub.	13500		13500	13500		13500
Foreign driller	50000		50000	50000		50000
Local driller	28800	28800		28800	27700	
Wells superstructure[c/] 35 @ $600	21000	21000		21000	21000	
Direct Construction cost:	217400	55750	161650	198400	53375	145025

	3-Year Depreciation			5-Year Depreciation		
	Total	Local	Foreign	Total	Local	Foreign
Field overhead	80500		80500	80500		80500
Overhead and profit	104300		104300	97600		97600
Taxes (local)	76400	76400		71500	71500	
Total cost:	478600	132150	346450	448000	124875	323125

Part 2: Cost for subsequent 18-month periods

Assumptions: The foreign driller has been replaced by a local driller at $2400 per year. The hydrogeologist is no longer needed full time. Its cost and other costs for field overheads are included in the item "Overhead, Profits and Taxes."

	3-Year Depreciation			5-Year Depreciation		
	Total	Local	Foreign	Total	Local	Foreign
Direct Construction costs	171000	59350	111650	152000	56975	95025
Overhead, Profits & Taxes:	114000	85500	28500	101300	76975	25325
Total Cost:	285000	144850	140150	253300	132950	120350

Footnotes:

a/ Total cost c.i.f. Niger: $71,400. The present practice by private contractors is to use a 3-year write-off period. The proposed equipment could probably last 5 years. The outcome under both assumptions is presented in the table.

b/ Based on present practice of local contractors.

c/ Assuming that 5000 feet correspond to 35 wells. The present average cost of superstructures is $600.

d/ Based on present practice of local contractors, See Table 1, Section 5-3, page 50.

The following table presents the costs per foot of the proposed drilled wells and of the present hand-dug, cement-lined wells.

In U. S. dollars	Total Cost	Local Cost	Foreign exchange cost
I. Proposed Drilled Wells after initial 18 month period			
A) 3-Year Depreciation of equipment			
Direct Construction Cost	34.20	11.87	22.33
Total Cost	57.00	28.97	28.03
B) 5-Year Depreciation of Equipment			
Direct Construction cost	30.40	11.39	19.01
Total Cost	50.66	26.59	24.07
II. Present Hand-Dug Cement-lined Wells			
Direct Construction Cost	43.92	21.96	21.96
Total Cost	73.20	43.92	29.28

The Costs in Part II of the table are estimated on the basis of the generally accepted total cost of $73.20 per foot. Forty percent of this represents taxes, overhead expenses and profit. The distribution between direct construction costs, and total costs and between local and foreign costs was effected according to the summary table 1, section 5-3.

Total costs would be considerably lower for the drilled wells than they are today for the hand-dug, cement-lined wells. Even during the first pilot 18-month period, the direct construction costs would not exceed today's direct construction costs for hand-dug wells, but their foreign exchange content would be higher. The large total costs per foot during the trial period reflect the presence of the foreign hydrogeologist and driller. It should be noted, however, that they would also play a part in training their local counterparts.

In U. S. Dollars	Total Cost	Local Cost	Foreign Exchange Cost
Proposed drilled wells, during the 18-month pilot program			
A) 3-Year Depreciation			
Direct Construction Costs	43.48	11.15	32.33
Total Cost	95.72	26.43	69.29
B) 5-Year Depreciation			
Direct Construction Costs	39.68	10.67	29.01
Total Cost	89.60	24.97	64.63

The comparison of costs between the proposed method and the present costs of wells built by private contractors appears to be in favor of the proposed method.

It is even remarkable that, after the 18 month trial period, the proposed method would cost about the same as the present wells built in a human investment program, i.e. when the administratinn does not have to pay for voluntary local labor. Following we present an estimate of such costs excluding administrative overhead expenses and costs of studies:

PRESENT COST OF WELLS IN A HUMAN INVESTMENT PROGRAM IN U.S. DOLLARS PER METER AND PER FOOT.

	Total	Local	Foreign
Contractor's cost per meter	240	144	96
minus taxes, overheads, profits	96	72	24
	144	72	72
minus local labor (see section 5-3)	24	24	
minus gravel	8	8	
	112	40	72
Direct Construction Cost per foot:	$34.16	$12.20	$21.96

1.4 Extraction of water in the sedentary zone.

It is believed that in the case of water lifting by local women the 80 cm (31.5") contemplated diameter would not be an unbearable constraint. Whatever annoyance occasional waiting at the well may cause will be amply compensated by the great advantage of more plentiful water. The quantity of water effectively available per day is limited by the primitive method of extraction used. However, this is no excuse for failing to increase the output of the well. Indeed, it can be expected that primary education will eventually permit the introduction of hand pumps or other water lifting devices. When that time comes the proposed wells might provide water for small irrigation projects whereas the present cement-lined dug wells which hardly tap the water reserve will be obsolete.

Section 2, Surface Catchment Basins

Section 2.1 Surface Catchment Basins - Nomad Zone

The record indicates that where large supplies of water exist in the nomad zone e.g. deep wells equipped with pumps, fairly large concentrations of livestock comprising cattle, sheep and goats tend to congregate with the inevitable result of overgrazing beyond a reasonable economic limit. As the amount of pasture gradually diminishes in height and volume stock would be progressively moved away from the water supply according to their respective abilities to feed on short-length grass. Based on this criterion cattle would be the first to move followed by sheep; goats would then remain and continue feeding until forage was cropped too low to revive satisfactorily after a year or two.

In the case of hand-dug wells the same problems would be faced although on a less intense scale. Since it is economically expedient to obtain the maximum amount of water from each hole by penetrating through the water bearing level, large long-lasting supplies would be expected. It may be anticipated, therefore, that sheep herds would team up to draw water 24 hours per day in order to obtain the maximum amount of stock at a well.

In view of these circumstances and the opinion of several qualified and experienced observers as to the desirability of saving more rainfall in naturally occurring topographic depressions, a conservative approach is suggested viz: mechanically increasing the capacity of selected surface catchment areas of interior drainage using a front-end loader with back hoe (plates 34 and 35). Several manufacturers produce such equipment. This rubber-tired vehicle is versatile and self-contained in that, without assistance of a dump truck, or auxiliary equipment, it can rapidly excavate, transport and deposit in exact position, large volumes of earth.

The envisaged approach is that, using a national operator, under the guidance of a hydrogeologist, employing existing aerial photographs, topographic maps and surface inspection, selected depressions would be chosen suitable for conserving rainfall runoff by deepening (excavating) and damming, using the excavated earth, stone, rubble and laterite to block the exit of the enlarged pond that would be created.

Emphasis would be placed on deepening the surface depression (excavating) thus reducing dependence on earth dams in water retention.

Geologic and stratigraphic reasoning would be needed in selecting interior drainage areas for modification and enlargement so that impermeable horizons (e. g. clay and/or shale) would underlie the pond and prevent or significantly retard downward percolation.

Ponds would be located beyond the grazing distance of permanent water and in localities where good forage was most abundant. By prolonging the occurrence of temporary surface supplies, one or two months per year, not only would grass, otherwise partially consumed, be better utilized but also southward migration of livestock be advantageously delayed. Since the depressions would become desiccated by the end of the dry season, health hazards from permanently stagnant water would not occur.

The operation would: (a) exemplify the comparative ease and desirability of saving rainfall which costs nothing to put on site; (b) create a facility that could be used for a number of years, since excavations would silt up slowly considering the low stream gradients involved.

It is believed that in the nomadic zone where local labor for a human investment program is not easily forthcoming, the proposed light equipment would be more flexible, easier to transport, less likely to be immobilized for long periods when breakdowns occur than the present equipment used by the Genie Rural.

For these reasons it is suggested that such equipment be provided to Niger. The equipment would also be useful for the fulfillment of the program of surface water envisaged in the Ten-Year Perspective.

Duration of the program should be one full dry season period of 9 months followed by an additional year if the first were as successful as anticipated.

Caterpillar engineers at the Peoria, Illinois head office conservatively calculate that the back hoe, with 3.5 cubic foot capacity, (plates 34 & 35), capable of excavating to a depth of 15 feet, can remove 26 cubic yards of surface material per hour. The front-end loader attachment lifts 3 cubic meters and rapidly transports it to any desired point at a speed of about 15 m.p.h. It therefore appears that the recommended equipment is excellently suited to the assigned task of enlarging water-holding capacity of a shallow, naturally-occurring surface catchment basins. With easily-administered, low-cost maintenance, the machine will last for many years at a fairly low annual depreciation charge.

2.2 SURFACE PROGRAM COST

EQUIPMENT			
1 Loader & Back Hoe		$20,000	
1 3/4 Ton pick-up		3,400	
1 5 Ton 4 x 4 truck		6,000	$29,400
FREIGHT			$ 1,500
EXPATRIATE PERSONNEL			
Hydrogeologist (rate includes salary, overhead and per diem)	9 mos @ $3000/mo.		$27,000
LOCAL PERSONNEL			
Drivers	3 x 9 mos.		
Laborer	5 x 9 mos.		
	8 x 9 mos. @ $100/mo. (average)		$ 7,200
TRAVEL PERSONNEL			
Air Fares		$ 950	
Excess Baggage		600	
Hydrogeologist	10 days @ $100/day	1,000	$ 2,550
LOCAL MATERIAL			
Diesel Fuel	9 mos. @ $300/mo.	$ 2,700	
Gasoline & oil	9 mos. @ $300/mo.	2,700	
Maps & Photos		1,000	$ 6,400

SURFACE PROGRAM COST, Cont'd

PROCUREMENT			
Purchasing	20 days @ $100/day	$ 2,000	
Advertising		300	
Telephone - Telegraph		100	$ 2,400
REPORT			
Final Report			$ 3,000
Total Estimated Costs			$79,450
Contingency Factor 10%			7,950
			$87,400
NOTE: Administrative overhead, management fee			30,590
		TOTAL	$117,990

2.3 COST ANALYSIS

1) Annual cost in U. S. dollars

	3-Year Depreciation			5-Year Depreciation		
	Total	Local	Foreign	Total	Local	Foreign
Equipment[a]	10666		10666	6400		6400
Maintenance[b]	3555	1775	1780	3555	1775	1780
Fuel, Gas, $600 per mo.	7200		7200	7200		7200
Labor & Misc., $800 per mo.	9600	9600		9600	9600	
Hydrogeologist, Maps[c]	--			--		
Total	31021	11375	19646	26755	11375	15380

2) Annual excavating capacity:

Per hour: 920 cubic feet or 26 cubic meters

Per day: 26 x 8 equals 208 cubic meters

Per year: 208 x 300 equals 62,400 cubic meters

3) Approximate cost per cubic meter excavated[d]

a) With 3-Year depreciation period: 49.2¢

b) With 5-Year depreciation period: 42.8¢

Footnotes to table 7:

a/ Total cost c.i.f. Niger: $32,000. The present practice by private contractors is to use a 3-year write-off period. The proposed equipment could probably last 5 years. The outcome under both assumptions is presented in the table.

b/ Based on present practice of local contractors.

c/ The cost of the hydrogeologist and of maps, although part of the cost of a surface program, is not included for purposes of comparison with available cost data which do not include the costs of such studies.

d/ Assumed equal to the volume of retained water.

We can see that the cost estimate (43-50¢ per cubic meter) is somewhat lower than the present cost of water holes built by the Génie Rural (56¢, Table 2, line 1-2). Two qualifications are, however, in order: Our computations include probably higher depreciation and maintenance charges than those of the administration. On the other hand we have neglected overhead administrative expenses which should be taken into account.

When local labor is available and ponds can be excavated in a human investment program the cost is markedly lower than with the proposed method.

It is believed that in the nomadic zone where local labor for a human investment program is not easily forthcoming, the proposed light equipment would be more flexible, easier to transport, less likely to be immobilized for long periods when breakdowns occur than the present equipment used by the Genie Rural. For these reasons it is suggested that such equipment be provided to Niger. The equipment would also be useful for the fulfillmentof the program of surface water envisaged in the Ten-Year Perspective.

Section 3: Recommended Future Study Programs

In addition to the pilot percussion programs and the surface catchment basin program, two study programs are recommended for Niger. First, a study of areas in, or at the limit of the sedentary zones where wells would open new land to agriculture. This program would require the services of one hydrogeologist and one agricultural expert for 9 man months each. They would require support from the Government of Niger for logistics. Second, study of a well program in the nomadic zone north of Maradi including soil configuration, quality of pastures and depth in which water is to be found. This program could be undertaken in conjunction with the program previously mentioned and would require the same staffing for a period of approximately six months.

Section 4

TIMING OF THE PROPOSED PILOT PROJECTS

PHASE 1: IMMEDIATE ACTION

Phase 1, described in sections 1 and 2 is a pilot project. It would include:

a) Immediate implementation of a limited wells program in the sedentary zone near Maradi and experimentation with the technique recommended.

b) Immediate implementation of a program to build surface catchment basins in the nomad zone.

It is expected that if the experimental programs are successful, other donors will want to adopt the techniques introduced. In this sense the original program might have an impact on Niger water resources development considerably beyond its present scope.

PHASE II: RECOMMENDED FUTURE ACTIVITIES - See Section 3

a) Study of areas in, or at the limit, of the sedentary zone where wells would open new land to agriculture.

b) Study of a well program in the nomadic zone north of Maradi including soil configuration, quality of pastures, and depth at which the water is to be found.

Any program must be designed to completely avoid any risk of overgrazing.[1]

---

1 See Appendix II5 for the implementation of wells and water points. It is to be noted that a difficulty to be faced would be to prevent the nomads from the region not covered by the project from migrating en masse to the area. It seems, however, that the grazing areas are well defined; in some ways, one can speak of loose ownership. Often the grazing area is owned de facto by the owners of the tradional wells. Therefore, it might be worthwhile to explore some plan by which nomadic groups would become owners of the wells constructed with USAID financing, in exchange for some low but real payment or tax. One advantage of such a plan is that it would also assure better maintenance of the wells. Another is that, by becoming semi-sedentary, the Peul nomads could progressively replace their M'bororo cattle with Azawaks. While the M'bororo are more resistant when walking long distances, the Azawaks produce more milk and more meat. The Touaregs who do not migrate south own Azawak zebus and their per capita income is about 50% above that of the Peuls. These advantages would be more readily forthcoming if the completion of an animal husbandry extension course by one of the members of the group could be made a condition for the assignment of a well to the group.

APPENDIX I

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APPENDIX II

ECONOMICS

Appendix II.1

POPULATION

1) The population of Niger was estimated at 3.5 million in 1966.

2) The annual growth rate is estimate at about 2.5-2.7%.

3) Urban population: 4 towns have a population of more than 10,000 each:

	population (estimate)	annual growth rate 1956-62
Niamey	50,000	10%
Zinder	25,000	8%
Maradi	20,000	7%
Tahoua	20,000	5%

4) Ethnic groups:

Haoussas:	about 50% of total population, mainly in south-central Niger
Djerma-Sonrai:	about 20% in southwest Niger
Touaregs:	about 8% in the Sahara and north-Sahelan region
Peuls:	about 12% widely distributed, some of them are sedentary
Beriberis:	about 5% in the East
Others:	about 3%
Foreigners:	about 5,000 Europeans and 30,000 Africans and North-Africans

Appendix II.1

5) Distribution between nomadic and sedentary population:

About 80% sedentary and 20% nomadic (Touaregs and Peuls)

6) Employment: Most of the active population is engaged in agriculture and animal husbandry. Only 20,000 are employed in other pursuits, including civil servants other than members of the armed forces.

Table 1-1

Distribution of Population by Administrative Divisions 1956-62 (estimates)

Cercles	1956	1957	1958	1959	1960	1961	1962
Agadès	48 119	49 616	51 270	653 180	55 387	57 837	60 273
Birni N'Konni	158 613	163 122	168 138	173 534	181 310	188 813	193 488
Dogondoutchi	123 416	128 757	133 886	139 226	144 482	149 844	154 623
Dosso	176 539	179 728	181 141	185 035	187 662	191 816	196 118
Filingué	115 745	118 120	120 568	123 094	125 692	128 360	131 139
Gouré	127 964	130 472	133 200	135 349	138 616	141 970	145 566
Madaoua	152 915	156 210	159 314	162 523	165 745	169 385	172 528
Magaria	148 236	164 083	171 966	175 699	181 052	187 412	196 304
N'Guigmi	40 805	41 998	42 959	44 957	46 339	47 824	49 335
Maradi	217 094	224 963	234 219	243 688	252 686	260 863	269 306
Niamey	220 306	227 517	235 196	244 416	254 145	264 191	274 165
Tahoua	231 530	238 183	245 348	252 999	260 831	268 872	277 129
Téra	139 894	144 555	149 393	154 339	159 332	163 480	168 794
Tessaoua	217 721	223 438	229 372	235 538	241 804	248 263	254 902
Tillabery	167 424	172 326	177 356	182 661	188 138	193 765	199 548
Zinder	261 660	265 597	269 635	275 921	280 543	285 711	292 455
Total	2 547 981	2 623 685	2 702 966	2 781 099	2 863 764	2 943 405	3 040 673

Source: Annuaire Statistique 1962, p.8

Appendix II.1

Table 1-2

Distribution of Population According to the Quantities of Rain in 1958

Zone	Climatology	Rain quantity	Habitants	Density p/Km2	Area in KM2
1	Sahelio-Sudanese	850-550	1.350.000	13.5	100.000
2	Sahelian	550-350	800.000	4	200.00
3	Sahelio-Saharian	350-000	350.000	1	350.000
4	Saharian	100-000	50.000	0.08	600.000
	of which with possible livestock	100-75	50.000	0.2	250.000
	without livestock	75-0	-	-	350.000
	Total		2.550.000	-	1.250.000[1]

[1] The total area mentioned here is less than the present total area. These figures were made before the Independence.
Source: Kassem, op. cit., p.8

Appendix II.2

AGRICULTURE

Table 2-1

Area and Production of Principal Crops, 1960-64

	Area under cultivation (In thousands of acres)					Production (In thousands of metric tons)				
	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964
Food crops	6,271	6,310	6,952	7,195	6,813					
Millet	4,179	4,051	4,545	4,661	4,362	718	776	934	971	1,014
Beans	926	1,054	1,173	1,250	1,242	46	53	73	80	67
Sorghum	1,087	1,119	1,146	1,198	1,119	222	275	320	352	314
Cassava	35	40	42	40	42	101	125	117	136	148
Rice	20	22	22	22	22	7	10	11	13	12
Corn	7	7	7	7	12	3	2	2	2	4
Sugar cane	5	5	5	5	5	28	33	33	31	38
Potatoes	5	5	5	5	2	17	27	30	24	19
Onions	2	2	2	2	2	19	26	24	23	24
Others	5	5	5	5	5	2	2	2	2	2
Cash crops	805	882	823	820	771					
Groundnuts 1/	793	862	798	788	736	99	100	135	145	131
Marketed production 2/						(77)	(67)	(92)	(114)	(106)
Cotton	12	20	25	32	35	1	3	5	6	6
Grand total	7,076	7,192	7,775	8,015	7,584					

[1] All data are in tons of shelled groundnuts (66 per cent of the unshelled groundnut tonnage)

[2] For the crop year beginning in the calendar year shown

Source: International Monetary Fund, op. cit., p.7

Appendix II.3

LIVESTOCK

Table 3-1

Livestock 1954-1964
(estimated)*

In thousands

Year	Cattle	Sheep	Goats	Horses	Donkeys	Camels
1954	2,200	6,000		86	300	252
1955	2,200	6,720		86	300	252
1956	2,910	6,720		99	276	246
1957	3,000	1,800	5,000	110	350	300
1958	3,500	1,825	5,000	110	350	300
--						
1960	3,490	1,810	4,925	116	298	349
1961	3,490	1,995	4,940	121	301	359
--						
1964	3,900	2,100	5,500	150	315	360

Source: Annuaire Statistique 1962, p.41, and Service de l'Elevage

*Note: Kassem makes the following comment on this table: "The estimation made by the Service de l'Elevage is based on calculations of their personnel in the field, also on numbers of vaccination especially in cattle. From the above mentioned figures, we can hardly judge what is the real annual growth rate. While the cattle population has increased 800.000 head in two years 1955/57 (36.3%) and another 500.000 head in 1958 (17%), it remained stable for 6 years, and suddenly increased 400.000 head (11.4%) in 1964." See Kassem, op. cit., p. 10.

Appendix II.3

Table 3-2

Livestock 1955-1964
(Official census)

In thousands

Year	Cattle	% growth	Sheep and goats	% growth	Camels	Horses	Donkeys
1955	1.771		4.424		223	82	221
		+3.2		+0.09			
1956	1.829		4.438		213	84	217
		+0.3		+0.1			
1957	1.835		4.243		209	81	212
		+1.3		-0.5			
1958	1.861		4.221		222	86	206
		+3.3		+0.25			
1959	1.922		4.232		213	89	212
		-3.7		-3			
1960	1.850		4.103		220	95	220
		+1.7		+0.5			
1961	1.881		4.126		229	101	218
		+3.3		-0.9			
1962	1.944		4.098		217	104	213
		+6.2		+7.8			
1963	2.066		4.419		242	116	239
		+4.3		+1			
1964	2.155		4.463		257	120	228
	Average	+2%		+0.53%			

Source: Service de l'Elevage, presented by Kassem, op. cit., p.11

Note: Kassem comments that "the growth rate of the official census is more understandable than that of the estimate. " See Kassem, loc. cit.

Appendix II.3

Table 3-3

Distribution of Livestock by Administrative Divisions
1964 (estimated)

In thousands

Division	Cattle	Sheep	Goats	Horses	Donkeys	Camels
Tillabery	225	100	190	13	10	4
Tera	250	60	225	10	10	4
Niamey	275	50	120	13	10	4
Tahoua	550	300	600	10	50	100
Maradi	250	100	500	10	20	15
Zinder	320	225	450	15	35	15
Goure	600	350	800	10	25	30
N'Guigmi	200	100	250	3	10	20
Agadez	130	100	200	1	30	100
Filingue	175	125	250	7	10	15
Tessaoua	200	150	400	10	20	5
Magaria	175	100	260	15	30	3
Madaoua	180	135	500	8	22	25
Konni	170	120	475	8	20	10
Dosso	100	50	130	10	5	5
Doutchi	100	50	150	18	8	5
Total:	3,900	2,100	5,500	150	315	360

Source: Service de l'Elevage

Appendix II.3

Table 3-4

Share of livestock exports in total exports
1963

Commodities	Million CFA	%
Animal products	3.670	54.15
Smoked dried fish	300	4.43
Hides and skins	100	1.48
Groundnuts	2.400	35.50
Cotton	150	2.22
Other agr. products (beans, onions, etc.)	100	1.48
Gum	20	0.30
Etain (tin) FOB	30	0.44
	6.770	100.00

Source: estimate by Kassem, *op. cit.*, p.9

Appendix II.4

Irrigation Projects in Niger

The figures presented in this appendix are derived from the Ten-Year Perspective and from the Four-Year Plan. They lead to even more pessimistic conclusions than our own in section 5-2 concerning the economic feasibility of such projects.

According to the Ten-Year Perspective 100,000 hectares are irrigable in Niger, 25,000 of which are to be irrigated by 1974. Plans for irrigating over 5,000 hectares are envisaged in the Four-Year Plan.

Total costs during the period 1965-68 should be $13,600,000 for 5,155 hectares irrigated and 1,950 hectares of soil restoration. The improved area should provide employment for 8,000 men plus 2,000 in related activities. The investment cost per man is then $1,360, exclusive of individual tools, working capital for seeds etc...

The gross net product expected from such an investment is estimated by the authors of the Plan at $1,768,000 per year. The annual costs (maintenance, depreciation of equipment but, not of the main construction work) should be $416,000. If we assume that seeds will cost about $178,000 the product per worker in agriculture would be only $146. The per capita product for a family of three would be $49.

If any interest rate of 6% is deducted, the net product per worker falls to $45, or $15 per capita.

For such meager results the annual number of hours of work is expected to be 1,700-1,900, significantly more than at present in dry farming.

Table 4-1

Appendix II.4

Irrigation Projects

	Surface (hectares) (Perspective)	(Plan)	Investment cost per ha. (Perspective)	Annual cost per (Plan)
1) Large projects*				
Goulbi de Maradi	4,000	200	$1,800 to $2,400	$60
Ader (Ibohamane)	2,000			
Maggia (Birni N'Konni)	2,000			
2) Irrigation by pumping				
Niger valley	4,000	1,755	$1,600	$80
Ponds and basins	3,800	910	$1,000	$40
3) Irrigation by gravity				
Niger valley	5,000	1,240	$720	n.a.
Ponds and basins	4,200	1,050	$400	$16
4) Other improvement projects				
Soil restoration Small irrigation projects of ½ ha. around village wells.	15,000	1,950	$400	$8
Total investment costs:	$50,000,000	$13,600,000		
Annual costs after completion:	$1,400,000	$416,000		

* 14,000 hectares in Komadogou are not included here. They will probably be part of the general development plan of the Chad basin.

Sources: Ten-Year Perspective, pp. 365-379
Four-Year Plan, pp. 223-251

Appendix II.5

DETERMINATION OF THE LOCATION OF WELLS IN THE NOMADIC ZONE

I. The following guidelines are presented as an example of the economic procedure that might be followed in determining the location of wells for animal use in the nomadic zone. The figures are rough estimates. In particular the number of hectares of pastures needed per cattle unit will vary from pasture to pasture and also from year to year. It should be more precisely estimated by the agricultural expert in charge of the program.

II. Elements to be considered:

1) Grazing area.

Del Perugia estimates that 6-7 hectares are needed per cattle unit, Kassem estimates 8-12 hectares, and the GON proposal mentions 8-10 hectares. To be on the safe side we shall use the maximum Kassem estimate, or 12 hectares per cattle unit.

2) Maximum distance from water to pasture.

Del Perugia estimates the maximum distance to be of the order of about 6 1/2 kilometers (half diagonal of the 9 kilometer square), while the proposal would accept 15 kilometers. In the latter case the animals would have to walk a maximum of 30 kilometers from water to pasture and back to water. This is obviously too much. We shall adopt a maximum distance of $8\frac{1}{2}$ kilometers (half diagonal of a 12 kilometer square).

3) Benefits from water.

The main improvements to be derived from a better water supply are expected to come from a better management of the livestock. However, whatever the method used, the absolute benefits to be obtained from a well will at first increase when the volume of water provided increases. But the benefits will increase at a decreasing rate because of the increased distance that the animals have to walk to and from the grazing area. Eventually, if the volume of water is above a certain amount the benefits will start to decrease absolutely. It is this characteristic of the benefits curve which was neglected in the drilled wells program in Niger.

4) Water supply from dug wells.

The water supply from a dug well for animal use is the smaller of the following:

a) Potential output from the well

b) Quantity of water which can be lifted per day.

Appendix II.5

The latter depends on the depth of the well. COGEFAF has suggested a formula to compute the actual supply, assuming that 6 teams of oxen can work simultaneously for 16 hours a day.

$$Q = \frac{230}{1 + 0.075\ h}$$

Q in cubic meters
h in meters

The results COGERAF obtained are the following:[1]

Q	h
92	20
71	30
57	40
48	50
42	60
37	70
32	80

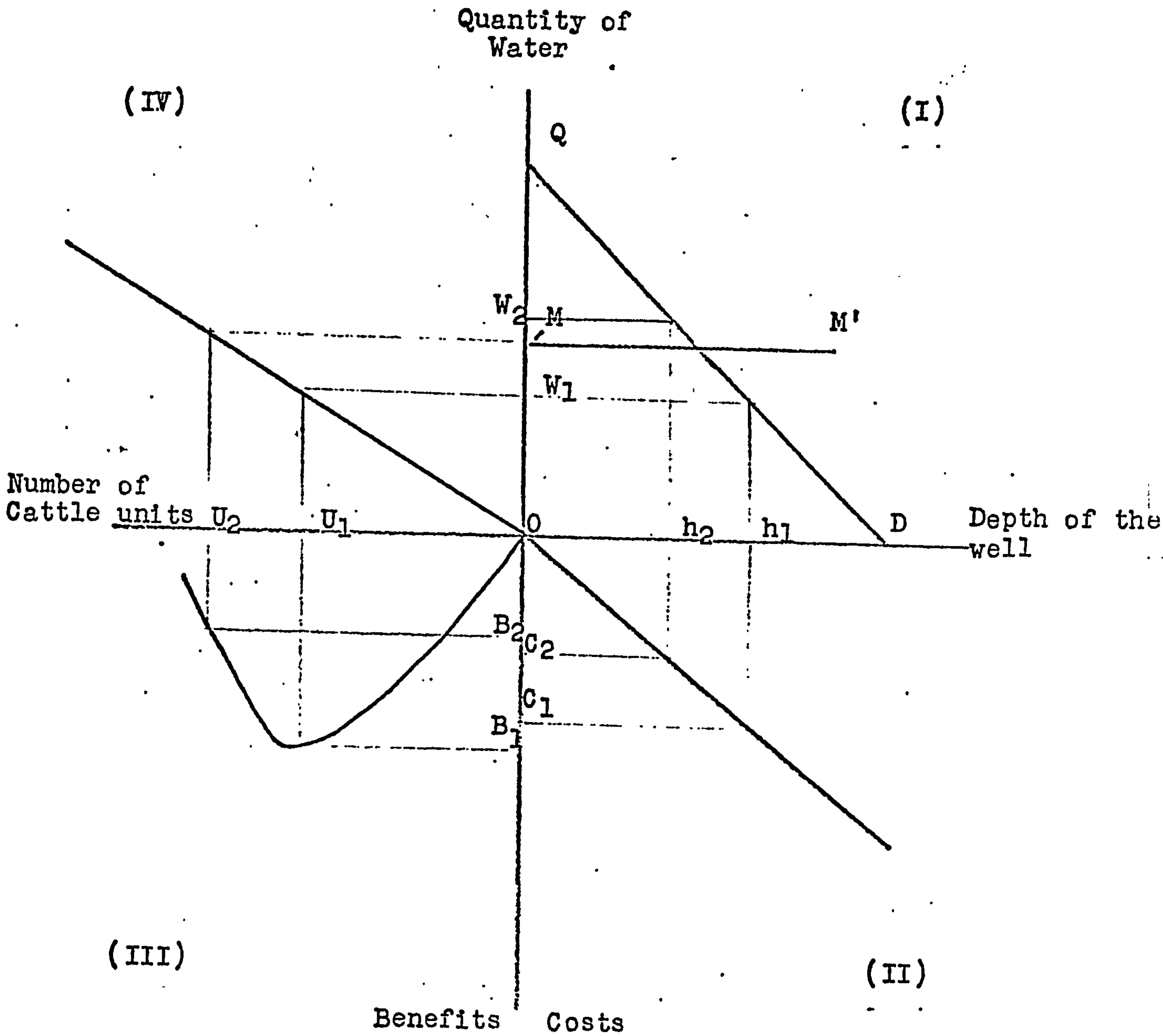
5) Water costs .

The costs are naturally proportional to the depth.

---

1 COGERAF, Amenagements de'hydraulique pastorale, Annexe a l'etude de la Region du Nord de Tahoua, p.3, p. 5

Diagram 6-1


Quantity of Water
(IV)
(I)
Q
W2
M
M'
W1
Number of Cattle units
U2
U1
0
h2
h1
D
Depth of the well
B2
C2
C1
B1
(III)
(II)
Benefits
Costs

Appendix II.5

III. An Example:

A 60 meter dug well with a potential water output of 3 cubic meters per hour will have, according to COGERAF, an actual output of only 42 cubic meters per day. This figure is, however, somewhat flexible because the livestock raisers often work all night at the well during the dry season. A cattle unit needs 40 liters per day. The well can then water about 1,200 cattle units which, in turn, require 14,400 hectares of pastures. This is the area of a 12 x 12 square (in kilometers). The maximum distance to pasture in any of the corners is about 8½ kilometer.

Should the depth of the well be smaller and the output greater than 3 cubic meters per hour, it might be worth considering building a narrower well in order to restrict the number of animals. On the other hand if the actual output is less than 50 cubic meters per day, the wells should be built closer to one another than 12 kilometers.

IV. Diagrammatic illustration:

The simplified diagram presented page 6-4 will illustrate the problem: when the depth of the well is Oh_1, the water supply is OW_1, the number of cattle units OU_1, the benefits OB_1, and the costs OC_1, smaller than the benefits. When the depth is only Oh_2, the water supply is limited to OM (smaller than OW_2) which could be lifted from the well. The output of the well is the constraint then. The number of cattle units if OU_2. The benefits are only OB_2, because of the shape of the benefits curve (absolutely diminishing returns). The cost OC_2 are higher than the benefits. To remedy this situation a narrower well is required: the line QD would then shift to the left.

Appendix II.6

RATIONALE FOR CHOICE OF CENTRAL AREA

The reasons for a concentration of the program in that zone and possible future activity there are the following:

(a) It is one of the areas where contacts between the nomadic and the sedentary populations are most extensive, particularly because of the larger proportion of Peul nomads who migrate south during the dry season while the Touaregs rarely migrate to the sedentary zone. Because of these migrations, the possibilities of a crisis when the land limit is reached are enhanced in that region. In 1962, there were an estimated 63,000 Peuls, 25,000 Touaregs and 522,000 sedentary people (plus 17,000 in the city of Maradi) in the divisions of Maradi, Tessaoua, Mayahi, Dakoro and Tanout, corresponding approximately to the area that we are considering. The results of the census results of the census probably underestimated the real population, particularly among the nomads who are more difficult to find. On the other hand, a number of the Peuls were already sedentary or semi-sedentary.

(b) The area contains also about 20% of the estimated livestock in Niger: about 600,000 cattle, 350,000 sheep and 1,100,000 goats. The distribution of livestock between sedentary and nomadic people is not available. Informed guesses put it at 1/3 belonging to the sedentary and 2/3 to the nomads. But the situation is further blurred when the sedentary entrust their animals to nomads for grazing in the northern pastures and when the nomads stay on the land of the sedentary, using water and grazing in exchange for manure.

(c) The nomad zone has not been spoiled by poorly prepared programs of drilled wells with pumping stations as is the case with the area north of Tahoua. Since the nomads have not been accustomed to receive freely flowing water, it might be possible for someone to undertake a well program which will limit the water obtainable from each well by the time and effort it takes to lift the water, thereby preventing overgrazing. A catchment basin program would also be decidedly beneficial in preventing overgrazing.

(d) The sedentary zone is one of great centers of groundnut production. It is mainly populated by industrious Hassaouas who may be more receptive to the introduction of hand pumps, especially around the urban centers of Maradi and Zinder. However lubrication and maintenance would be a substantial innovation in their daily routine and must be allowed for.

(e) New technology would benefit the owner and have a great chance of success. In the dallols, the water is found close to the surface and experiments with hand pumps could be made, especially since these areas are not too far from Maradi.

(f) The area is one of the main traditional passages for cattle on the hoof going to Nigeria where it is sold. It is therefore one of the priority areas for the organizatinn of "corridors" which will reduce friction between the nomads and the sedentary population and which will minimize the loss of weight by the cattle by providing water and eventually food. It is also an area where a meat market would yield good results.

(g) It also seems that a program of animal husbandry education should be undertaken at Maradi where a government school for assistants in animal husbandry exists.

(h) There is a U. S. farm extension center in Maradi, which could provide a nucleus for extension work concentrating on better husbandry methods. Such methods will only be accepted by the raisers when they will see the benefits they can derive from them. They will derive benefits only when markets are organized, with emphasis on meat quality. However, we think that they will then be quicker to adopt improved methods than is generally believed. Particularly it should be easy for them to make more use of the groundnut cakes available in the area and to confine the herds around the village to cropped fields while cutting the grass of the fallow fields by hand and storing it for winter feeding. The present habit of letting the animals roam freely wastes considerable amounts of good grass in the sedentary area: it is trampled under the feet of the herds.

Concentration of educational efforts on animal husbandry would bring faster results than trying to improve the farming methods. The output from a herd can be increased by a change in methods without any need for capital expenditures (plows, tools) or for working capital (fertilizers). Furthermore, it is not certain that the introduction of oxentracted plows is a wise policy from a national viewpoint, although it is certainly beneficial for the individual. Indeed, if the peasant who uses a plow has an incentive to increase the amount of land he cultivates, the appearance of the land limit and of agricultural unemployment will be accelerated.

(i) The U. S. farm extension center could also be the rallying point of the Peace Corps program of well building with the help of the villagers in villages where water is found close to the surface. Depending on the local conditions, some of the wells could be fitted experimentally with hand-pumps. On the other hand we think that much would be gained if the Peace Corps program devoted part of its effort to an attempt to make the villagers maintain their wells. The number of abandoned wells which could be rehabilitated is unknown but could be sizeable. On the other hand, it is important that much of the maintenance of the new wells be done by the villagers. Otherwise the OFEDES will be burdened with an impossible task. Eventually one could envisage the creation of light maintenance support crews who would only supply the breathing equipment needed during work at great depth.

(j) The proximity of the railway terminal at Kano in Nigeria and the existence of a good road from Kano to the border would minimize the transportation cost of imported raw materials and equipment and facilitate the access by a U. S. contractor if one could be found for the wells. In any case concentration of the program in one area would lower some of the fixed costs of the contractor.

APPENDIX III

GEOLOGY

APPENDIX III.1

Section 1.

AREA INSPECTED

Field investigations were made both in the air (1,000 mi.) and on the surface (1,500 mi.) totaling approximately 2,500 miles along routes outlined on plate 2. The party was accompanied by Mr. Vaidon of the Office of the Inventory of Hydraulic Resources who supplied abundant constructive comments and information.

Many widely-scattered deep bore holes equipped with pumping stations and cement-lined hand-dug shallow wells made by various donors and Government together with those made by inhabitants were inspected. Habitual concentrations of livestock around points of permanently available water and the condition and distribution of pasture were noted. The number and extensive distribution of areas of converging drainage were first detected from the air. Livestock was still watering at some of the larger ponds but the majority were dry. From this originated the concept and value of a catchment basin development experiment for conserving rainfall at judiciously selected places.

DESCRIPTION OF REGION STUDIED

Area

The region reviewed forms a triangle bounded by Niamey on the west (Lat. 13°45'N - Long. 2°05'E) Zinder on the east (Lat. 14°N - Long. 9°E) and Agades in the north (Lat. 17°N - Long 8°D) and has an area of approximately 50,000 square miles.

Topography

Respective elevations are Niamey 800 feet, Zinder 1,598 feet and Agades 1,634 feet indicating a very gradual upward ground slope toward the ENE. Most of the terrain is essentially flat with local gentle hog backs that slightly modify the horizon only when viewed in a down-dip direction. However, near Niamey terraces are more numerous and pronounced (photograph 6).

Rainfall

With rainfall varying from 7 inches to 24 inches during the June to September wet season, little valley development has resulted in modern times. A few broad, subdued, gravel-filled valleys dating from a previous erosion cycle, trend southwestward toward the Niger River and are now occupied by broad agricultural plains and farm lands.

Climate

The climate is hot and dry, particularly in the north. There is however, a great difference between night and day temperature. Cloud cover is uncommon.

Land Use

North of latitude 14 the land is devoted to grazing. Elsewhere assorted agriculture, chiefly millet and peanuts, prevails as shown on plates 27 and 28.

Population

This slightly surpasses 3,000,000. The average density is less than 3 persons per square kilometer. The distribution of inhabitants, concentrated in the most favorable fringe of the country, is presented on plate 22.

AVAILABLE INFORMATION

Topographic Maps

The country has been variously topographically mapped at 50,000; 100,000; 200,000; 500,000; and 1,000,000 scales. Coverage at 1,000,000 is complete. World aeronautical charts of 1,000,000 scale also exist over the entire country.

Miscellaneous Maps

These relate to Public Administration, Communications, Agriculture, Education and Migration patterns.

Geological-Hydrogeological Maps & Reports

Many scattered and a few summary reports have been written which convey a good reconnaissance summary. Others exist besides those listed in the bibliography.

Water Well Records

Some 8,000 of the 12,000 existing hand-dug wells have, at one time or another, been visited. Approximate positions and serial numbers are indicated on topographic maps. Some data concerning well diameter, lithology, water analysis, drilling depth and static water level are recorded on individual well data sheets. Periodic visits to check the water level are not made except at a few points. There is a vast amount of archived data available for compiling all-important contour maps of the phreatic water level but the limited staff has been too occupied with routine work to initiate this task.

The distribution of dug water wells for each square degree is shown on plate 3 from which it may be noted that they are most abundant in the southern sedentary zone where most of the population resides. Time was not available for us to plot each location on 50,000 topographic maps, a monumental task. Government personnel were too few to assist.

GEOLOGICAL RESUME

Surrounded by folded metamorphic rocks of the Hoggar, Adrar des Ilforas and Air to the north and of Nigeria, Dahomey and Haute-Volta to the south, the Iullemmeden basin, named after the Touareg Federation which populate its central part, is filled with Paleozoic, Mesozoic and Tertiary formations.

In the Paleozoic, a gulf, widely open to the north, penetrates southwards between the Adrar and Air without going beyond the actual southern limit of these massifs. It is filled with formations from Cambrian to Namurian age. Each formation overlaps the preceding one towards the south. In this direction thicknesses diminish at the same time as the deposits become more and more coarse.

During the Mesozoic and Tertiary, the West African Shield was progressively coated by an accumulation of piedmont deposits that were periodically invaded by seas coming from the northeast. The marine environment was transitory, the chief periods of submergence having occurred during the Upper Cenomanian, Turonian, Lower Senonian and Maestrichtian. At the end of the Maestrichtian, subsidence south of the Adrar mountains permitted a Paleccene invasion to come in from the northwest.

As in the Paleozoic each transgression overlaps the preceding or underlying one, towards the south. In this direction the marine series diminish in thickness and pass laterally into continental materials.

During the middle Eocene, movements of uplift gave the basin its present aspect. The basin thus formed was filled, during the Tertiary with fluvial and lacustrine deposits characterized by the presence of oolitic iron ore.

All Mesozoic and Tertiary strata have been slightly warped during the phases of uplift located around the basin margin. In the region of Zinder, recent faulting is present.

STRUCTURE

The tectonic pattern consists of a north-south axis along a basement high between basement exposures which trends NNW-SSE through Agades and Damergou(plate 4). To the west, (Niger Basin) and east (Chad Basin) of this axis lie synclinal downwarps or broad troughs filled with Cretaceous through Tertiary continental deposits with Paleocene marine intercalations. Dips do not exceed two degrees.

NNE-SSW tension block faulting is widely distributed through the basement but this has not penetrated overlying deposits except east of Niamey where a doubtful NW cross-fault has been detected by resistivity investigations.

STRATIGRAPHY AND HYDROGEOLOGY

These data appear on the following page:

* NIGER BASIN

Stratigraphy: Local Nomenclature	Stratigraphy: Universal Nomenclature	Lithology	Hydrology
(G) Alluvium	(Quaternary)	Stable Dunes	Phreatic horizon
(E) Continental Terminal	(Tertiary)	Sand, Sandstone with argillaceous lenses	Phreatic horizons in 3 zones the lower being semiartesian
(D) Eocene	(Tertiary)	Clay, sand & thick sandstond zones	Artesian horizon near Dogondoutchi
(C) Cretaceous	(Marine)	Mostly clays and marls	Impermeable bed
(B) Continental Intercalaire	(Permian up to Cretaceous)	Sands of the Tegama facies	Deep water horizon often artesian
		Marls of Irhazar	Impermeable bed
		Sandstone of) Assaouas) Sandstone of) Agades or) Sandstone of) Tchinezzinne)	Deep Artesian Water Horizons
(A) Crystalline Basement	(Precambrian)	Crystalline basement of Liptako, Damergou and Mounio and of l'Air Massif	Subterranean wate at less than 20 m. depth in the zone of weathering

* Greigert, J. "Description des Formations Cretacés et Tertiaires du Bassin des Illumeden (Afrique Occidentale)" (1963)

CHAD BASIN

Stratigraphy: Local Nomenclature	Stratigraphy: Universal Nomenclature	Lithology	Hydrology
(G) Recent	Quaternary	Aeolian Dunes (ergs)	Generally dry
(F) Lower	Quaternary	Tchad Group: Mostly clay with some sandy intercalations	Impervious beds and artesian horizons
(C) Marine	Cretaceous	Marls and Clays	Impervious bed (if present thinner tha in the Niger basin)
(B) Continental Hamadien & Continental Intercalaire	Cretaceous	Sandstones of the Tegama facies perhaps Marls of Irhazar	Upper part slightly permeable; phreatic horizons & artesian horizons. Impermeable
(A) Crystalline	(Precambrian)	Crystalline basement of l'Air Massif, of Damergou and Mounio	Underground water at less than 20 m. depth in the zone of weathering.

* Greigert, J. "Description des Formations Cretacés et Tertiares du Bassin des Illumeden (Afrique Occidentale)" (1963)

A. Pre-Cambrian Basement

Exposures occur at Liptako, Damergou, Mounio and in the l'Air Mountains. These rocks are similar to other pre-Cambrian zones in West Africa, Ghana, Mali, Upper Volta and Ivory Coast and comprise 1) metamorphics cut by quartz and aplite veins; 2) igneous intrusions such as granite, diorite, gabbro, gneiss. Water is present at shallow depths, in the neighborhood of 20 meters, at Liptake and about 60 meters in Ghana and the Ivory Coast.

B. Continental Intercalaire

Composed of:

1)	Agades Sandstone) Tchierzzine Sandstone)	Coarse, conglomeratic, porous especially west of l'Air Massif. Collects rainfall from Air.
	overlain by:	
2)	Irhazar Shales	Cover creating artesian conditions in sandstone beneath
3)	Tegama (Facies) Sandstone	

This makes up the largest part of the Intercalaire and is widely exposed. Permeability is good. In the Niger Basin, the Tegama aquifer horizons underlie impervious zones of the Cretaceous while, in the Chad Basin, shales of the Tchad Group probably contribute to this impermeability.

The Tegama aquifer is exploited by a few pumped wells for Nomadic livestock, eg. at Tahoua. (plate 4)

The westernmost well reaching this horizon is at Digdiga, (T.D. 690 m.) where water rises to within 18 m. of the surface. If this well had been located a little farther west in the Dallol Bosso, artesian flow would have resulted.

The westward subsurface extension of the Gres Tegama in the Niger Basin has not been ascertained. It may not extend throughout the entire basin. Also it may become more shaly and impervious in this direction.

East of Niamey, there may be a fault which cuts the Continental Terminal east of Niamey. A well between Niamey and the Dallol Bosso would shed much information on this question which is germane to water supply for western Niger from this horizon.

The Continental Intercalaire outcrops between Tanout and Zinder but is poorly pervious. e.g. a 405 m. well at Damergou penetrated 100 m. of Continental Intercalaire but production was too small for exploitation. Puits (hand-dug wells) here would probably not be very productive.

(NOTE: Stratigraphy south from Agades must be studied in order to predict subsurface conditions. Surface work would have to be undertaken before drilling any wells between Agades and Tanout or Tanout and Zinder).

C. Cretaceous

The upper part is marine and of the following ages:

Age	Lithology
Maestrichtian	Largely clay
L & M Senonian	Clay and sand
Upper Turonian	Clay & argillaceous limestone
Lower Turonian)	Continental Hamadien in Tchad
U. Cenomanian)	Gres Tegama or Continental Intercalaire

D. Eocene

The Eocene sandstone is water-bearing around Dogondoutchi and Kiesse (P1-1) and may be recharged northward from Nigeria. Continental Terminal should have less potential since it derives water from a region of lower rainfall in the north.

Aquifers of the Niger basin probably drain southward via Gaya, on the Niger River below Niamey, where the elevation is 161 m. above tide.

E. Continental Terminal

Outcrops of sandy sediments with shale intercalations are limited to the western part of the Niger basin. This gives rise to sub-artesian possibilities beneath shale intervals and perched water tables above them.

There are two semi-artesian aquifers and one free water table (at top) in this stratigraphic interval.

Depth to water varies from 40 to 75 m. and is an uncertain factor to be considered in digging wells. Bore holes are not recommended. The Continental Terminal is fringed by a dry zone westward toward the Niger River.

Less water is found in the Continental Terminal northward from the latitude of Niamey.

F. Chad Group

Argillaceous sediments of this group reach thicknesses of several hundred meters in the center of the basin.

Some thin aquifers are exploited in the northeast part of Nigeria.

In eastern Niger, between Maine Soroa and Lake Chad, exploitation has commenced of a middle aquifer, which is artesian. Production here is less than 1 to 3 m^3/hr. The Continental Terminal, west of the Air Massif, yields more than 2 to 3 m^3/hr. There is some expectation for the presence

of artesian sandstones in the lower Tegama facies (correlating with the Continental Intercalaire or Continental Hamadien) northward toward Agadez.

G. Dunes & Alluvium

Dunes and alluvium are widespread throughout the country. These provide a very good area for infiltration if the supply minus evaporation balance is satisfactory.

Alluvium is found along the Niger River and dry creek beds where water may be found at a depth of approximately 2 meters.

WATER RESERVES

Although a much-needed estimate of water reserves, recharge potential, producing rates and safe yield has never been made in Niger, it is reasonable to predict that sufficient quantities of water to meet anticipated demand is available for the foreseeable future. Investment in water is therefore basically sound.

Regarding water-bearing horizons, these occur in (see Plate 9).

a. three semi-artesian horizons in the upper Tertiary Continental Terminal suite of formations

b. several levels in the Tertiary of the Lake Chad region, including artesian production

c. Cretaceous Continental Intercalaire, an equivalent of the highly-productive Nubian sandstone of Egypt and North Africa, in general.

In much of Niger today, wells are widely spaced so that a situation of saturation drilling has not been approached. About 12,000 hand-dug wells have been made through National effort and 8,000 are listed on records. Various donors, with an assist from Government, have completed some 1,600 cement-lined wells for human and livestock needs. Unfortunately, borings have usually been terminated at the top of water-bearing horizons, leaving appreciable volumes of untapped fluid draining away down the hydraulic gradient. If modern, drilling and completion techniques were adopted the cost of water finding would be considerably reduced by increasing yields of wells, thus permitting a reduction in the number of borings required to satisfy demand at any given locality.

It is interesting to note that the Continental Intercalaire is a southern extension of the Cretaceous Nubian sandstone that surrounds exposures of the African Basement, shield situated in the Hoggar and Air Mountains. Many thousands of years ago, under moist climatic conditions, the Nubian, in places 1,000 meters thick, was fully charged with water. Despite arid conditions which followed and prevail today, the water remained stored. Vast quantities are being withdrawn in the western desert of Egypt and throughout the tier of countries bordering the south shore of the Mediterranean.

Although water replacement to the Nubian is nominal the reservoired volume is so great that supplies will last for many years at the present withdrawal rate. The Republic of Niger is extremely fortunate in that the Nubian reservoir is practically untapped.

APPENDIX III.2

Section 2. DATA ON DRILLED WELLS

A small amount of the total information desired concerning drilled wells was obtained from files of the hydrogeological department and appear on the following pages. The data would be valuable in future hydrogeological work and merit retention in this report.

ABALAK FORAGE

Cercle Tahoua

Coordinates: $6^{o}14'E$ $15^{o}23'N$

Elevation: 428.58 m.

Section:

Quaternary:	0-27	Sand & shale
Continental Intercalaire:	27-125	Sandstone & Sand (Tegama facies)

Log Attached

Rig: Failing M-1

TCHADAOUA FORAGE (1964)

Cercle Maradi

TOTAL DEPTH: 150 m.

STATIC LEVEL: 59.00

PRODUCTION: 900 lt/hr. DRAWDOWN 14.75 m.

NAPPE: 69 m. - 75 m.

STRAT. LOG: attached

TCHADAOUA BIS (1964)

TOTAL DEPTH: 148.50 m.

STATIC LEVEL: 27.75 m.

PRODUCTION: 1200 lt/hr

DRAWDOWN: 100%

NAPPE: 39 to 43 m

TAMAYA FORAGE

TOTAL DEPTH: 152 m.

COORDINATES: 6°46'35"E 15°47'30"N

ELEVATION: 463 m.

MACHINE: Joy 275

SECTION:

0- 6 m. Sand and facies Tegama

6-152 To Continental Intercalaire. Coarse to fine sand. Below 60 m. is cross-bedded.

SCREENS: 6" INOX 120-136.29 m.

TOP GRAVEL PACKING: About 80 m.

DEVELOPMENT: Surging and pumping

STATIC LEVEL: 78.35 m. Altitude Static Level 385 m.

PRODUCTION: 94 m^3/h. Drawdown 3.5 m.

SCREENS: 41.65 m. below static level. 20 m. longscreen

PRODUCTION HORIZON: Tegama facies of Continental Intercalaire

TARNA FORAGE No. 1

Cercle Maradi

(Goulbi de Maradi Area)

TOTAL DEPTH:	19.35 m.
PRODUCTION:	35 m^3/h
DRAWDOWN:	110 m.
STATIC LEVEL:	2.85 m.
SECTION:	
0- 15	Coarse sand
15- 19.35	Red shale
SCREENS:	8 - 15.65

APPENDIX IV

MISCELLANEOUS PROGRAMS APPLICABLE

TO NIGER

MISCELLANEOUS PROGRAMS APPLICABLE TO NIGER

In addition to previous suggestions for 1) action programs through rainfall conservation in naturally-occurring surface catchment basins beyond the grazing range of permanent well water where forage is good and 2) education in pilot percussion drilling technique to demonstrate a comparatively inexpensive method of securing underground water supplies, in combination with sophisticated hydrogeological procedure, there appear to be miscellaneous approaches through which significant assistance could be offered the Republic of Niger. Several of them are:

NATURAL RESOURCES SURVEY

1. Water. A total evaluation of water resources in Niger has never been undertaken.

Generally speaking a total evaluation of water resources in a country includes an assessment of the data available from a qualitative inventory of existing wells, stream gauges, meteorological stations and geological and hydrological reports; a determination of the present and projected future needs of the country, and an exploration program aimed at assessing true availability and quality of surface and subsurface water resources and safe levels for utilization. If required, drilling programs are executed to extend total knowledge and define the limits of sub-surface water availability and quality, safe exploitation limits, well spacing standards and the recharge rate, transmissibility, storage coefficients, productivity and other characteristics of the aquifers.

The above studies result in specific exploitation projects for municipal, industrial and agricultural development. Included are, where appropriate, programs aimed at regulating run-off of surface water and developing water storage areas. Finally, the potential for hydro-electric power exploitation is fully explored and, assuming the establishment of feasibility, plans formulated for project execution.

2. Agriculture. If cattle and water are considered the backbone of Niger's natural wealth, agriculture is a close second. Although this subject has received intermittent attention, considerable long range benefit should be gained through compilation, coordination and review of existing data supplemented by additional information to round out the picture. From these efforts would result a balanced knowledge of the country's maximum potential and an optimum plan for progress

through both internal effort and outside support. Drawing on these reserves of information, convincing, documented rationale, of utmost advantage in preparing requests, may be marshalled.

In this approach, agronomists, plant ecologists, soils scientists, hydrologists and range development specialists develop inter-faces and conduct an overall agricultural resources inventory and analysis. Agronomic analysis is undertaken in support of increased production. Present marketing practices are analyzed, potential new markets delineated and estimates made of absorption capacity. In all areas, detailed development plans, complete in every respect, are formulated and specific projects programmed for execution.

3. Range Management. Contacts with experts in this field indicate that, although range management has not progressed significantly, the need for implementing this policy is highly advantageous especially in preventing overgrazing near permanent water supplies and bringing about other benefits.

In range management all factors supporting meat production are examined critically, including suitability of land for intensive development, availability of developed or underdeveloped land for expansion, climatic and physical factors influencing development, communications, access to and availability of processing facilities, possibility of development of grass and forage crops, economics of meat production and market analysis. Where findings are favorable, specific recommendations are made for industrial development action. Wild life management studies are undertaken in areas where appropriate.

4. Economic Minerals. To the extent that an analysis of economic minerals, especially from the air, leaves something to be desired, a careful search for additional resources would be opportune. The area of greatest prospect would probably lie within the zone if igneous basement rocks of northern Niger, especially where faulting may have produced a climate requisite for mineralization. Sedimentary iron ore is another possibility.

An undertaking oriented in this direction would assess the economic mineral wealth, utilizing the following tools in carrying out a systematic program in accordance with the established methods of scheduling and procedures; photo-geology, airborne magnetics (rubidium gradiometer instrumentation), electro-magnetic and scintillometer studies, integrated field survey parties for geological, geophysical and geochemical exploration, core drilling and laboratory analysis.

Recommendations are then prepared for project execution aimed at maximum, but controlled, exploitation of all economically feasible deposits.

5. Construction Materials. In theory and in practice, the location and evaluation of construction materials is an asset, both country-wide and from a standpoint of local employment. A case in point is the cement plant at Malbaza. Although limestone is advantageously accessible to the main east-west route, we understand that the rock is not of top quality. For this reason, the product has no real export value. Had further search revealed better base material, national income through export to neighboring countries would have been provided.

Assisted by photogeology and field geology surveys, materials suitable for dwellings, roads, dams and other construction, are geographically located and volumetrically and qualitatively appraised. When commercially feasible, deposits are defined, plans for exploration activities are completed.

APPENDIX V

PHOTOGRAPHS AND PLATES

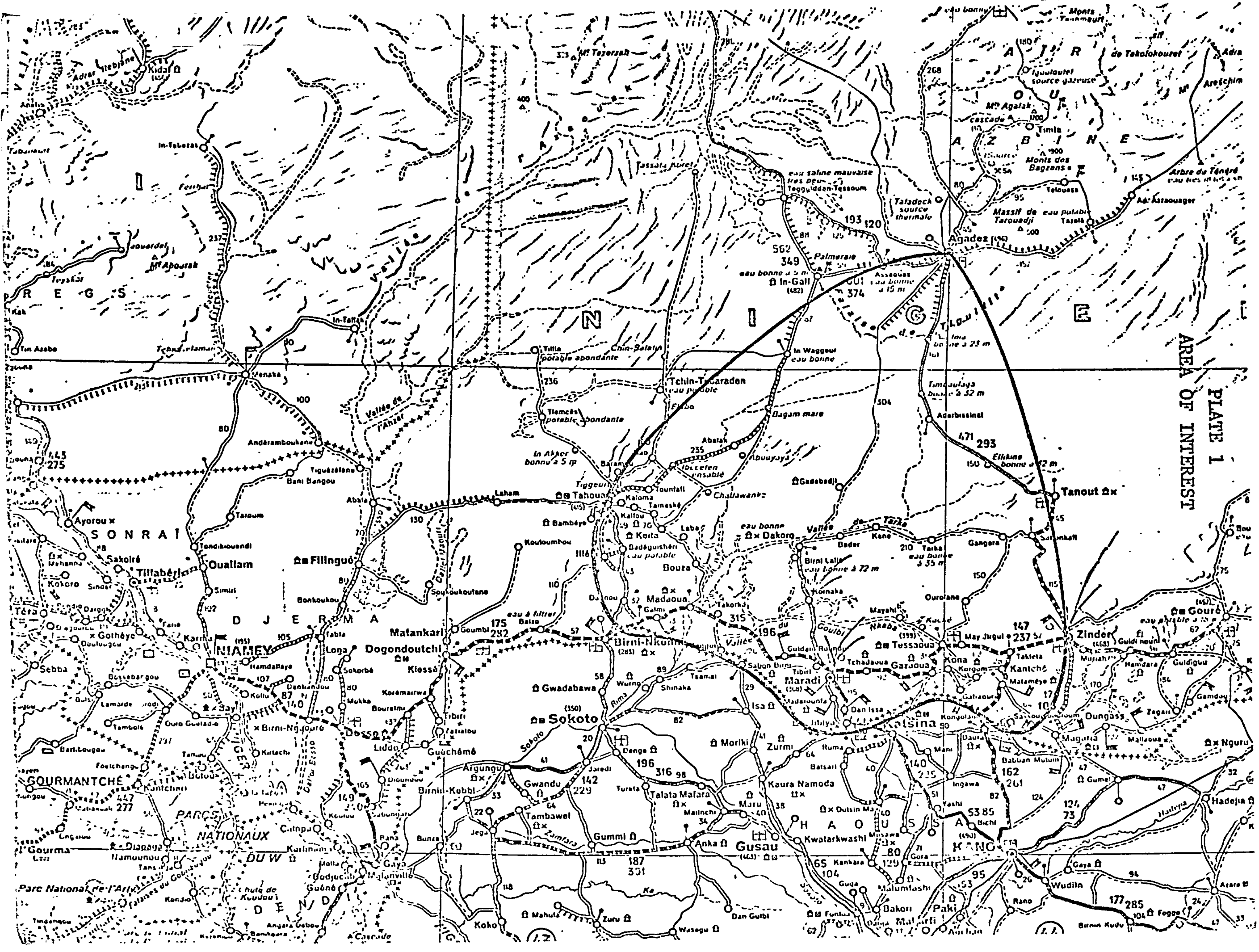


PLATE 1

AREA OF INTEREST

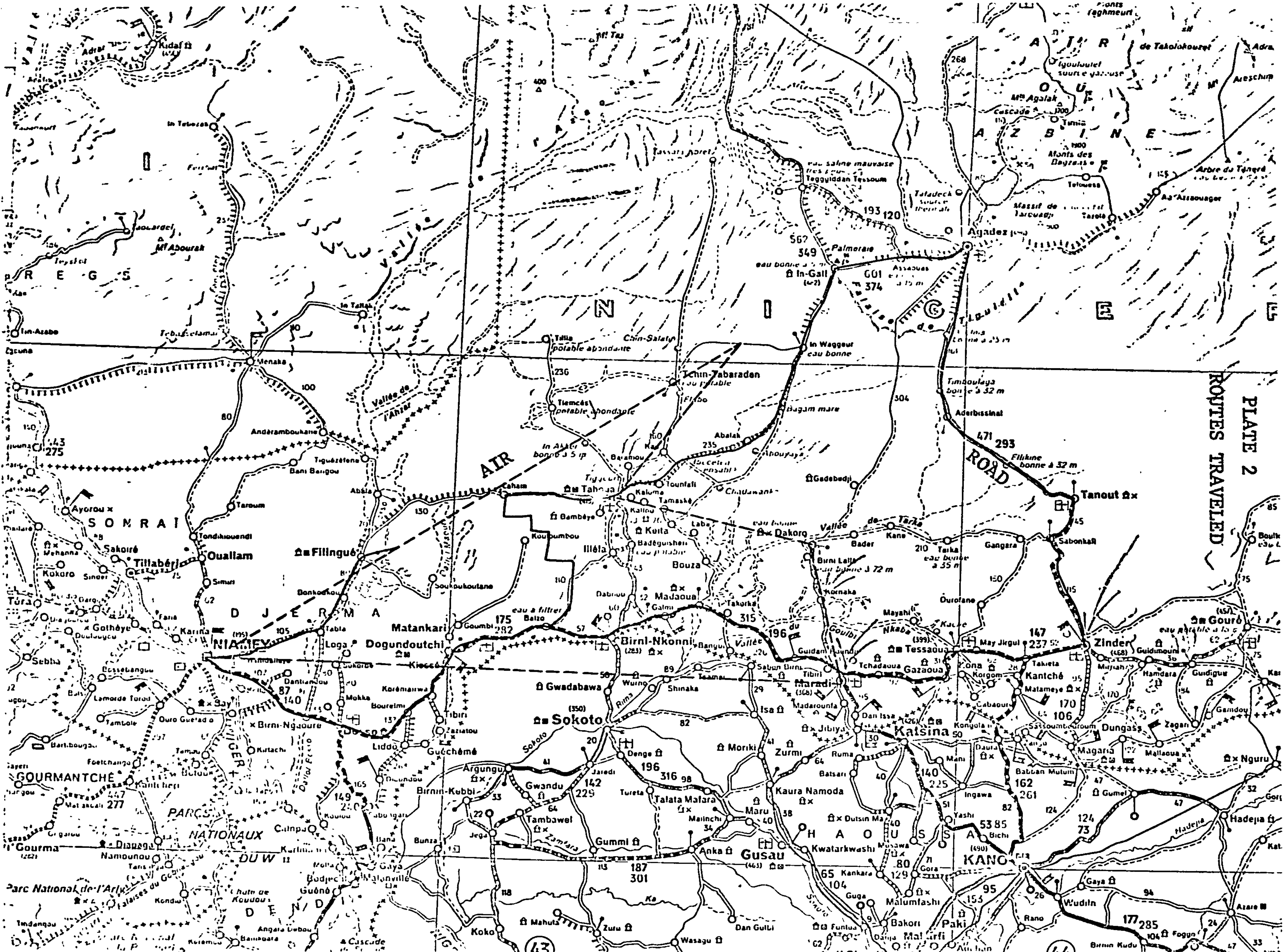


PLATE 2
ROUTES TRAVELED

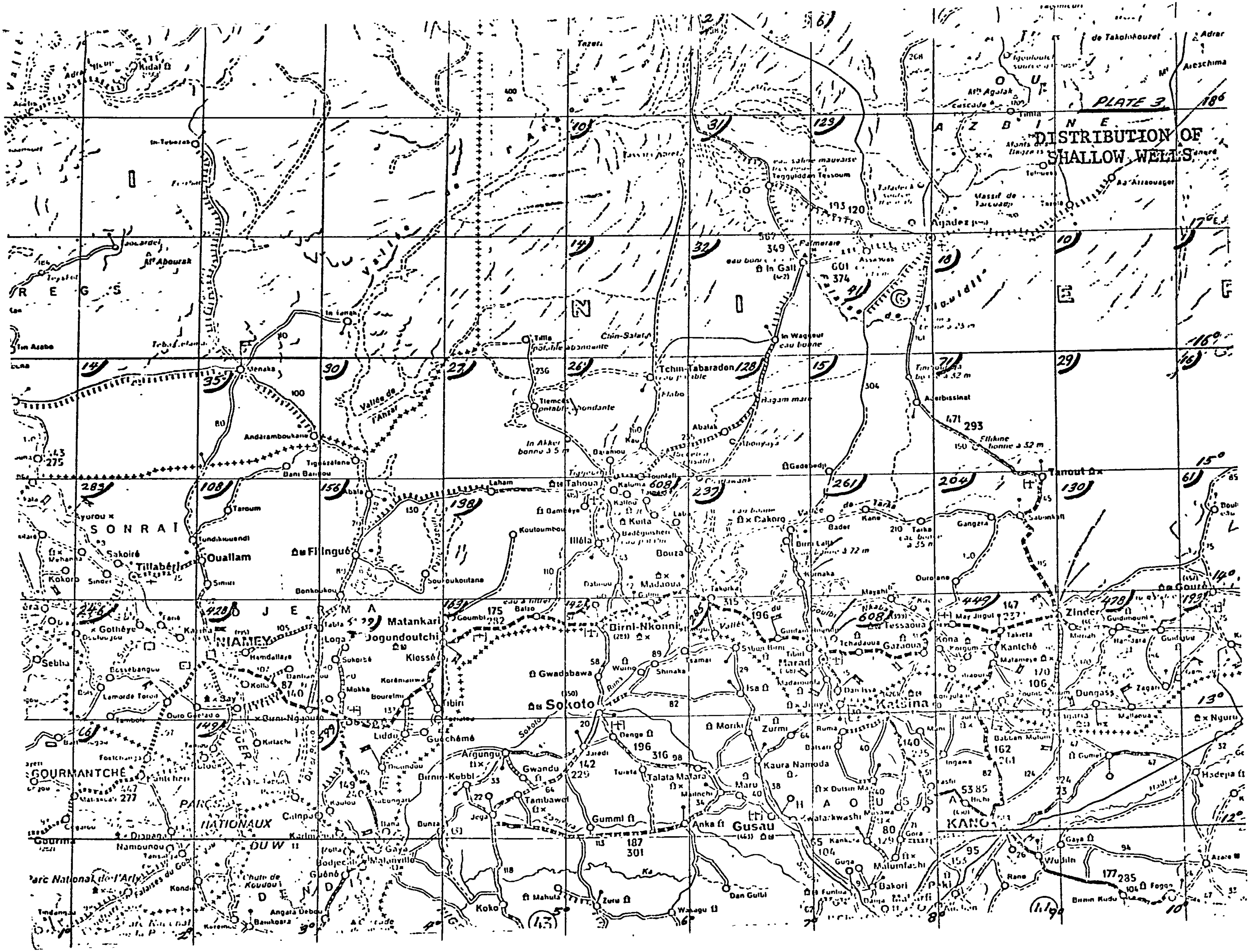


PLATE 3
DISTRIBUTION OF
SHALLOW WELLS
Agadez
In Gall
Tchin-Tabaraden
Tahoua
Filingué
Ouallam
Tillabéri
NIAMEY
Dogundoutchi
Matankari
Birni-Nkonni
Madaoua
Tessaoua
Zinder
Tanout
Maradi
Katsina
Sokoto
Gwadabawa
Argungu
Gwandu
Gusau
Kaura Namoda
Zurmi
KANO
Hadeja
Gumel
Gaya
Malanville
Kandi
Koko
Anka
Dan Gulbi
Tambawel
Jega
Birnin Kebbi
GOURMANTCHÉ
SONRAÏ
DJERMA
HAOUSA
Vallée de l'Azar
Parc National de l'Arly
PARCS NATIONAUX
Say

PLATE-4

LES RÉGIONS NATURELLES

DU BASSIN DES IULLEMMEDEN

Ag	Agadès	M	Mentess
ALA	Alanlara	MD	Madaoua
An	Ansongo	MK	Malkurfuna
C	Chinazaron	MN	Ménaka
CS	Chin Salatin	MR	Maradi
D	Dogondoutchi	N	Niamey
Dg	Digdiga	O	Ouezel'
Dk	Dakoro	Sh	Séhinn
Do	Dosso	SK	Sokoto
Ek	Ekkineouane	T	Tahoua
Ef	Efféinatess	Ta	Tanout
EL	Elleba	Te	Ténékert
F	Filingué	Tk	Mt. Tazerzait Kebir
Ga	Gao	To	Taouardel'
[illegible]	Gaya	Z	Zinder
I	Ibécéten	300	Dogondoutchi km 300
Ig	Mts Iguellala		

Socle cristallin.

Auréole primaire. Tassili Oua N'Ahaggar.

Auréole Continental intercalaire et Continental hamadien. Surfaces planes dénudées ou couvertes de regs du Ténéré et de la Plaine de l'Irhazer. Plateaux ensablés du pays du Tégama et de la région Maradi-Zinder. Surface plane broussailleuse. du Sokoto.

Côte cénomano-turonienne. Un talus argileux parfois large de plus de 10 km la précède.

Auréole Crétacé moyen. Dalles calcaires à contours persillés entourées de talus argileux et de dunes fixées.

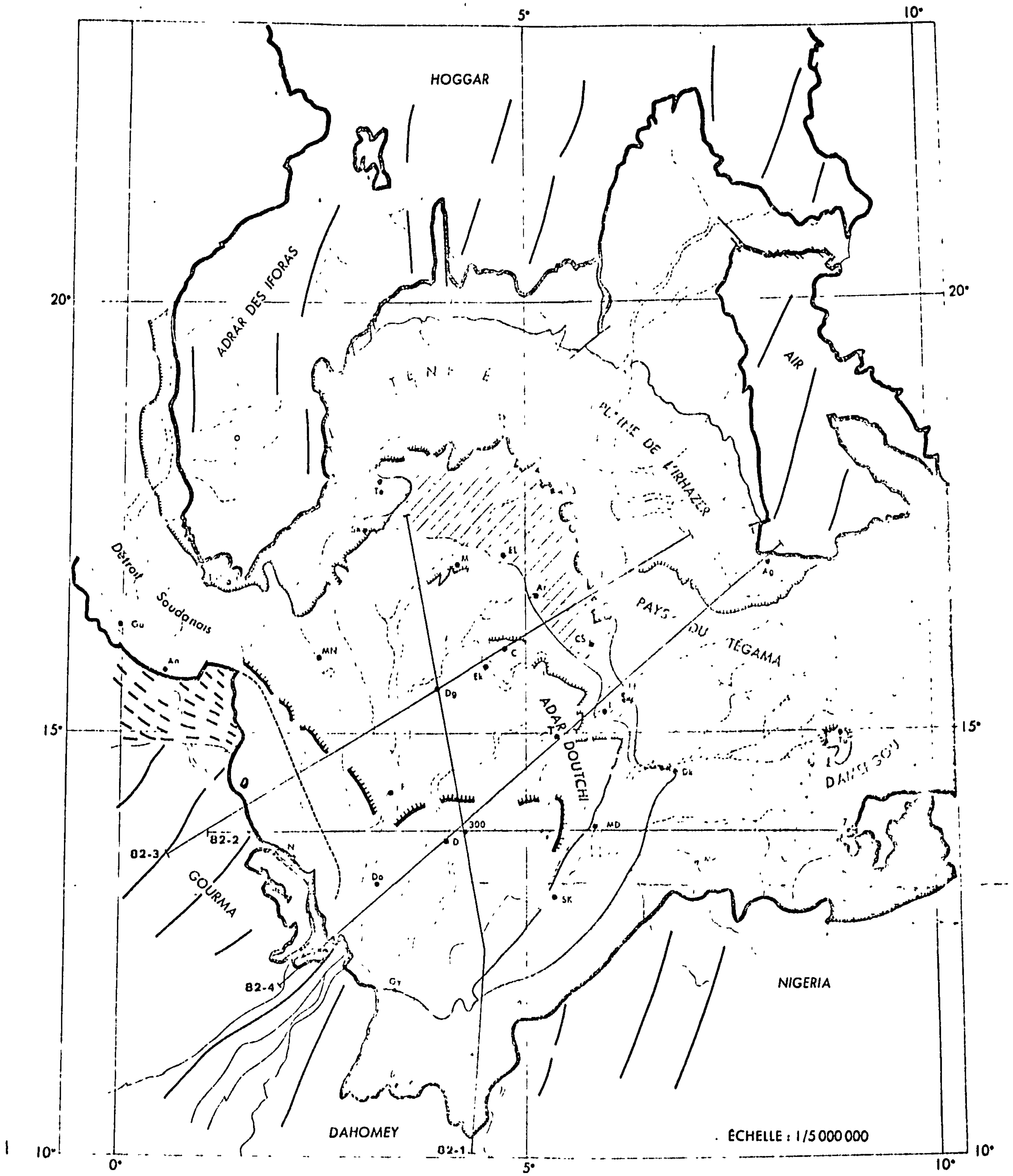
Côte sénonienne et paléocène Haute falaise très ravinée couverte d'éboulis. En avant de la côte, talus argileux et erg fixé. En arrière, dans l'Adar Doutchi, plateaux de calcaires paléocènes ou de grès ferrugineux du Continental terminal, et vers l'Ouest surface broussailleuse, ensablée, à topographie confuse dominée par des crêtes ou des dalles très ravinées de la série argilo-sableuse à lignites sous des carapaces ferrugineuses.

Côte des grès argileux du Moyen-Niger. Larges plateaux et innombrables buttes tabulaires recouverts par la "brousse tigrée" et entourés de dunes fixées.

Formations du Tchad. Dunes fixées récentes, en longs alignements NW-SE. Les sillons interdunaires sont actuellement envahis par les eaux de la nappe phréatique qui, depuis 10 ans, remontent sous l'effet de l'augmentation de la pluviométrie.

Directions tectoniques du socle cristallin.

Tracé des coupes 82-1 82-2 82-3 82-4.



HOGGAR
ADRAR DES IFORAS
AIR
PLAINE DE L'IRHAZER
Détroit Soudanais
PAYS DU TEGAMA
ADAR DOUTCHI
GOURMA
NIGERIA
DAHOMEY
B2-1
B2-2
B2-3
B2-4
300
ÉCHELLE : 1/5 000 000
5°
10°
20°
15°
0°

COUPES

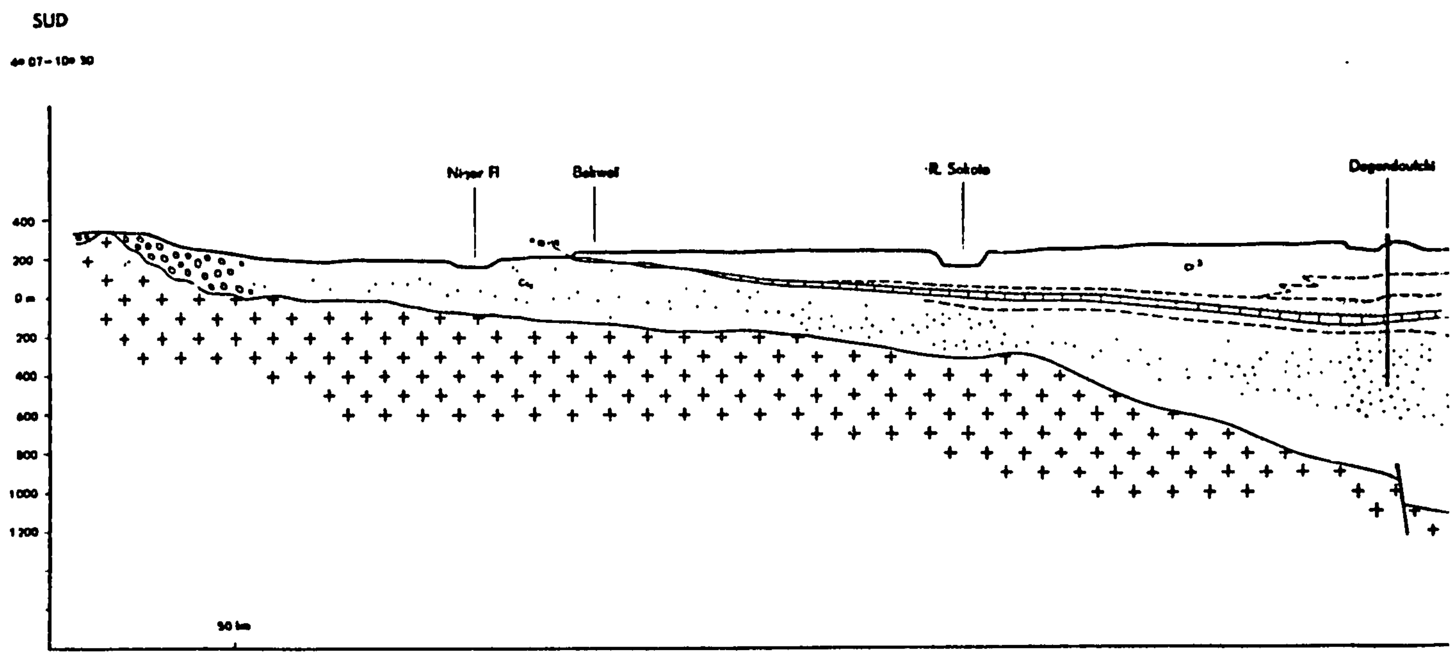


Planche n° 82-1

... SCHÉMATIQUES A TRAVERS LE BASSIN DES IULLEMMEDEN

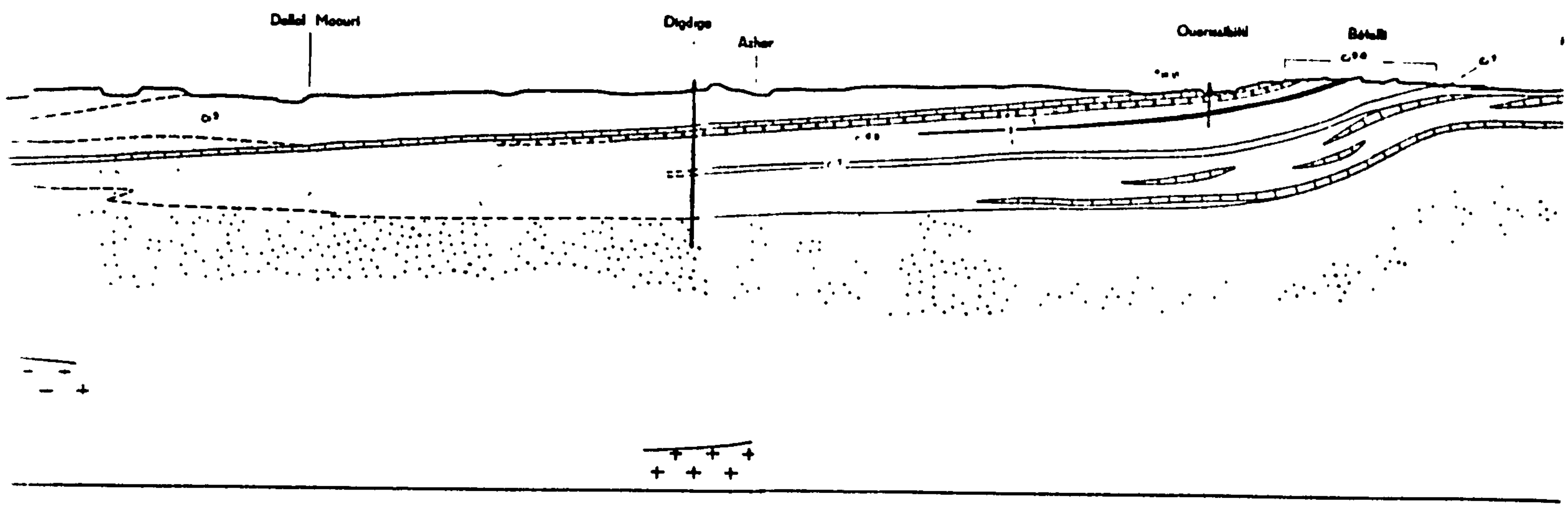
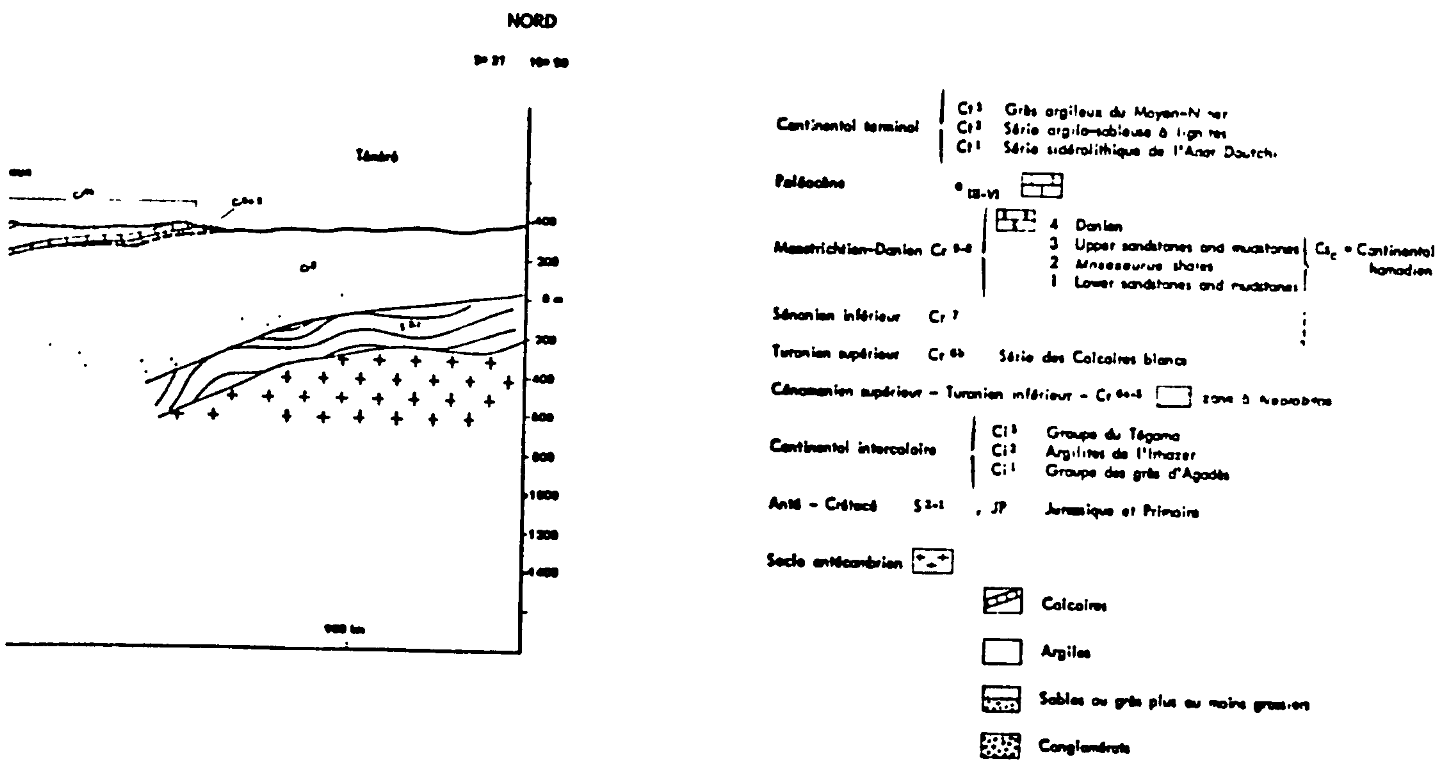


PLATE 5



NORD
Téméré
Continental terminal
Ct 3 Grès argileux du Moyen-Niger
Ct 2 Série argilo-sableuse à lignites
Ct 1 Série sidérolithique de l'Ader Doutchi
Paléocène
Maastrichtien-Danien Cr 9-8
4 Danien
3 Upper sandstones and mudstones
2 Mosasaurus shales
1 Lower sandstones and mudstones
Ct c = Continental hamadien
Sénonien inférieur Cr 7
Turonien supérieur Cr 6b Série des Calcaires blancs
Cénomanien supérieur - Turonien inférieur - Cr 6a-5
Continental intercalaire
Ci 3 Groupe du Tégama
Ci 2 Argilites de l'Imazer
Ci 1 Groupe des grès d'Agadès
Anté - Crétacé
Jurassique et Primaire
Socle antécambrien
Calcaires
Argiles
Sables ou grès plus ou moins grossiers
Conglomérats

COUPES SCHÉMATIQUES A TRAVER

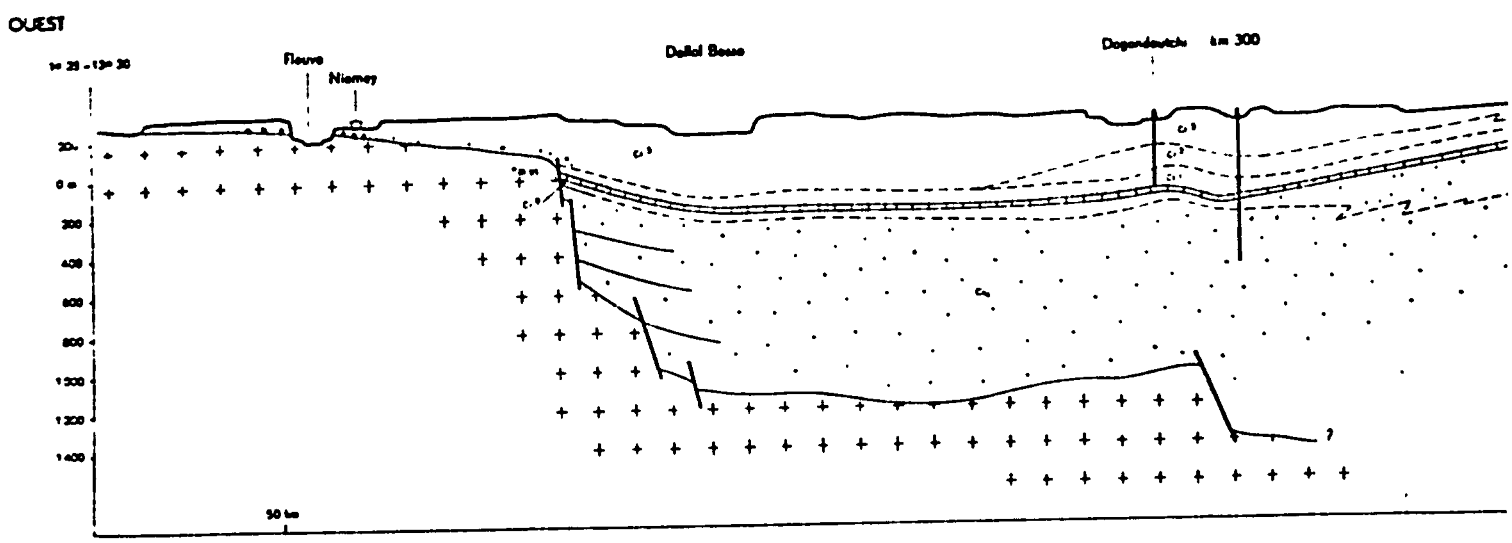


PLANCHE N° 82-2

...ES A TRAVERS LE BASSIN DES IULLEMMEDEN

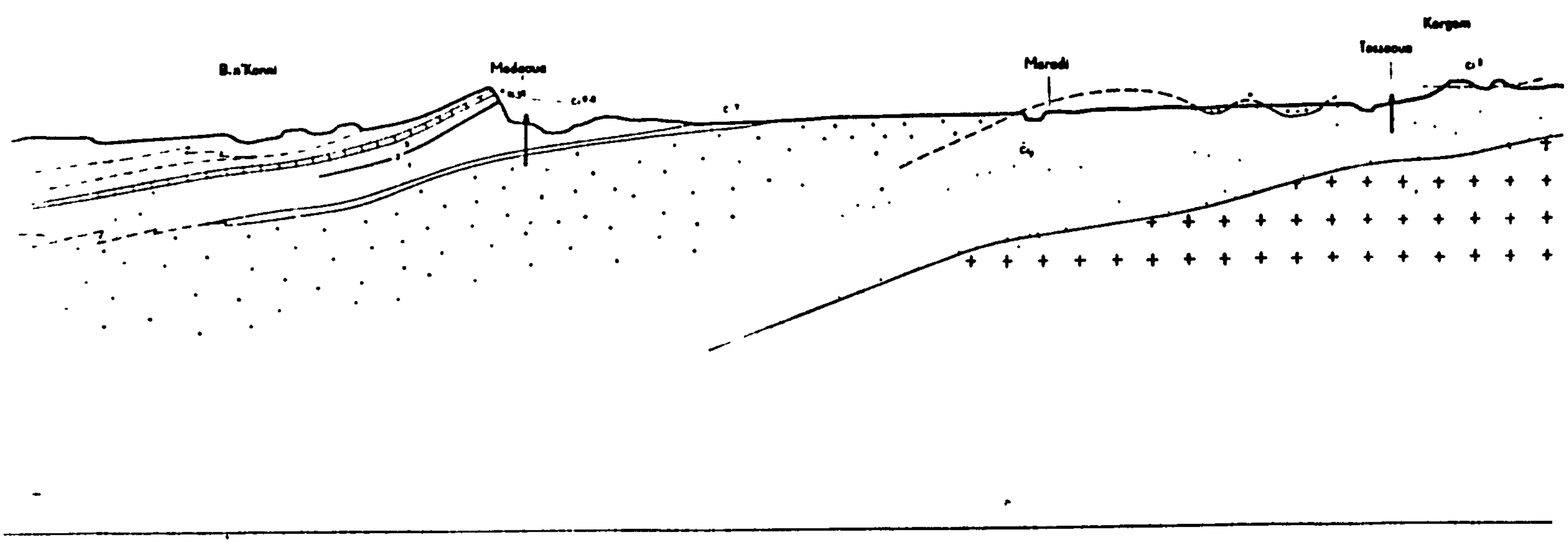
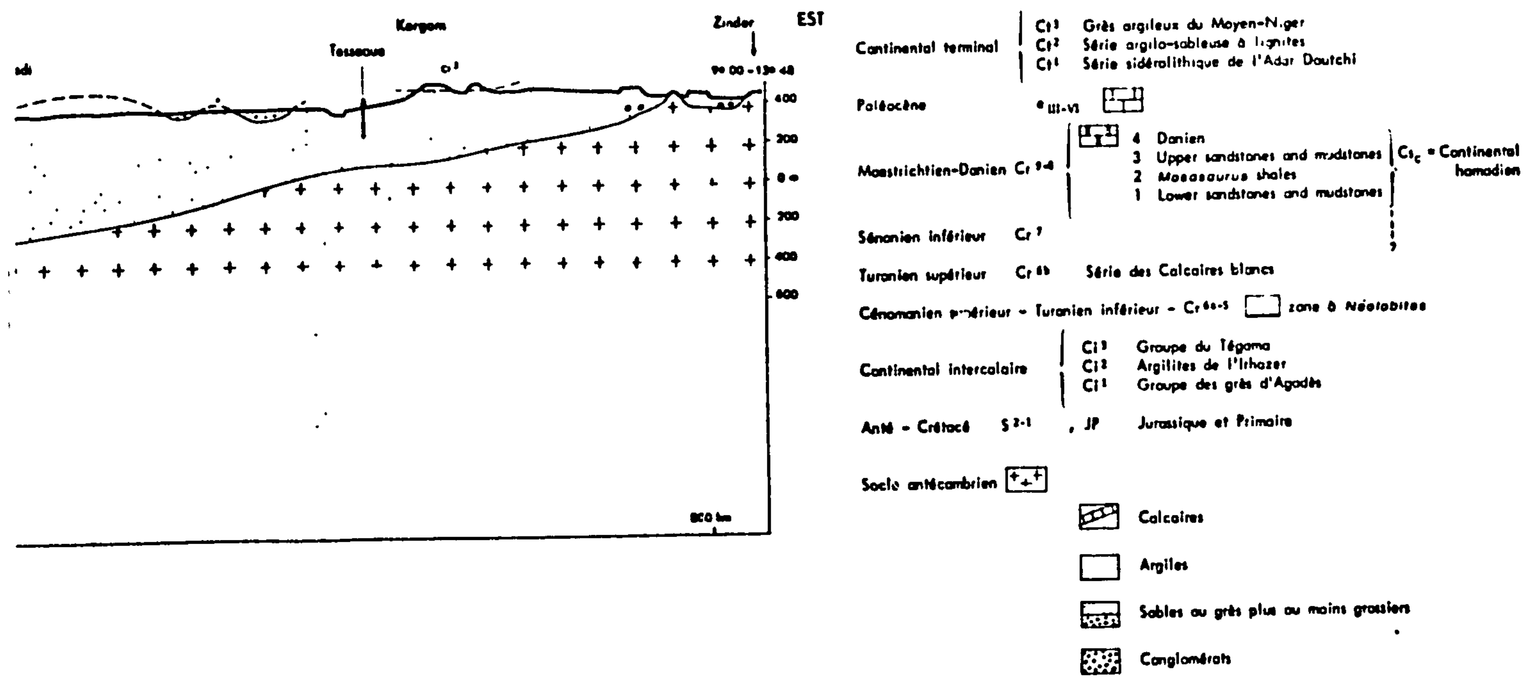
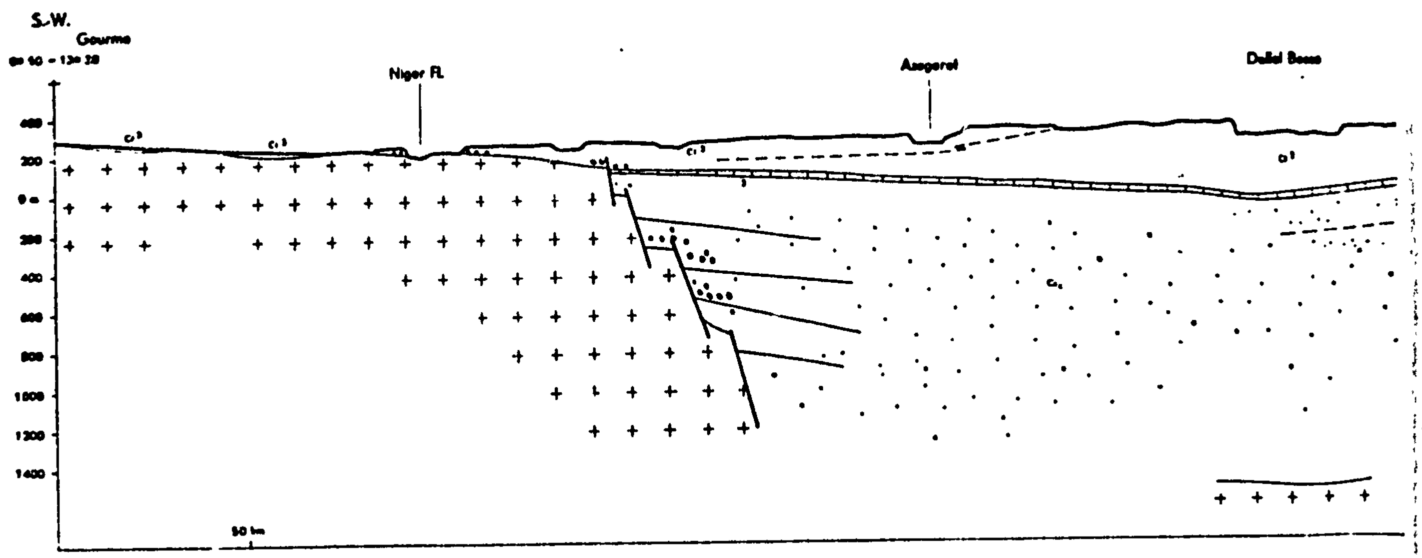


PLATE 6


Kargom
Tessaoua
Zinder
EST
Continental terminal
Ct3 Grès argileux du Moyen-Niger
Ct2 Série argilo-sableuse à lignites
Ct1 Série sidérolithique de l'Adar Doutchi
Paléocène
4 Danien
3 Upper sandstones and mudstones
2 Mosasaurus shales
1 Lower sandstones and mudstones
Maestrichtien-Danien
Cs = Continental hamadien
Sénonien inférieur
Turonien supérieur
Série des Calcaires blancs
zone à Néolobites
Continental intercalaire
Ci3 Groupe du Tégama
Ci2 Argilites de l'Irhazer
Ci1 Groupe des grès d'Agadès
Anté - Crétacé
Jurassique et Primaire
Socle antécambrien
Calcaires
Argiles
Sables ou grès plus ou moins grossiers
Conglomérats

COUPES SCHÉMATIQUES A T



A TRAVERS LE BASSIN DES IULLEMMEDEN

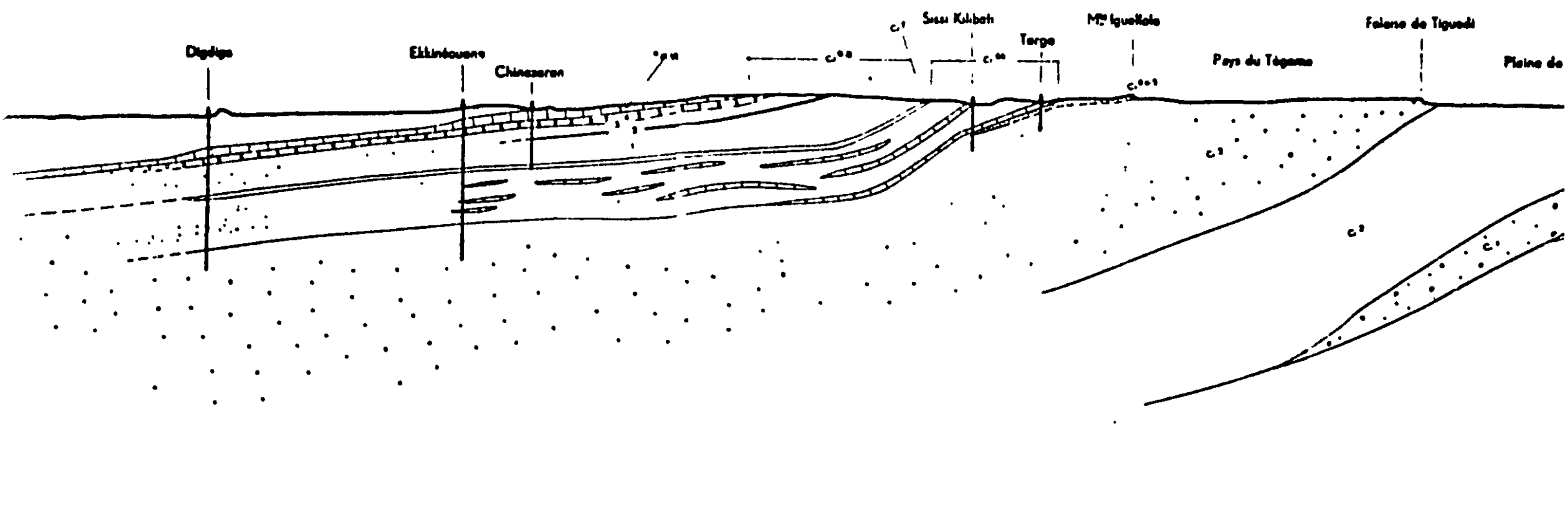
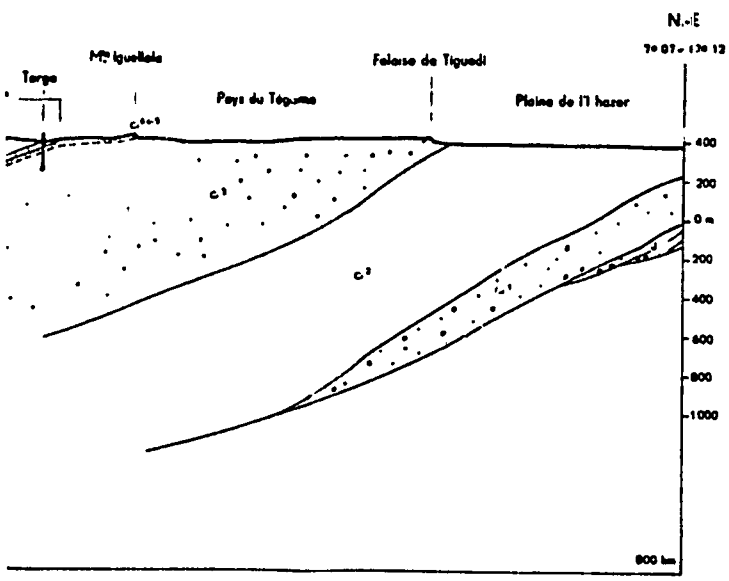


PLATE 7



Continental terminal
- Ct^3 Grès argileux du Moyen-Niger
- Ct^2 Série argilo-sableuse à lignites
- Ct^1 Série sidérolithiqur de l'Adar Doutchi

Paléocène e_{III-VI}

Maestrichtien-Danie · Cr^{9-8}
- 4 Danien
- 3 Upper sandstones and n stones
- 2 *Mosasaurus* shales
- 1 Lower sandstones and mudstones

Cs_c = Continental hamadien

Sénonien inférieur Cr^7

Turonien supérieur Cr^{6b} Série des Calcaires blancs

Cénomanien supérieur – Turonien inférieur – Cr^{6a-5} zone à *Néolobites*

Continental intercalaire
- Ci^3 Groupe du Tégama
- Ci^2 Argilites de l'Irhazer
- Ci^1 Groupe des grès d'Agadès

Anté – Crétacé S^{2-1} JP Jurassique et Primaire

Socle antécambrien

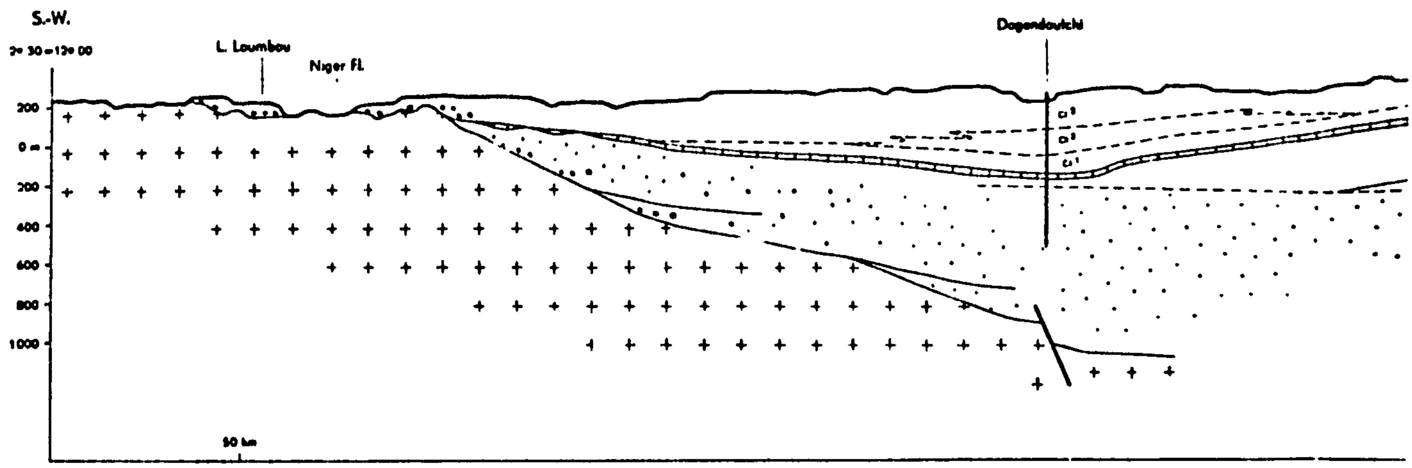
Calcaires

Argiles

Sables ou grès plus ou moins grossiers

Conglomérats

COUPES SCHEMATIQUI



... QUES A TRAVERS LE BASSIN DES IULLEMMEDEN

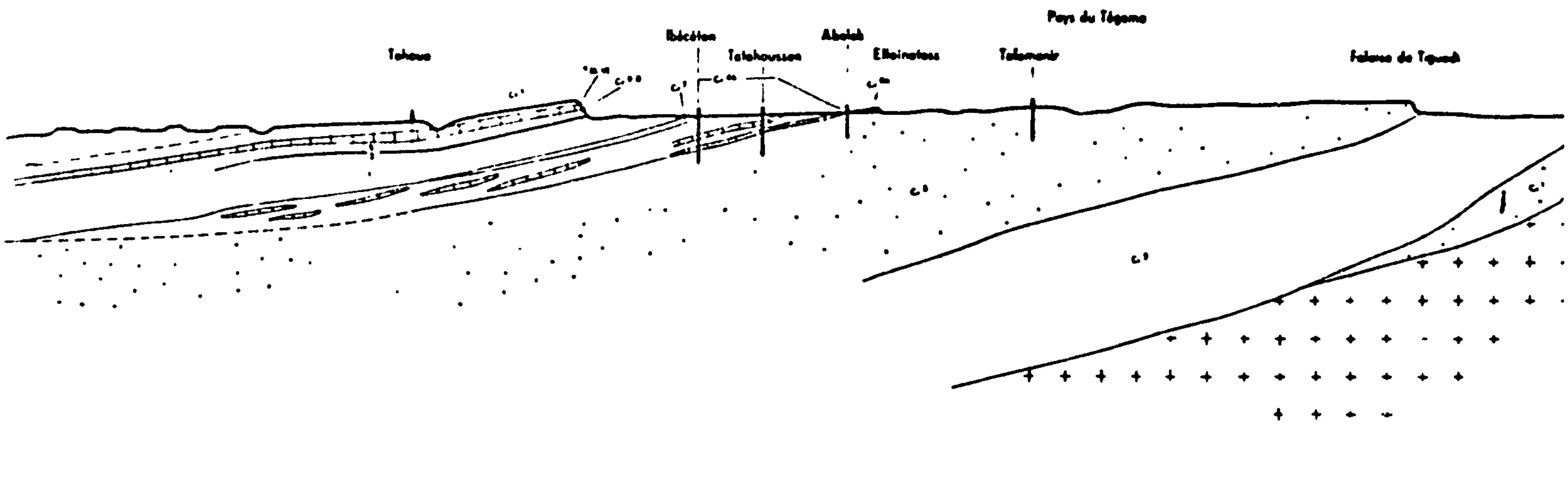
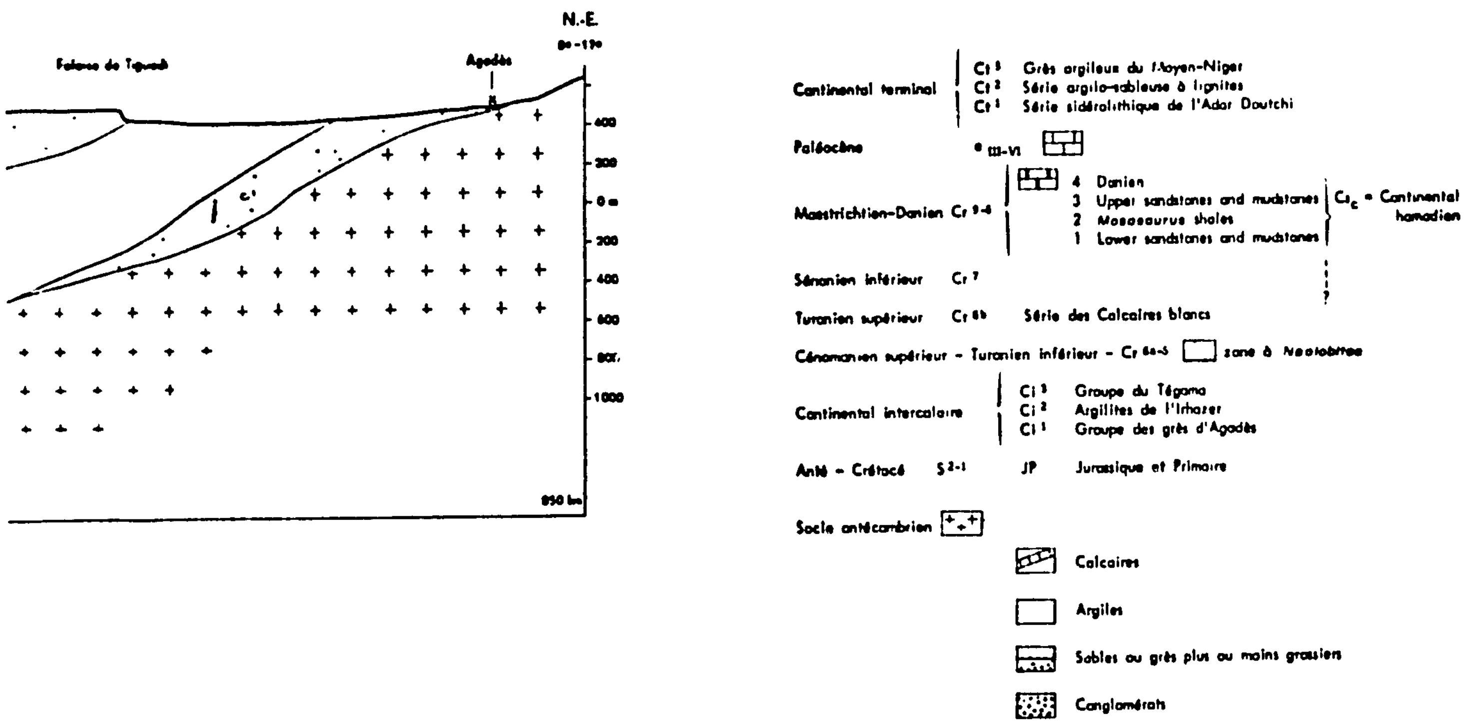
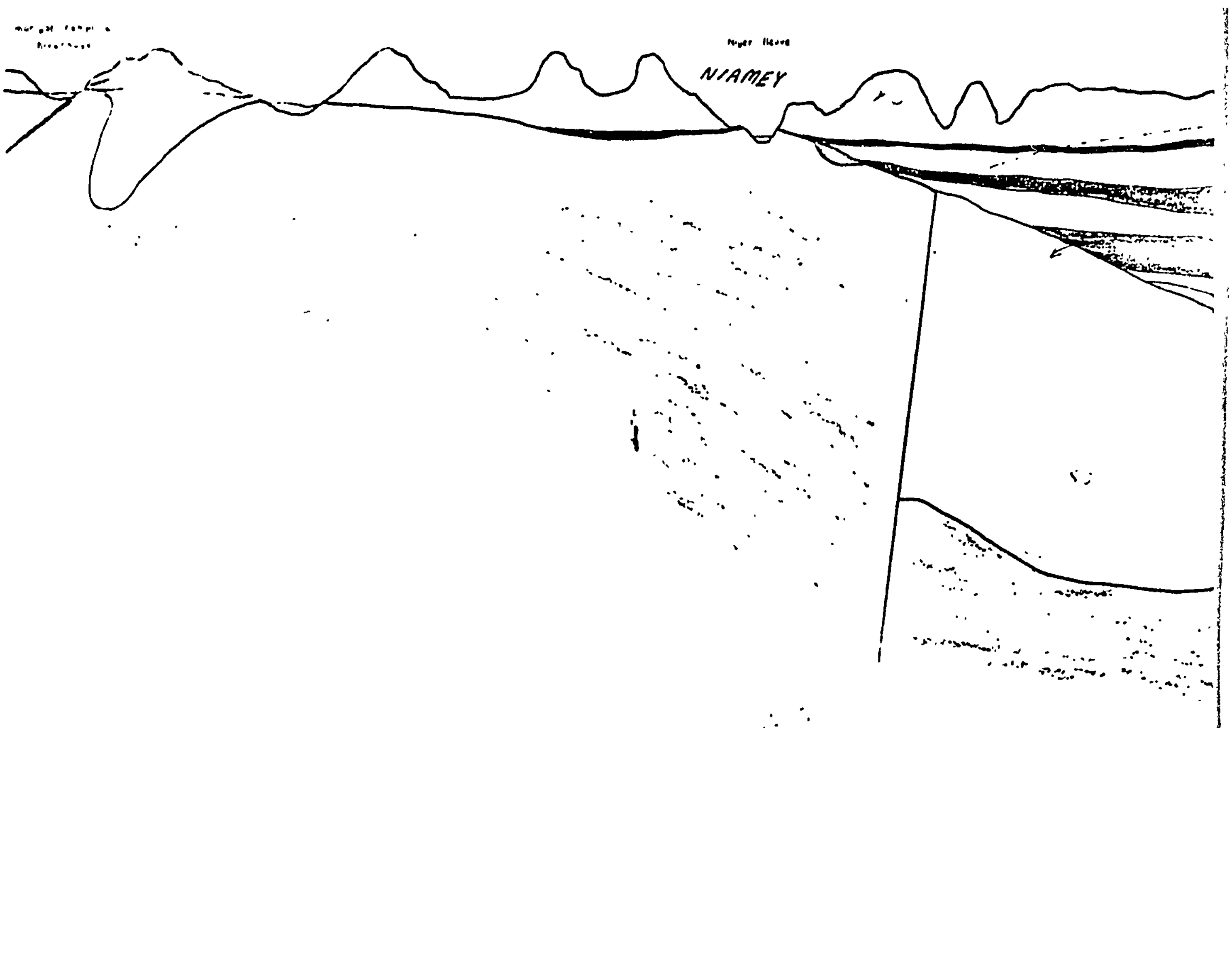


PLATE 8

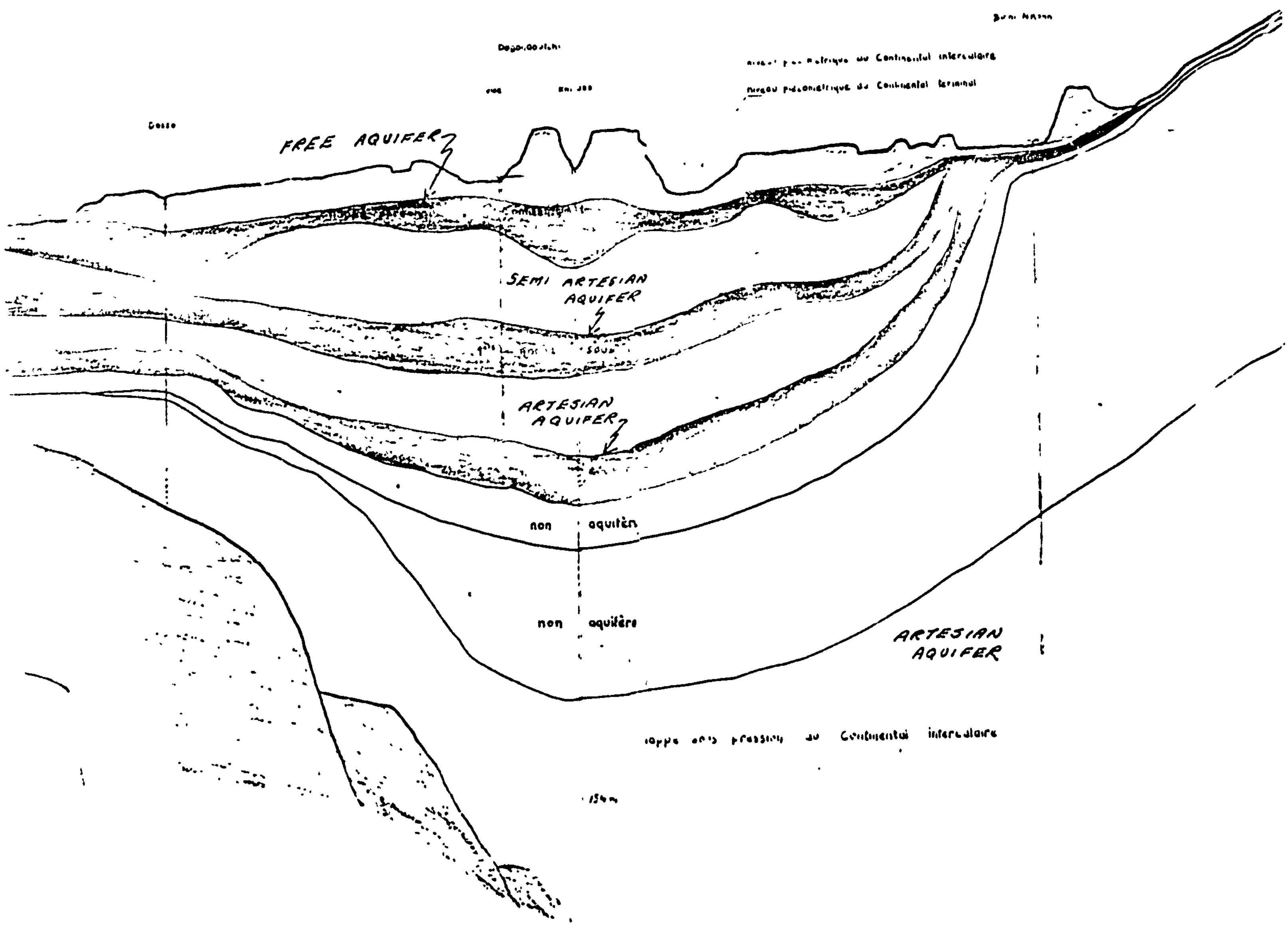


N.-E.
Agadès
400
200
0 m
200
400
600
1000
850 km
Continental terminal
Ct 3 Grès argileux du Moyen-Niger
Ct 2 Série argilo-sableuse à lignites
Ct 1 Série sidérolithique de l'Ador Doutchi
Paléocène
Maestrichtien-Danien Cr 9-8
4 Danien
3 Upper sandstones and mudstones
2 Mosasaurus shales
1 Lower sandstones and mudstones
Cr = Continental hamadien
Sénonien inférieur Cr 7
Turonien supérieur Cr 6b Série des Calcaires blancs
Cénomanien supérieur - Turonien inférieur - Cr 6a-5 zone à Neolobites
Continental intercalaire
Ci 3 Groupe du Tégama
Ci 2 Argilites de l'Irhazer
Ci 1 Groupe des grès d'Agadès
Anté - Crétacé S 2-1 JP Jurassique et Primaire
Socle antécambrien
Calcaires
Argiles
Sables ou grès plus ou moins grossiers
Conglomérats


NIAMEY

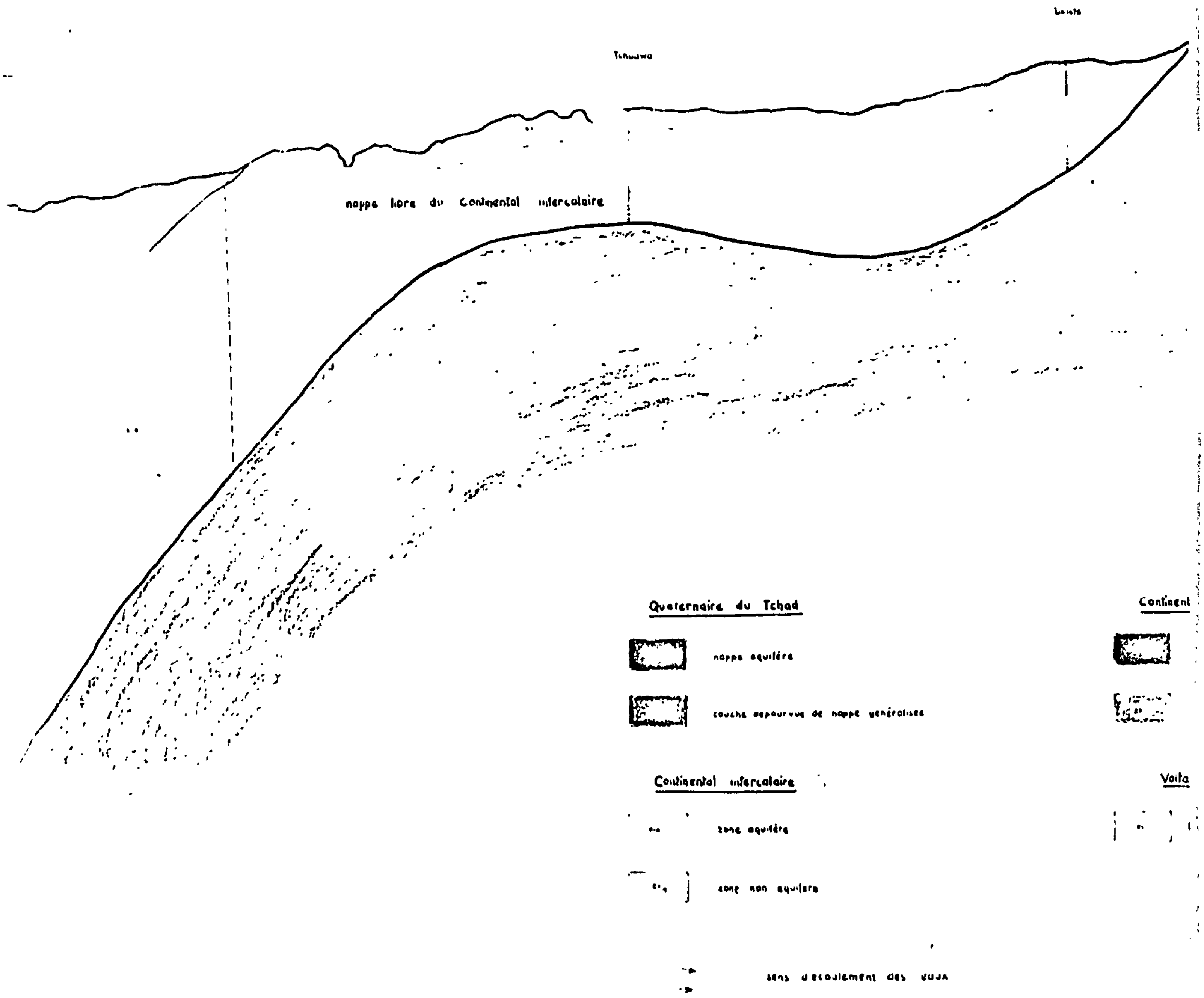
C

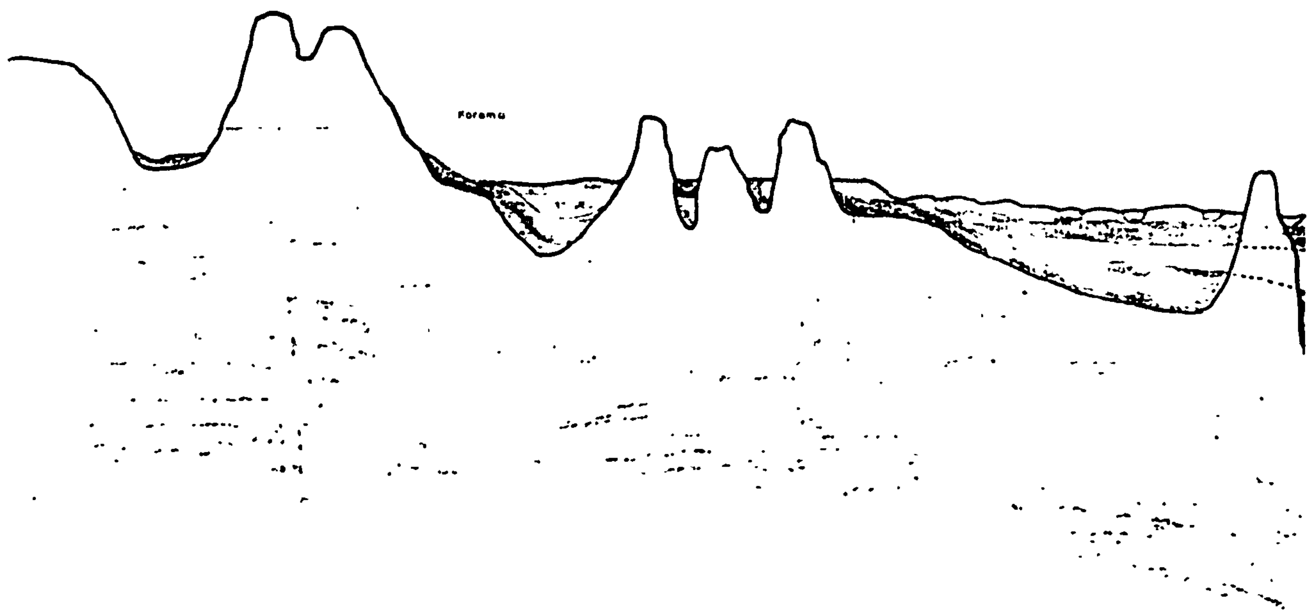
de la frontière de la Haute-



oupe hydrogéologique

ta au Lac Tchad suivant le 14ème parallèle





Eocène | (non aquifère)

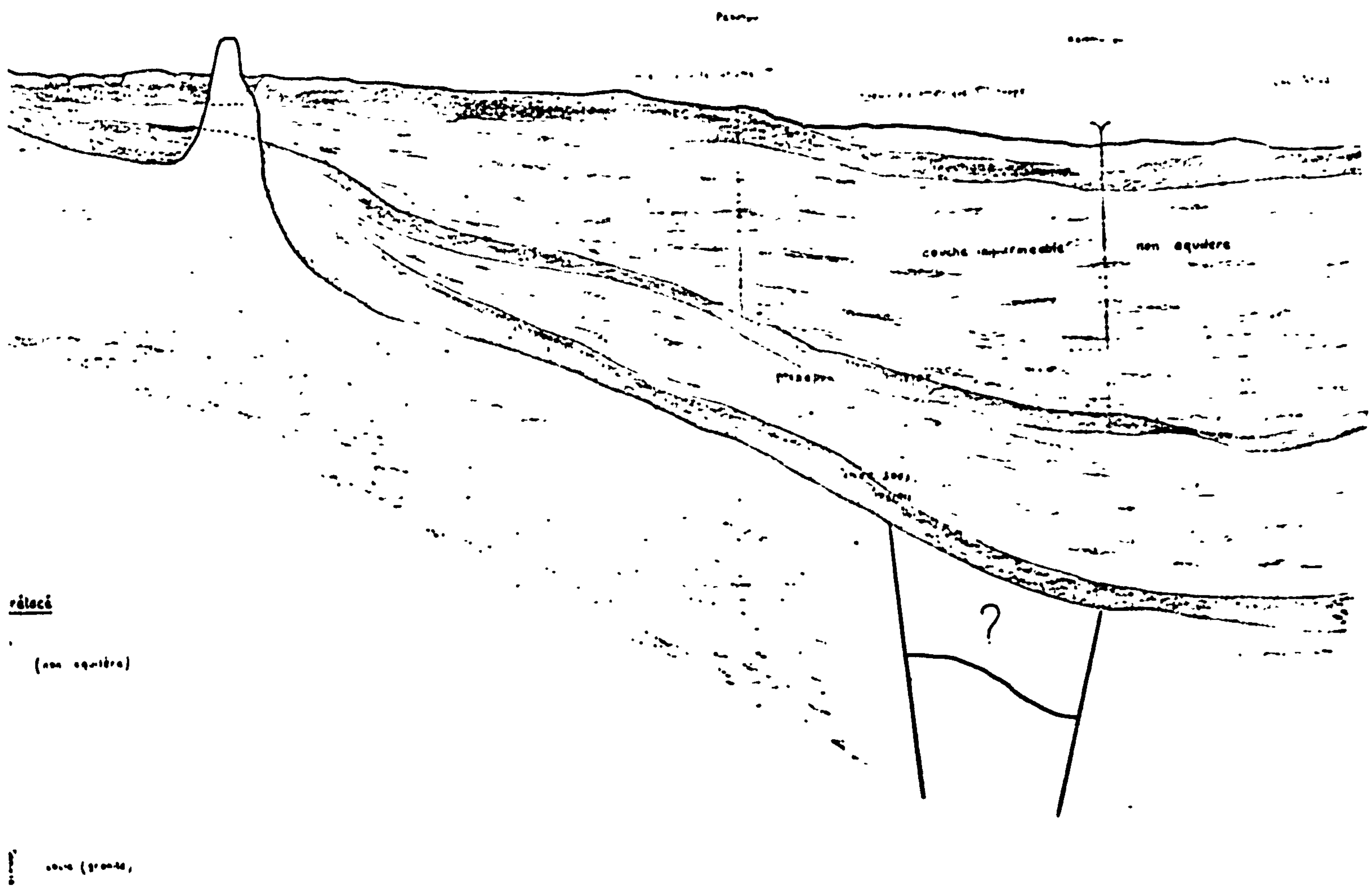
Crétacé | (non aquifère)

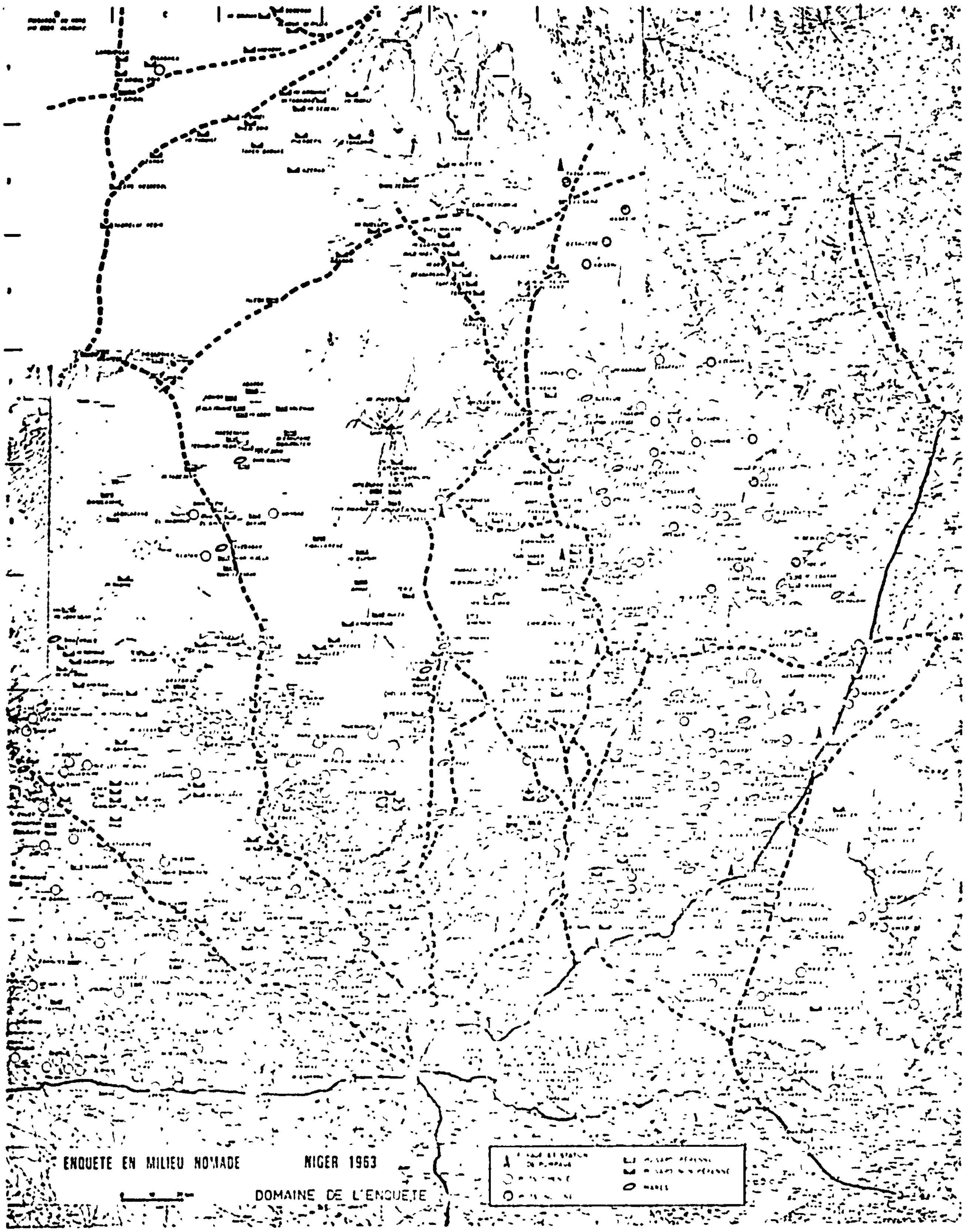
arène granitique

(grande)

horizontale 1:500 000

PLATE 9




ENQUETE EN MILIEU NOMADE
NIGER 1963
DOMAINE DE L'ENQUETE

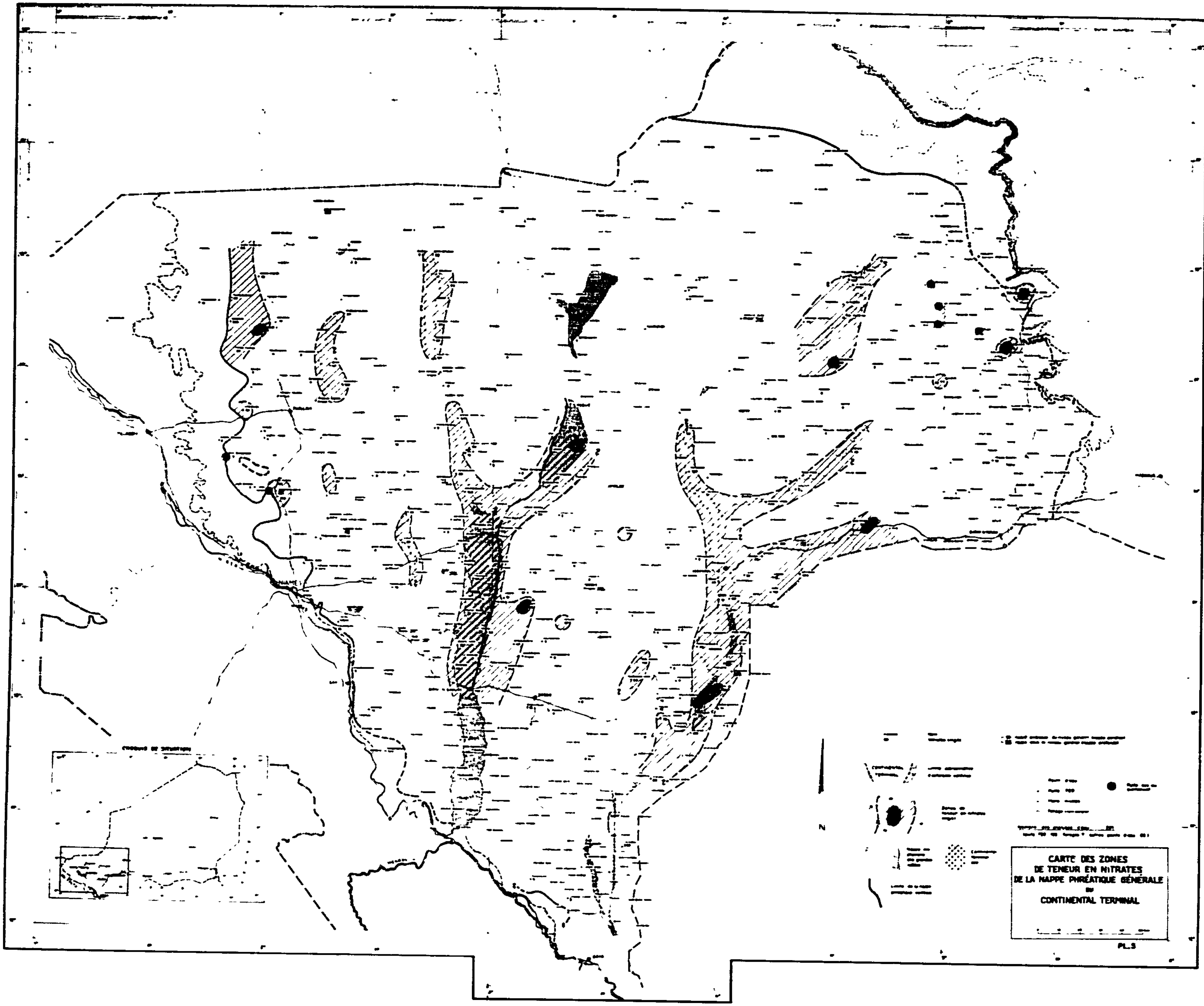

CARTE DES ZONES
DE TENEUR EN NITRATES
DE LA NAPPE PHRÉATIQUE GÉNÉRALE
du
CONTINENTAL TERMINAL
PL.5

PLATE 11

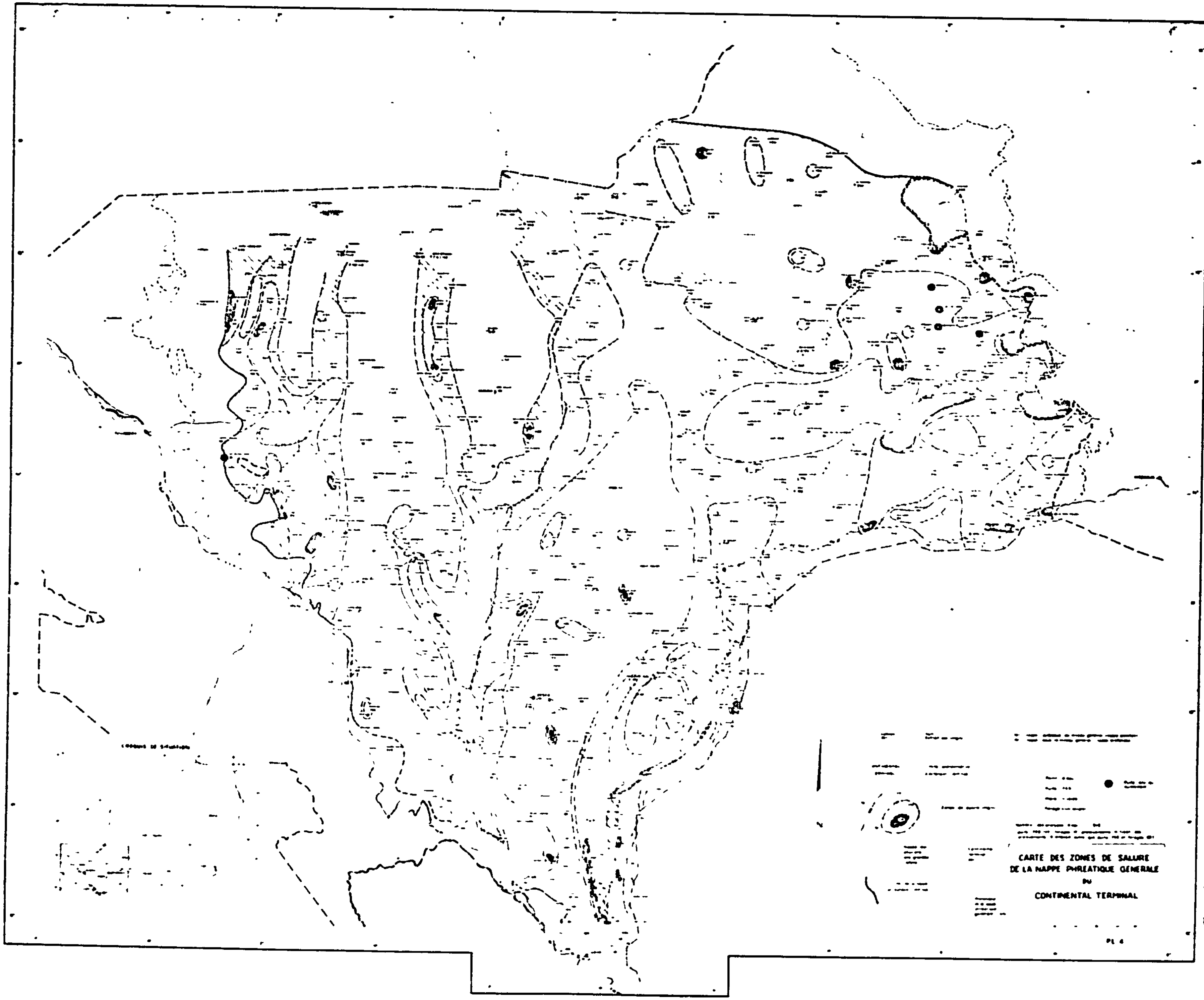

CARTE DES ZONES DE SALURE
DE LA NAPPE PHREATIQUE GENERALE
DU
CONTINENTAL TERMINAL
PL 4

PLATE 12

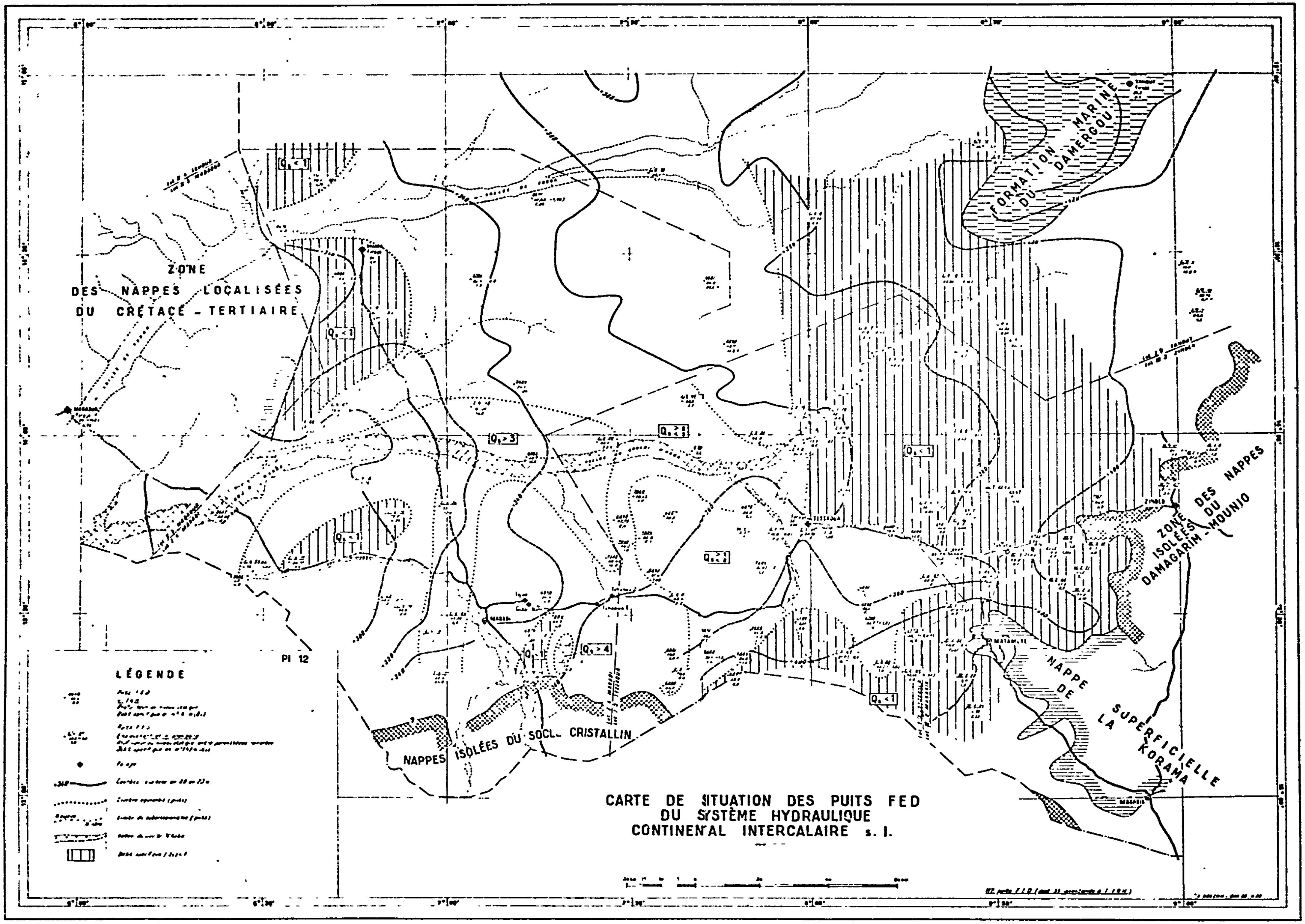
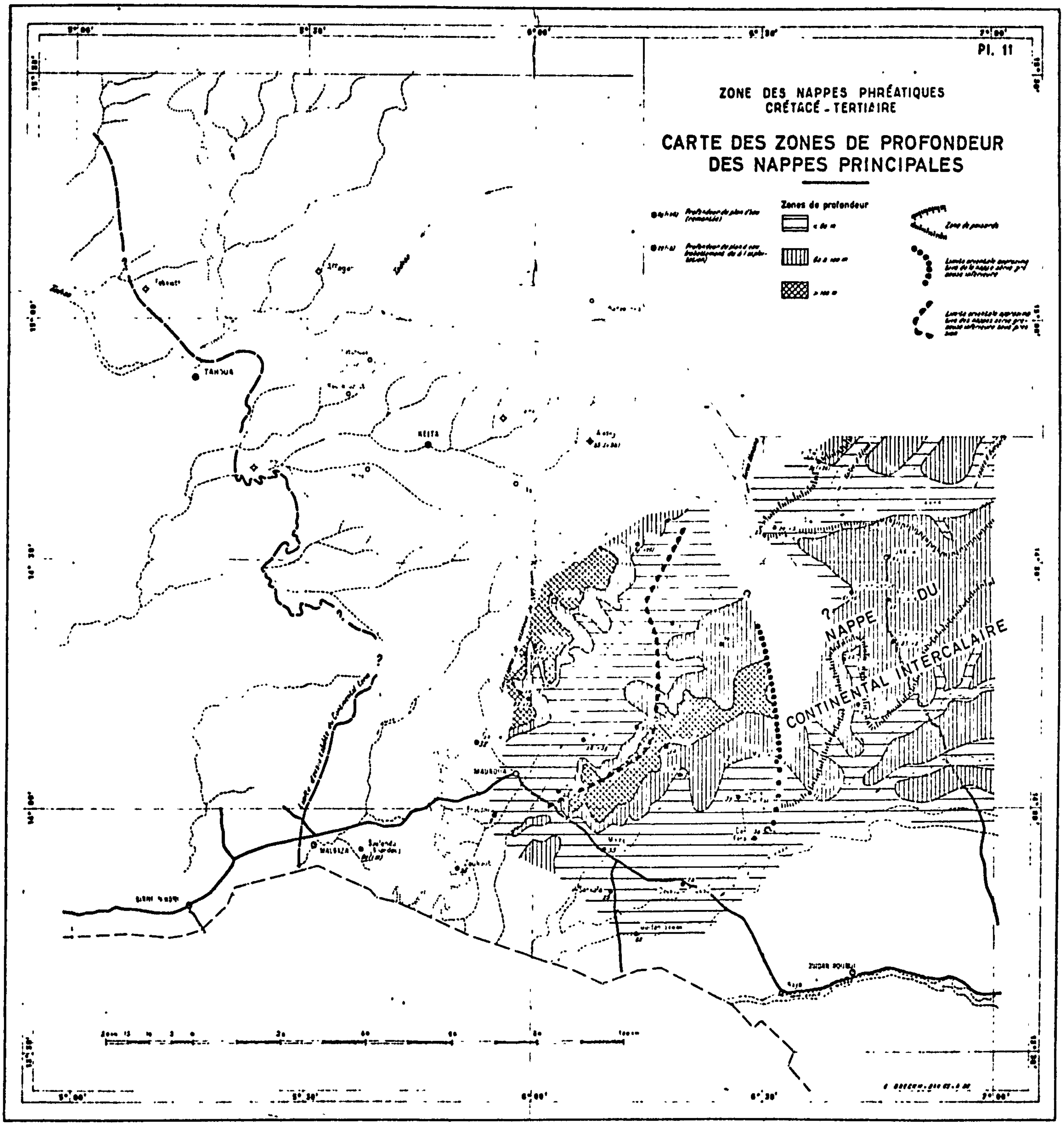

ZONE DES NAPPES LOCALISÉES DU CRÉTACÉ - TERTIAIRE
FORMATION MARINE DU DAMERGOU
ZONE DES NAPPES ISOLÉES DU DAMAGARIM - MOUNIO
NAPPE SUPERFICIELLE DE LA KORAMA
NAPPES ISOLÉES DU SOCLE CRISTALLIN
Pl 12
LÉGENDE
CARTE DE SITUATION DES PUITS FED
DU SYSTÈME HYDRAULIQUE
CONTINENTAL INTERCALAIRE s. l.

PLATE 13

PLATE 14


Pl. 11
ZONE DES NAPPES PHRÉATIQUES
CRÉTACÉ - TERTIAIRE
CARTE DES ZONES DE PROFONDEUR
DES NAPPES PRINCIPALES
Zones de profondeur
NAPPE DU CONTINENTAL INTERCALAIRE
TAHOUA
KEITA
MAURORIA
MALBAZA
BIRNI N'KONI
ZINDER

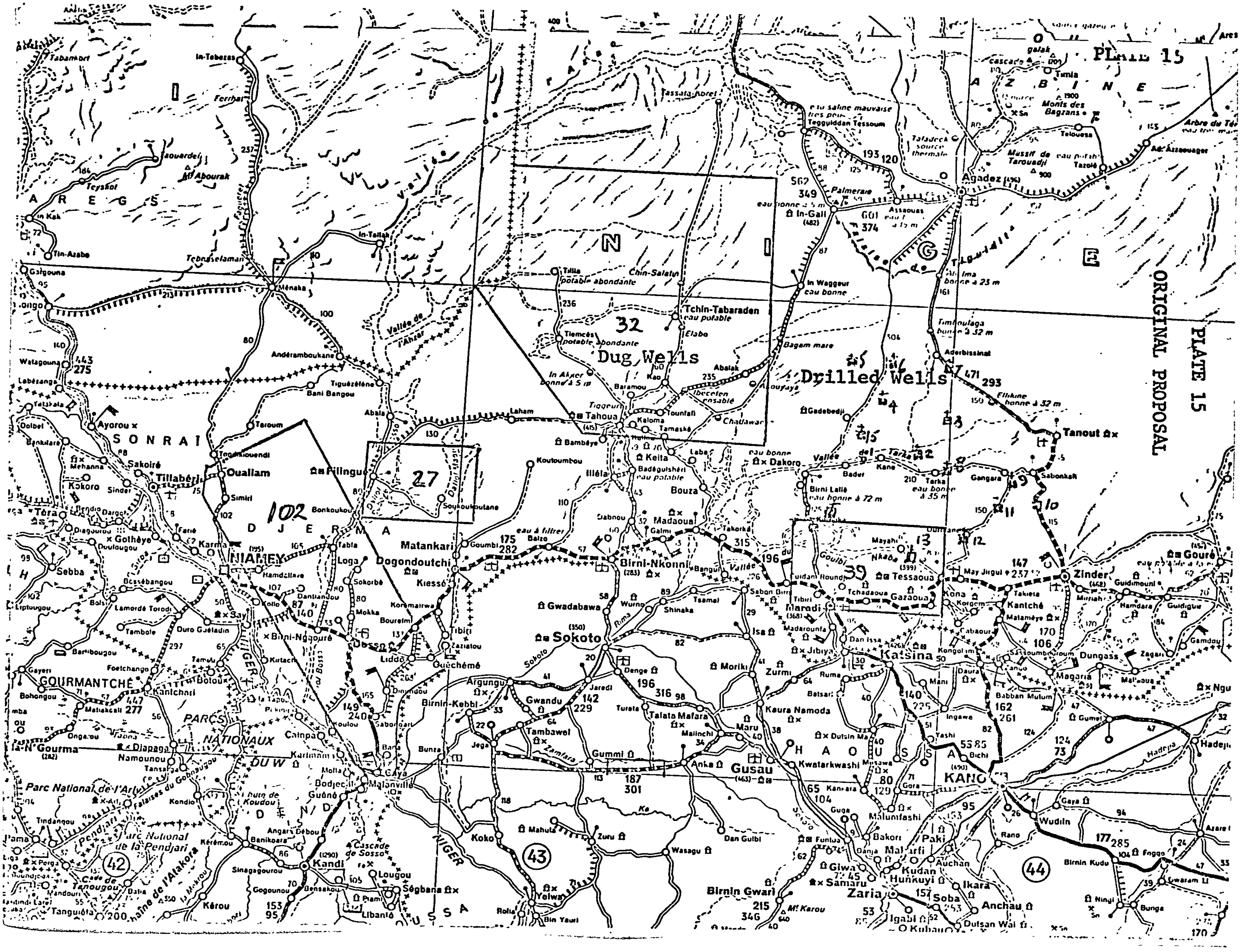


PLATE 15
ORIGINAL PROPOSAL
Dug Wells
Drilled Wells
32
27
102
39
13
NIAMEY
Tahoua
Agadez
Zinder
Tanout
Maradi
Tessaoua
Dogondoutchi
Birni-Nkonni
Madaoua
Filingue
Tillabéri
Ouallam
Dosso
Sokoto
Katsina
KANO
Zaria
Gusau
Kandi
Ménaka
Tchin-Tabaraden
In-Gall
Dakoro
Gouré
Magaria
Dungass
GOURMANTCHÉ
DJERMA
SONRAI
PARCS NATIONAUX DU W
NIGER

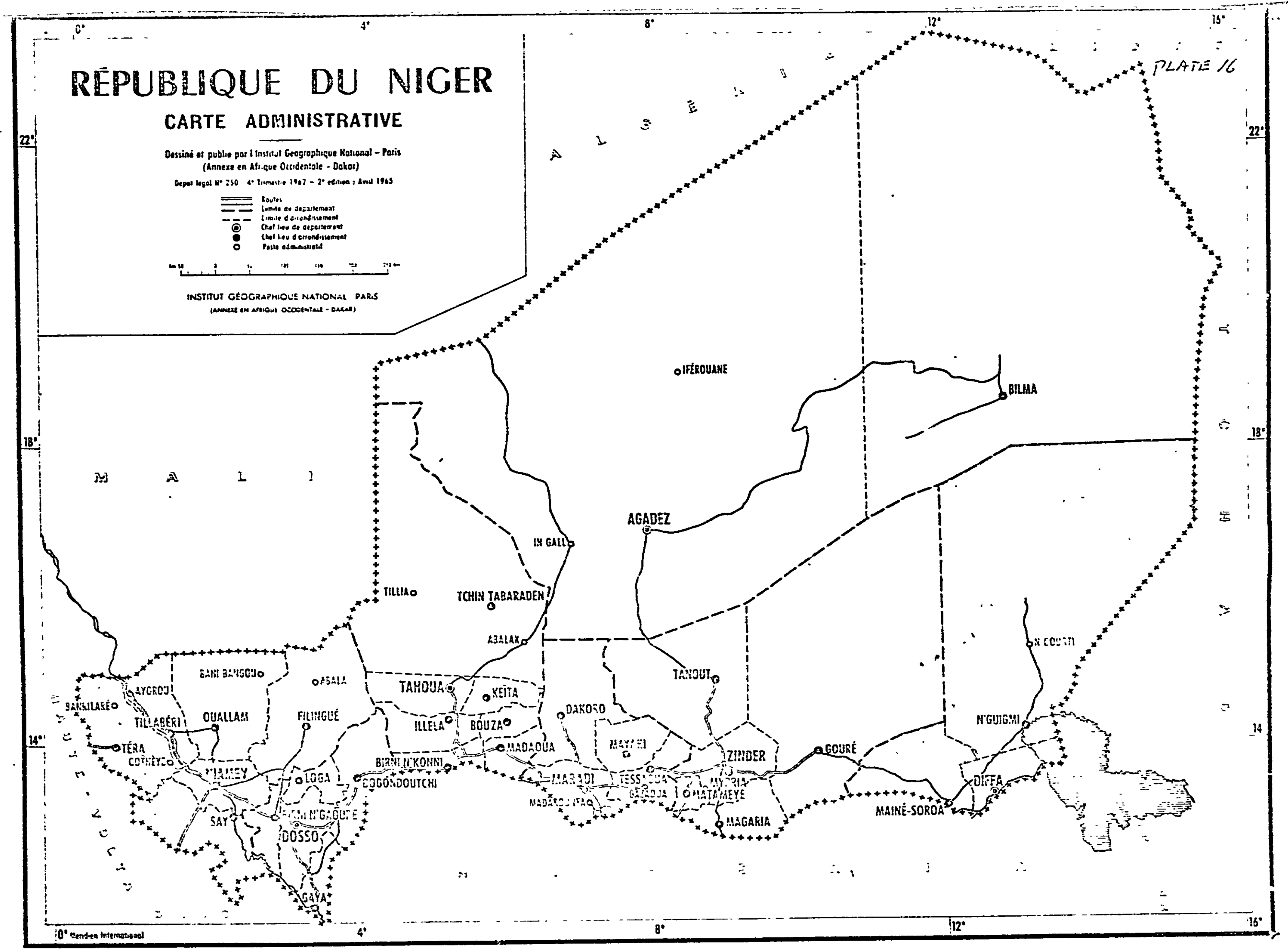


PLATE 16
RÉPUBLIQUE DU NIGER
CARTE ADMINISTRATIVE
Dessiné et publié par l'Institut Géographique National - Paris
(Annexe en Afrique Occidentale - Dakar)
Routes
Limite de département
Limite d'arrondissement
Chef lieu de département
Chef lieu d'arrondissement
Poste administratif
INSTITUT GÉOGRAPHIQUE NATIONAL PARIS
(ANNEXE EN AFRIQUE OCCIDENTALE - DAKAR)
MALI
IFÉROUANE
BILMA
AGADEZ
IN GALL
TILLIA
TCHIN TABARADEN
ABALAK
BANI BANGOU
ABALA
AYOROU
BANKILARÉ
TILLABÉRI
OUALLAM
FILINGUÉ
TÉRA
NIAMEY
LOGA
SAY
DOSSO
GAYA
TAHOUA
KEITA
ILLELA
BOUZA
MADAOUA
BIRNI N'KONNI
DOGONDOUTCHI
DAKORO
TANOUT
ZINDER
GOURÉ
MARADI
TESSAOUA
MATAMEYE
MAGARIA
N'GUIGMI
N'GOURTI
DIFFA
MAINÉ-SOROA
0° Méridien International

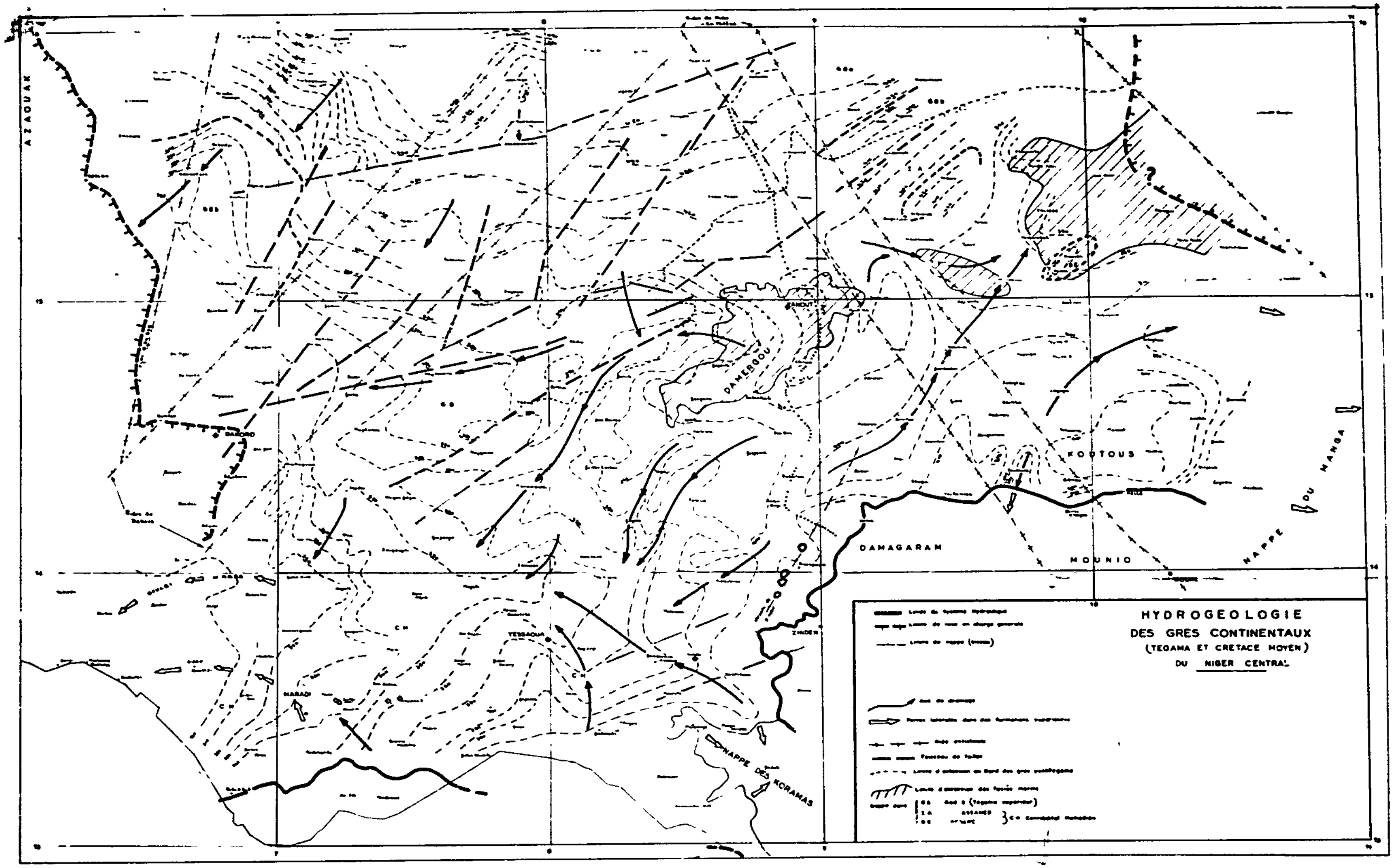
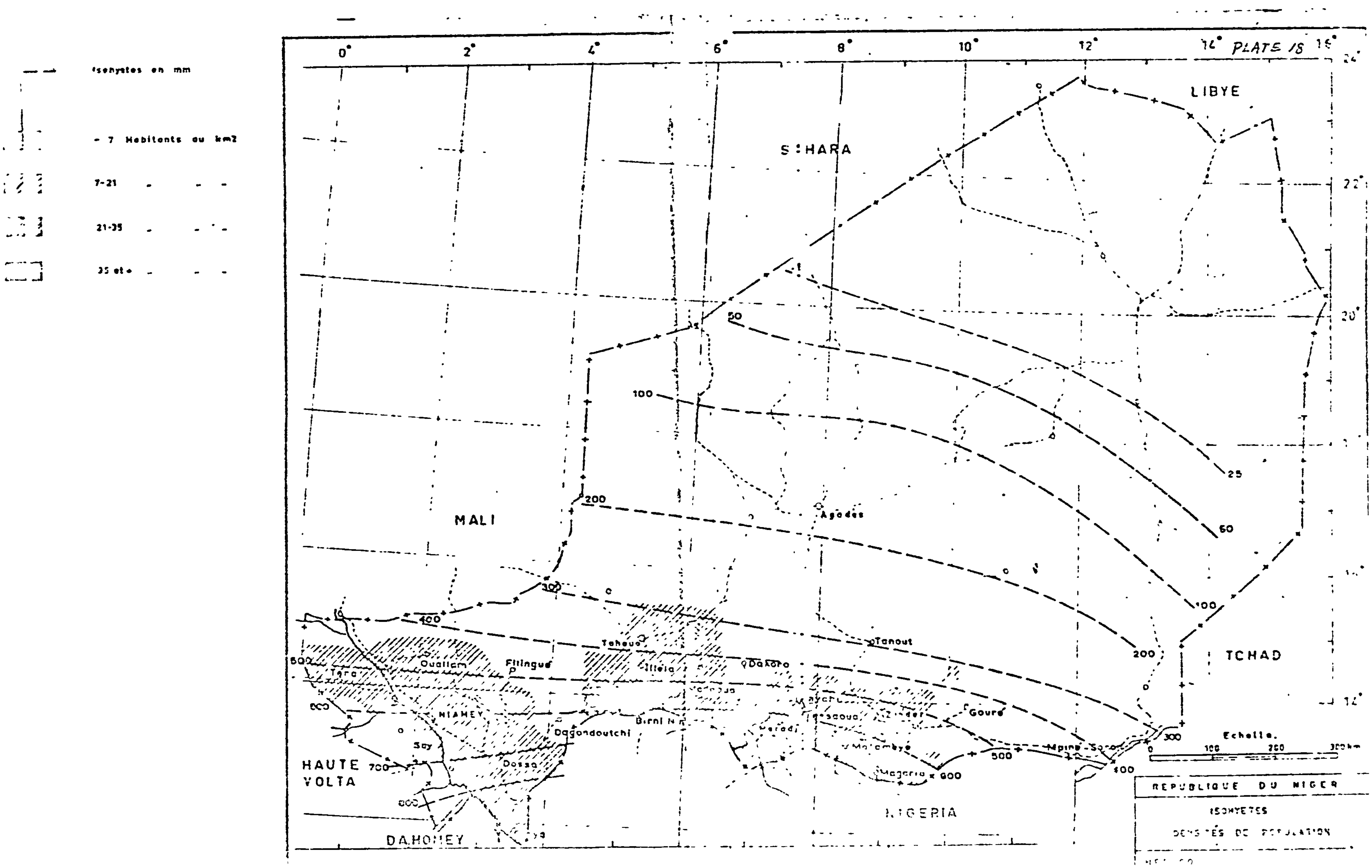

HYDROGEOLOGIE
DES GRES CONTINENTAUX
(TEGAMA ET CRETACE MOYEN)
DU NIGER CENTRAL
AZAOUAK
DAMERGOU
KOUTOUS
DAMAGARAM
MOUNIO
NAPPE DU MANGA
NAPPE DES KORAMAS
MARADI
ZINDER
TESSAOUA
DAKORO

PLATE 17



Isohyetes en mm
- 7 Habitants au km2
7-21
21-35
35 et +
PLATE 15
LIBYE
MALI
TCHAD
NIGERIA
HAUTE VOLTA
DAHOMEY
Agades
Tahoua
Illela
Dakoro
Tanout
Ouallam
Tera
Filingue
NIAMEY
Say
Dosso
Dogondoutchi
Zinder
Goure
Magaria
Echelle.
REPUBLIQUE DU NIGER
ISOHYETES

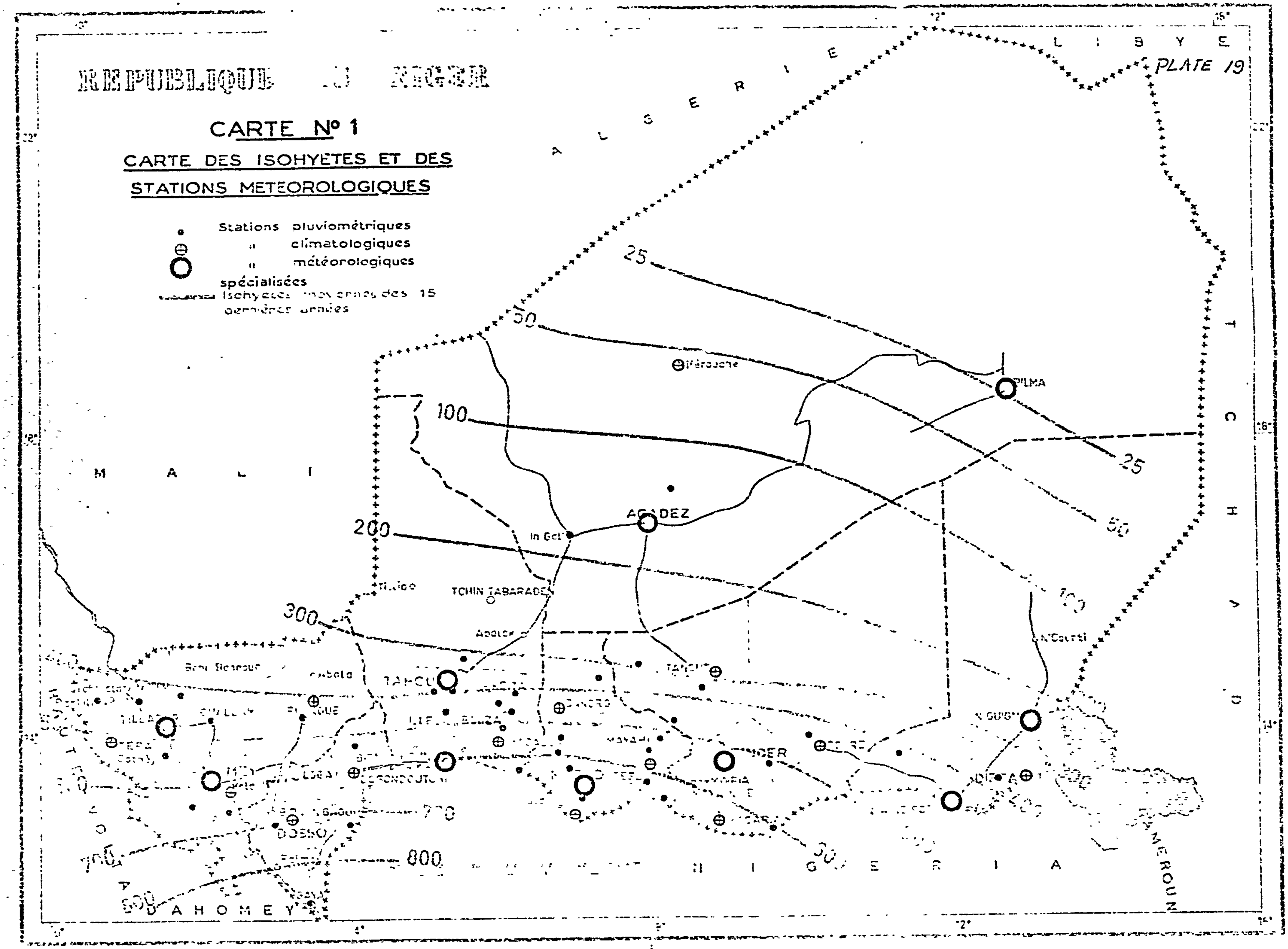


PLATE 19
REPUBLIQUE DU NIGER
CARTE N° 1
CARTE DES ISOHYETES ET DES
STATIONS METEOROLOGIQUES
Stations pluviométriques
" climatologiques
" météorologiques
spécialisées
Isohyètes moyennes des 15
dernières années
A L G E R I E
L I B Y E
M A L I
T C H A D
N I G E R I A
D A H O M E Y
CAMEROUN
AGADEZ
In Gall
TCHIN TABARADEN
TAHOUA
ZINDER
MARADI
NIAMEY
N'GUIGMI
DIFFA
BILMA
25
50
100
200
300
800

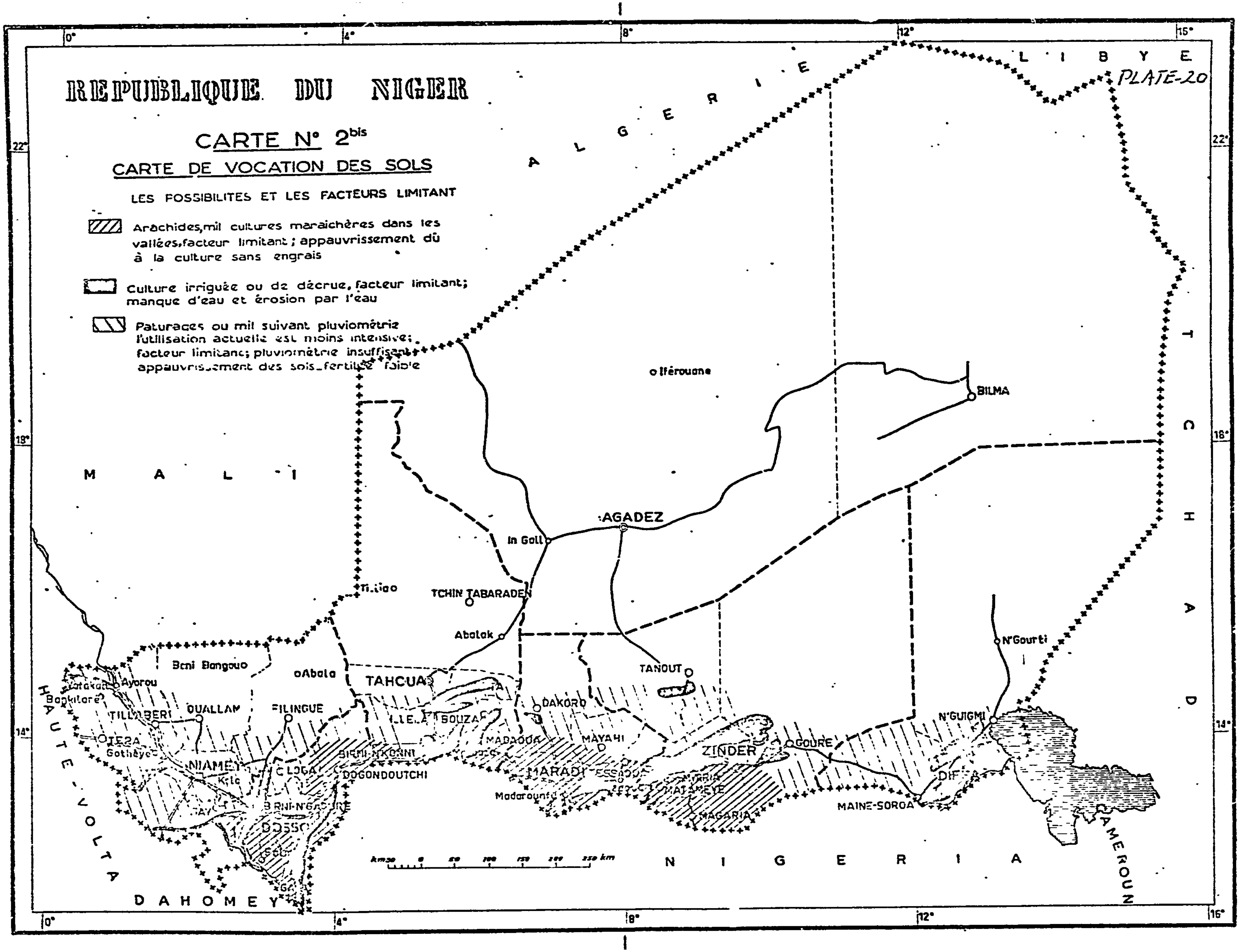


PLATE-20
REPUBLIQUE DU NIGER
CARTE N° 2bis
CARTE DE VOCATION DES SOLS
LES POSSIBILITES ET LES FACTEURS LIMITANT
Arachides, mil cultures maraichères dans les vallées, facteur limitant ; appauvrissement dû à la culture sans engrais
Culture irriguée ou de décrue, facteur limitant; manque d'eau et érosion par l'eau
Paturages ou mil suivant pluviométrie l'utilisation actuelle est moins intensive; facteur limitant; pluviométrie insuffisant appauvrissement des sols fertilité faible
ALGERIE
LIBYE
MALI
TCHAD
NIGERIA
HAUTE-VOLTA
DAHOMEY
CAMEROUN
Iférouane
BILMA
AGADEZ
In Gall
TCHIN TABARADEN
Abalak
TANOUT
N'Gourti
N'GUIGMI
Beni Bangouo
Ayorou
Abala
TAHOUA
TILLABERI
OUALLAM
FILINGUE
DAKORO
MAYAHI
ZINDER
GOURE
NIAMEY
DOGONDOUTCHI
BIRNI-N'KONNI
MARADI
MADAOUA
Madarounfa
MATAMEYE
MAGARIA
MAINE-SOROA
DOSSO
Gothèye
TERA
0°
4°
8°
12°
15°
16°
14°
19°
22°

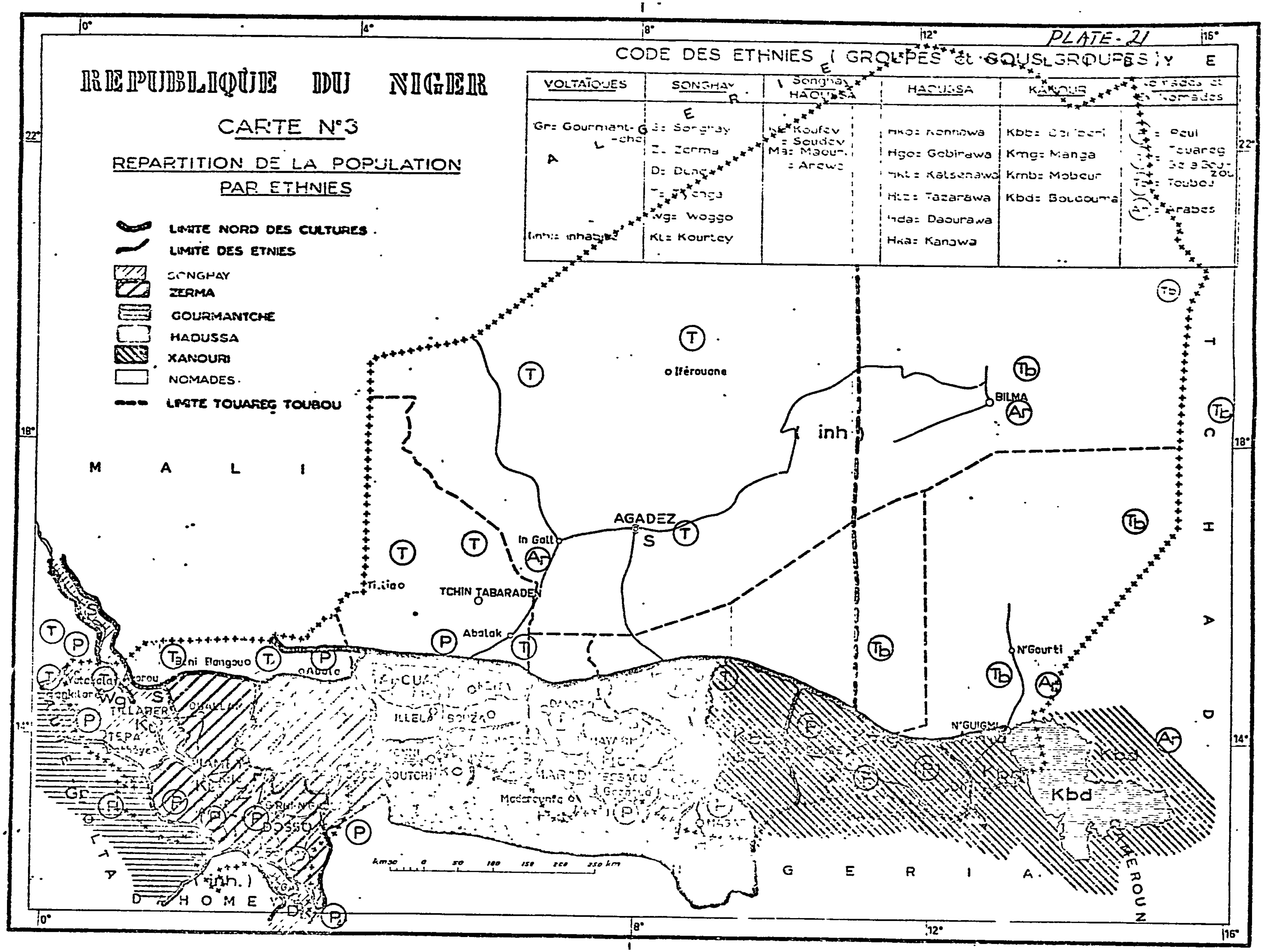
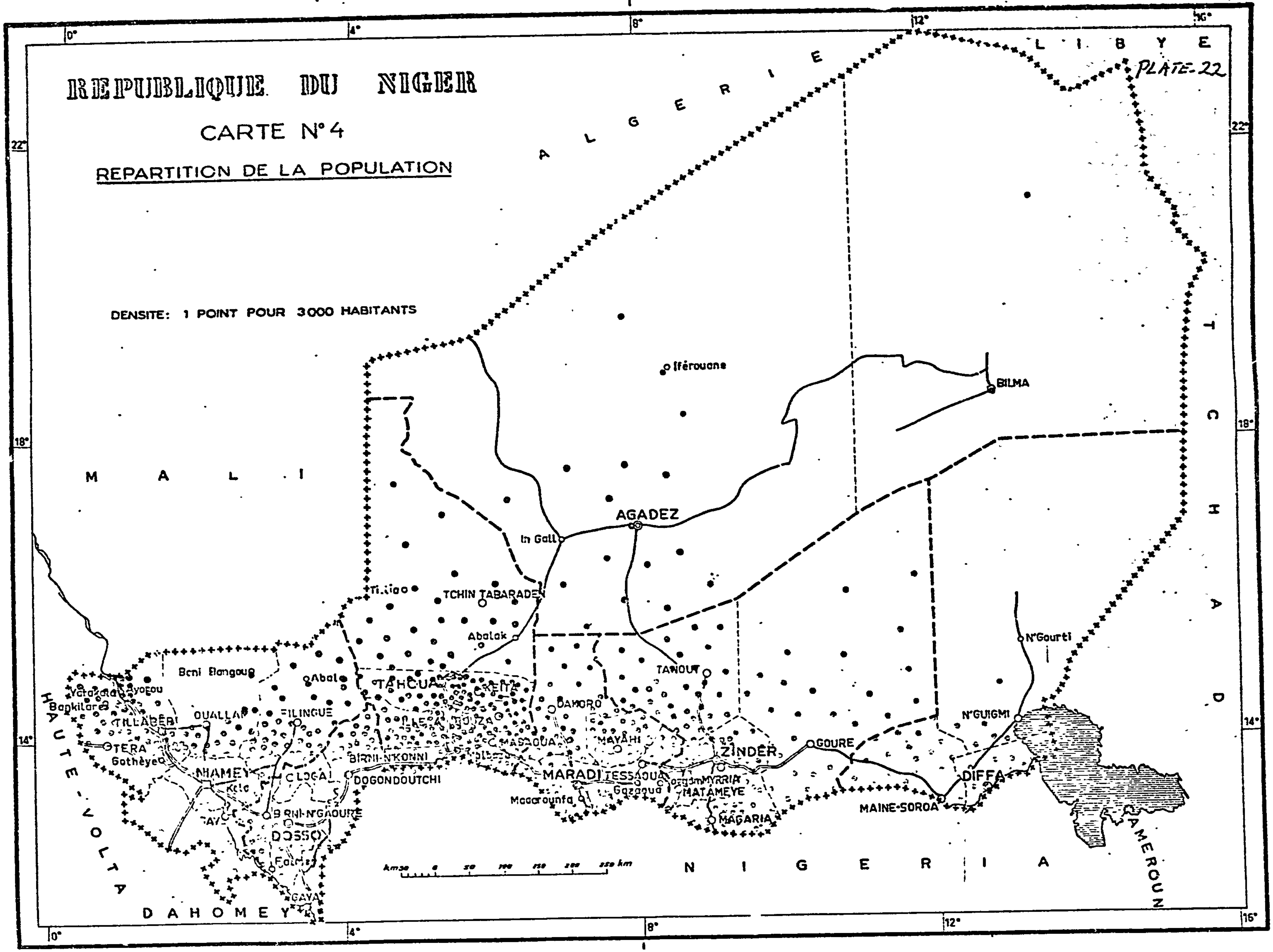


PLATE-21
REPUBLIQUE DU NIGER
CARTE N°3
REPARTITION DE LA POPULATION PAR ETHNIES
LIMITE NORD DES CULTURES
LIMITE DES ETNIES
SONGHAY
ZERMA
GOURMANTCHE
HAOUSSA
KANOURI
NOMADES
LIMITE TOUAREG TOUBOU
CODE DES ETHNIES (GROUPES et SOUS GROUPES)
VOLTAÏQUES
SONGHAY
HAOUSSA
Gr: Gourmantche
Inh: inhabité
Kt: Kourtey
Hgo: Gobirawa
Htz: Tazarawa
Hda: Daourawa
Hka: Kanawa
Kmg: Manga
Kbd: Boudouma
Peul
Touareg
Toubou
Arabes
MALI
Iférouane
BILMA
inh
AGADEZ
In Gall
Tiliago
TCHIN TABARADEN
Abalak
N'Gourti
N'GUIGMI
Kbd
DOSSO
(inh.)
km 50 0 50 100 150 200 250 km
0°
4°
8°
12°
15°
16°
22°
18°
14°


REPUBLIQUE DU NIGER
CARTE N°4
REPARTITION DE LA POPULATION
DENSITE: 1 POINT POUR 3000 HABITANTS
PLATE 22
ALGERIE
LIBYE
TCHAD
MALI
NIGERIA
DAHOMEY
HAUTE-VOLTA
CAMEROUN
AGADEZ
In Gall
Iférouane
BILMA
TCHIN TABARADEN
Abalak
TAHOUA
Tiliao
Beni Bangoug
Abal
FILINGUE
OUALLAM
TILLABERI
Bankilaré
TERA
Gothèye
NIAMEY
Kolo
SAY
BIRNI-N'GAOURE
DOSSO
GAYA
LOGA
DOGONDOUTCHI
BIRNI-N'KONNI
MADAOUA
DAKORO
MAYAHI
TANOUT
MARADI
TESSAOUA
Gazaoua
Madarounfa
MATAMEYE
MIRRIA
MAGARIA
ZINDER
GOURE
MAINE-SOROA
DIFFA
N'GUIGMI
N'Gourti
0°
4°
8°
12°
16°
14°
18°
22°

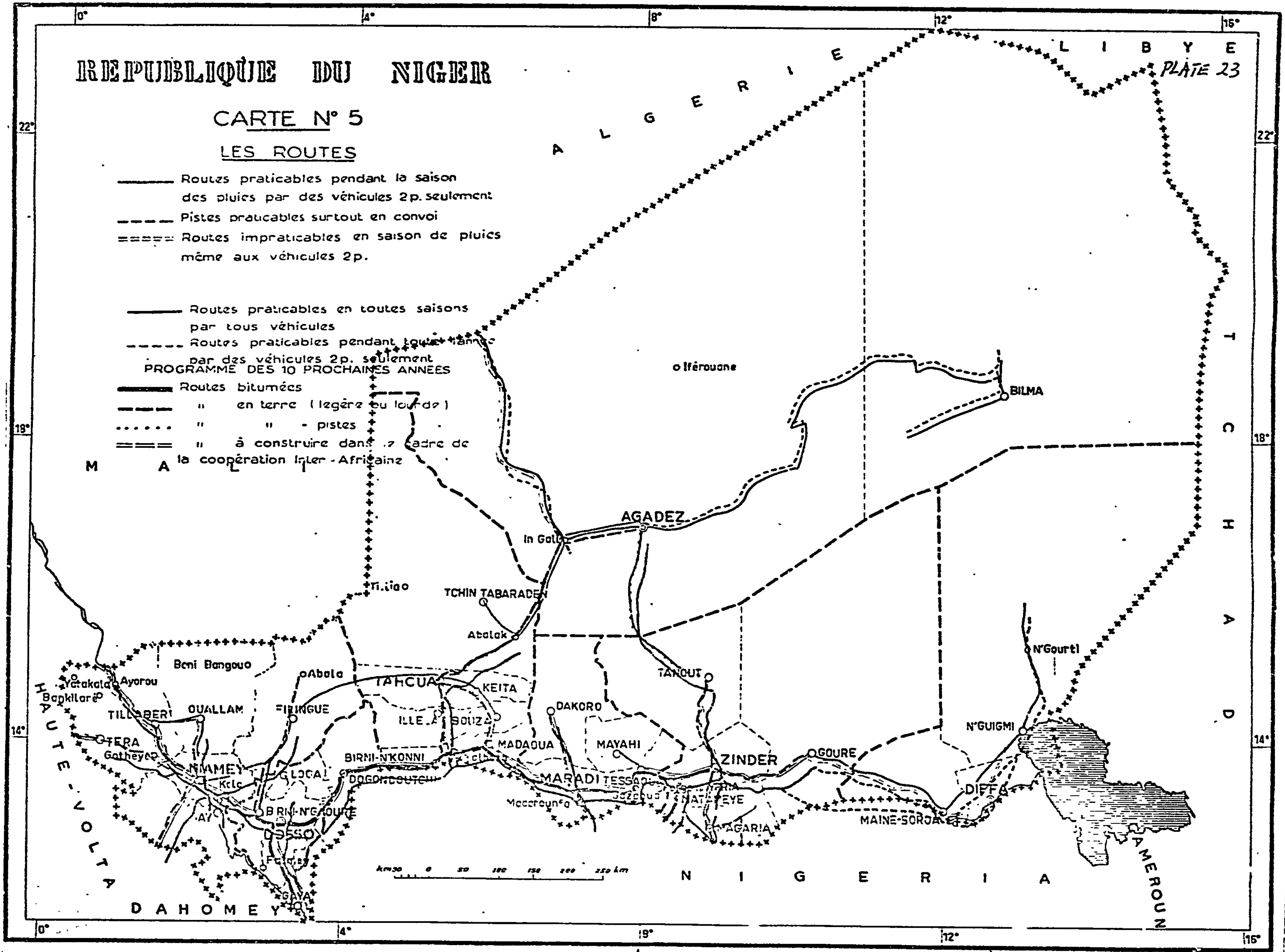


PLATE 23
REPUBLIQUE DU NIGER
CARTE N° 5
LES ROUTES
Routes praticables pendant la saison des pluies par des véhicules 2p. seulement
Pistes praticables surtout en convoi
Routes impraticables en saison de pluies même aux véhicules 2p.
Routes praticables en toutes saisons par tous véhicules
Routes praticables pendant toute l'année par des véhicules 2p. seulement
PROGRAMME DES 10 PROCHAINES ANNEES
Routes bitumées
" en terre (legère ou lourde)
" " - pistes
" à construire dans le cadre de la coopération Inter-Africaine
ALGERIE
LIBYE
TCHAD
MALI
HAUTE-VOLTA
DAHOMEY
NIGERIA
CAMEROUN
AGADEZ
In Gall
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TCHIN TABARADEN
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Beni Bangouo
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FILINGUE
ILLELA
BOUZA
DAKORO
TANOUT
N'Gourti
N'GUIGMI
TERA
Gotheye
NIAMEY
Kolo
LOGA
BIRNI-N'KONNI
DOGONDOUTCHI
MADAOUA
MAYAHI
MARADI
TESSAOUA
ZINDER
GOURE
DIFFA
MAINE-SOROA
MAGARIA
MATAMEYE
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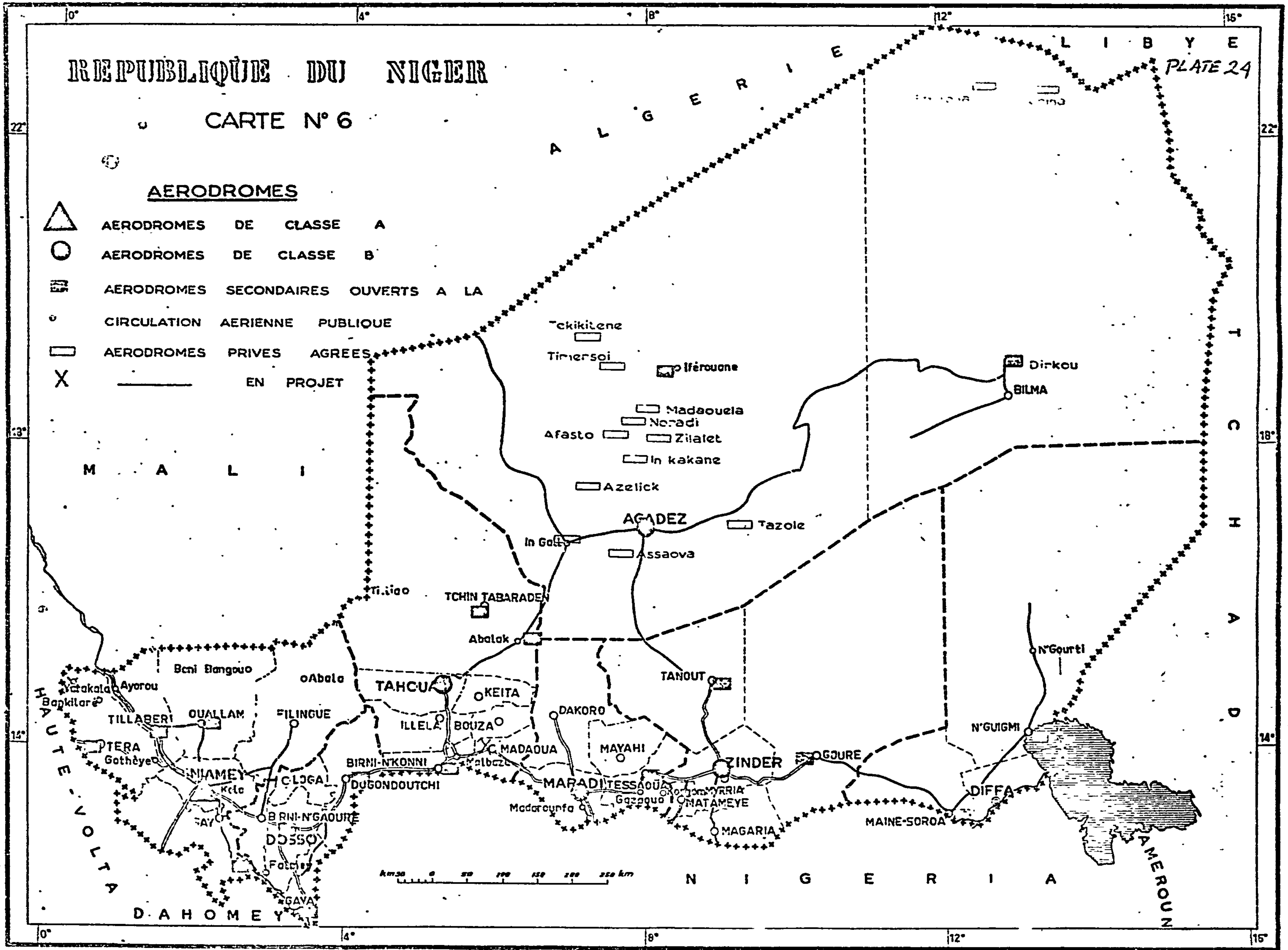
REPUBLIQUE DU NIGER
CARTE N° 6
PLATE 24
AERODROMES
AERODROMES DE CLASSE A
AERODROMES DE CLASSE B
AERODROMES SECONDAIRES OUVERTS A LA CIRCULATION AERIENNE PUBLIQUE
AERODROMES PRIVES AGREES
EN PROJET
ALGERIE
LIBYE
TCHAD
MALI
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DAHOMEY
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Zilalet
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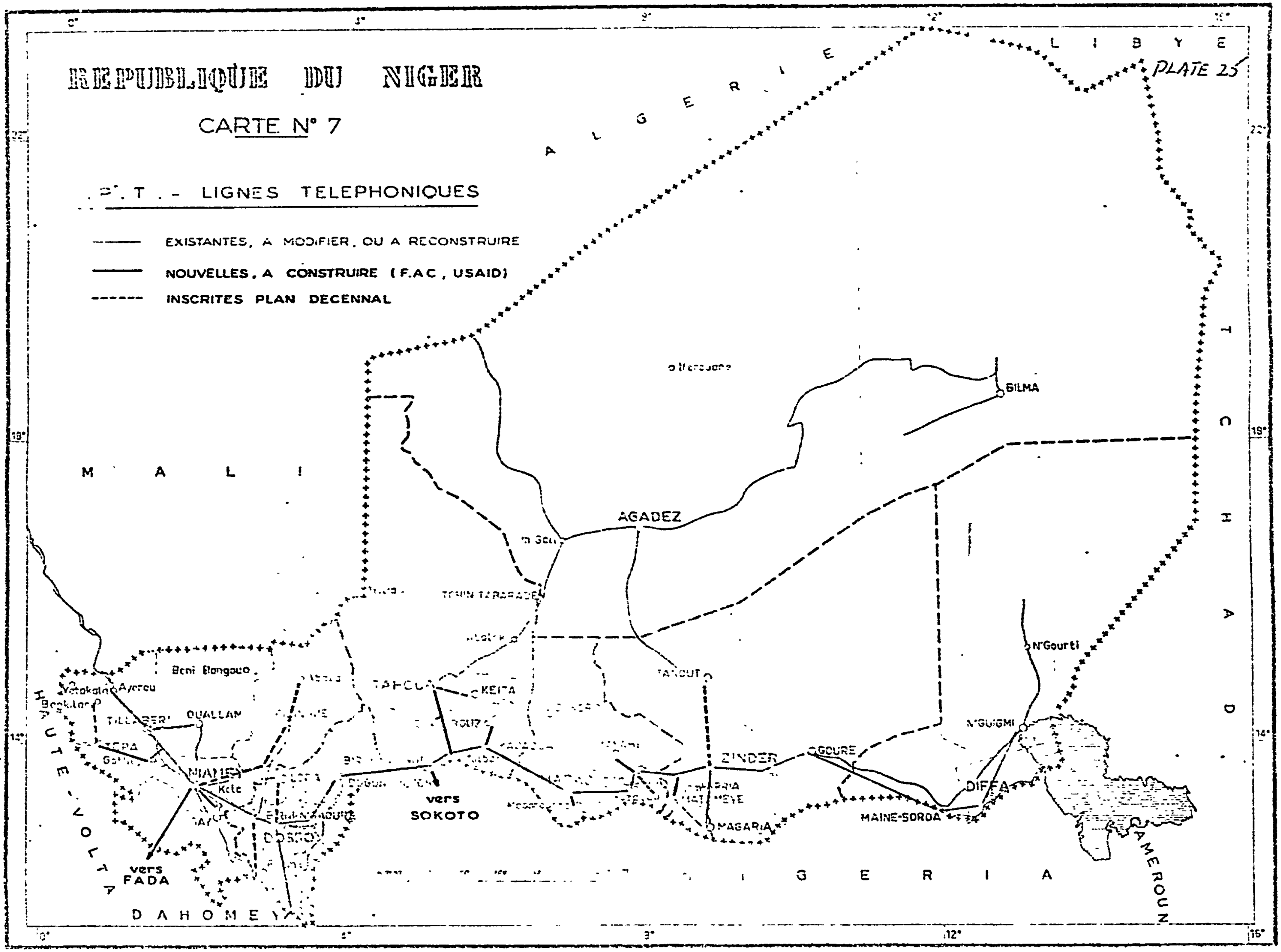

PLATE 25
REPUBLIQUE DU NIGER
CARTE N° 7
P.T. - LIGNES TELEPHONIQUES
EXISTANTES, A MODIFIER, OU A RECONSTRUIRE
NOUVELLES, A CONSTRUIRE (F.A.C, USAID)
INSCRITES PLAN DECENNAL
A L G E R I E
L I B Y E
T C H A D
M A L I
N I G E R I A
D A H O M E Y
HAUTE-VOLTA
CAMEROUN
BILMA
AGADEZ
NIAMEY
TAHOUA
KEITA
ZINDER
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DIFFA
MAINE-SOROA
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N'Gourti
MAGARIA
OUALLAM
TILLABERI
TERA
DOSSO
Ayorou
Beni Bongouo
vers SOKOTO
vers FADA

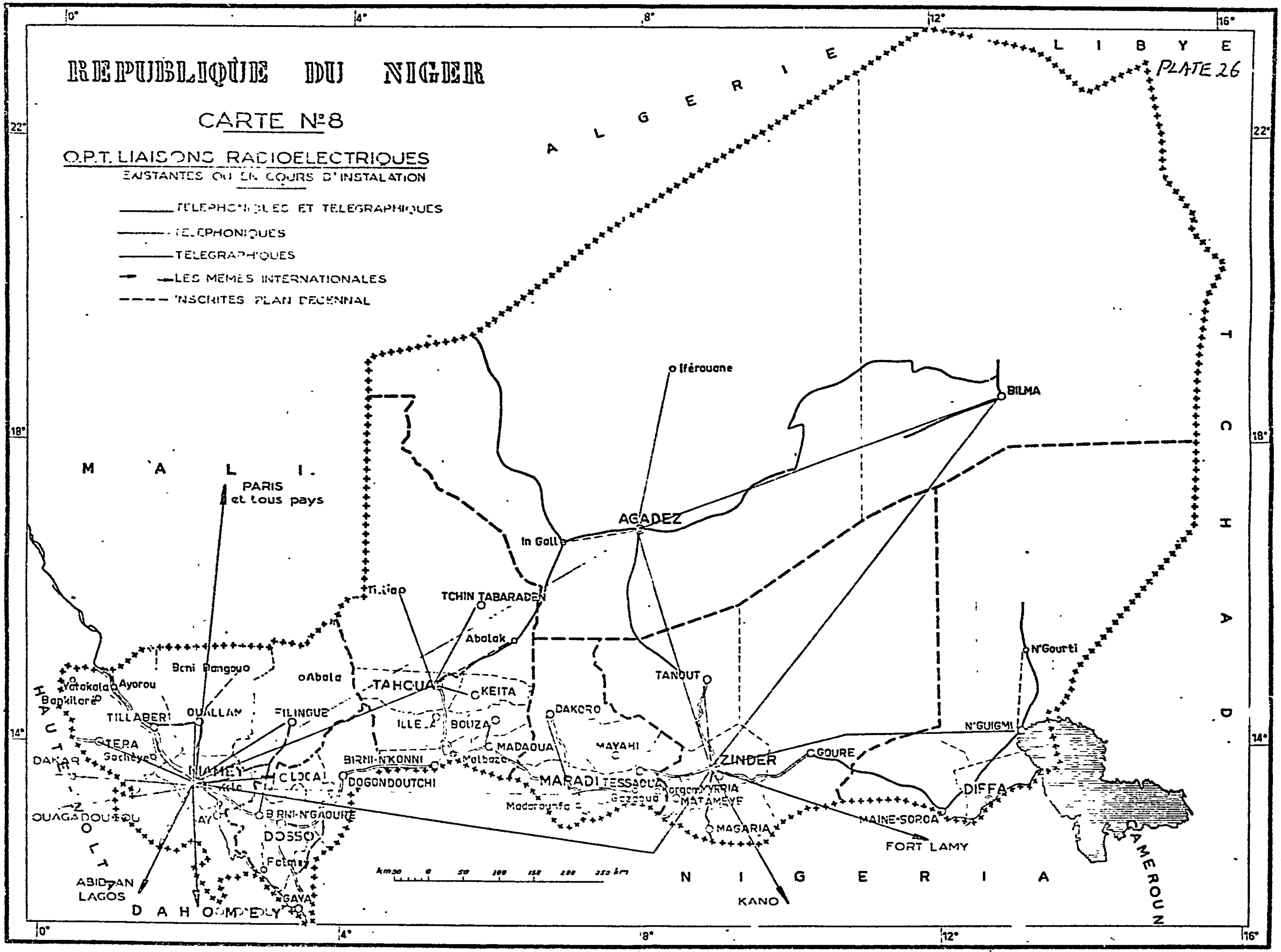
PLATE 26
REPUBLIQUE DU NIGER
CARTE N°8
O.P.T. LIAISONS RADIOELECTRIQUES
EXISTANTES OU EN COURS D'INSTALATION
TELEPHONIQUES ET TELEGRAPHIQUES
TELEPHONIQUES
TELEGRAPHIQUES
LES MEMES INTERNATIONALES
INSCRITES PLAN DECENNAL
ALGERIE
LIBYE
TCHAD
MALI
NIGERIA
HAUTE VOLTA
DAHOMEY
CAMEROUN
PARIS et tous pays
Iférouane
BILMA
AGADEZ
In Gall
TCHIN TABARADEN
Abalak
TAHOUA
KEITA
ILLELA
BOUZA
MADAOUA
DAKORO
MAYAHI
TANOUT
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GOURE
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DIFFA
MAINE-SOROA
FORT LAMY
KANO
MAGARIA
MATAMEYE
MARADI
TESSAOUA
BIRNI-N'KONNI
DOGONDOUTCHI
FILINGUE
OUALLAM
TILLABERI
Ayorou
TERA
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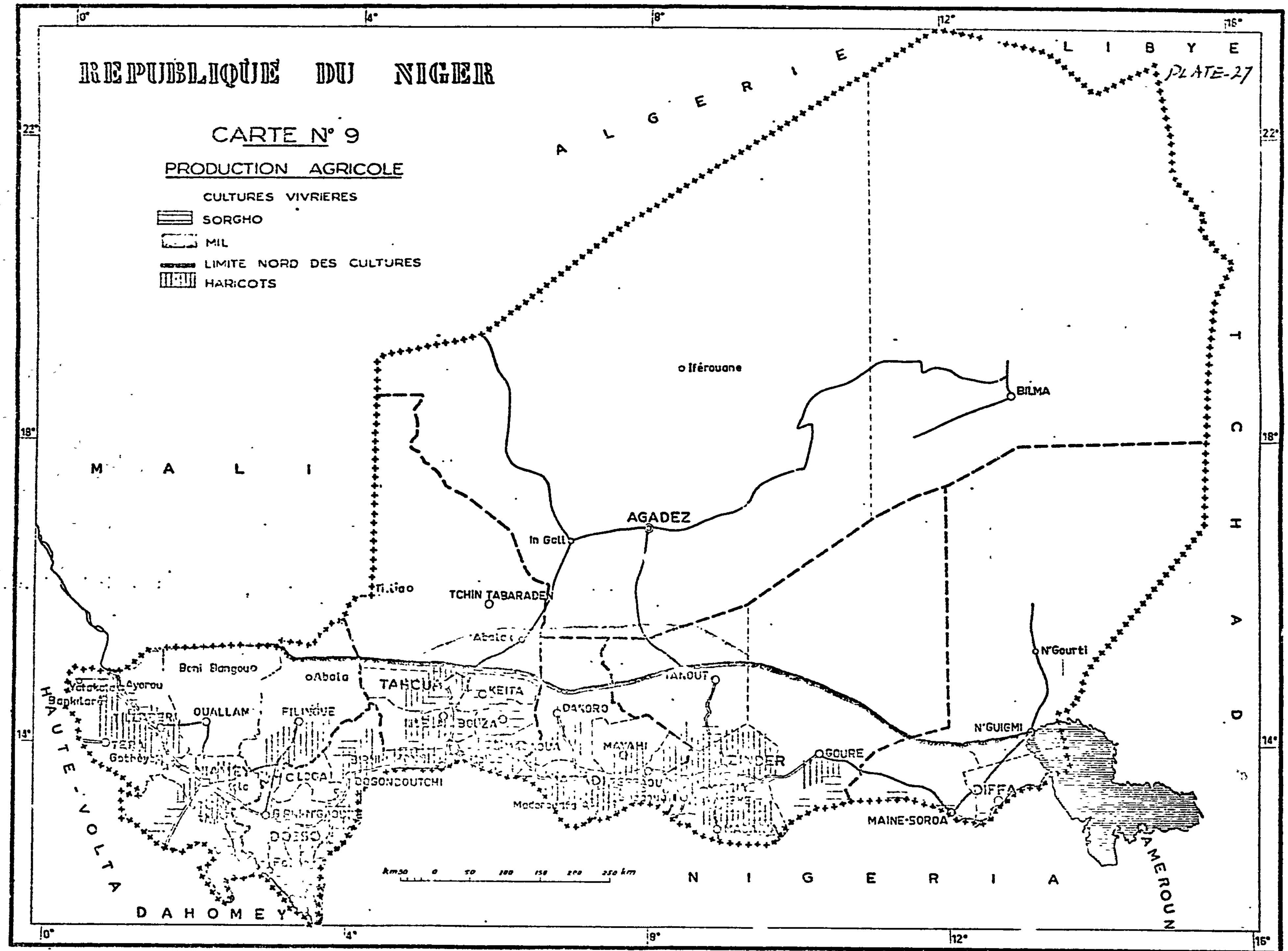

REPUBLIQUE DU NIGER
PLATE-27
CARTE N° 9
PRODUCTION AGRICOLE
CULTURES VIVRIERES
SORGHO
MIL
LIMITE NORD DES CULTURES
HARICOTS
ALGERIE
LIBYE
MALI
TCHAD
NIGERIA
CAMEROUN
HAUTE-VOLTA
DAHOMEY
Iférouane
BILMA
AGADEZ
In Gall
TCHIN TABARADEN
Tillia
N'Gourti
N'GUIGMI
GOURE
MAINE-SOROA
DIFFA
TANOUT
DAKORO
MAYAHI
KEITA
BOUZA
TAHOUA
FILINGUE
OUALLAM
Ayorou
Beni Bangou
DOGONDOUTCHI
DOSSO
Madaroumfa

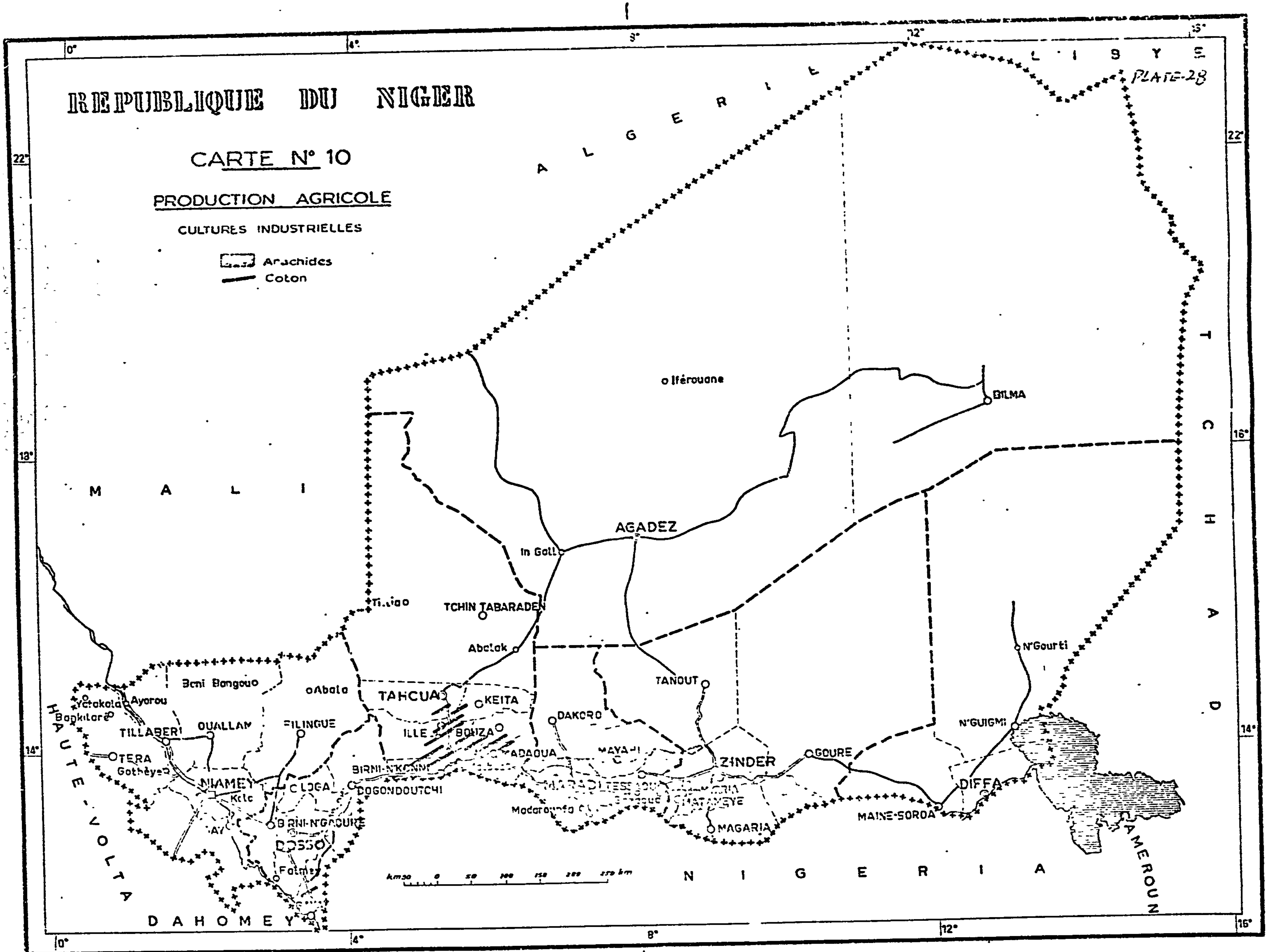
PLATE-28
REPUBLIQUE DU NIGER
CARTE N° 10
PRODUCTION AGRICOLE
CULTURES INDUSTRIELLES
Arachides
Coton
ALGERIE
LIBYE
MALI
TCHAD
NIGERIA
HAUTE-VOLTA
DAHOMEY
CAMEROUN
Iférouane
BILMA
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DAKORO
MAYAHI
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GOURE
N'Gourti
N'GUIGMI
DIFFA
MAINE-SOROA
MAGARIA
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Madarounfa
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DOGONDOUTCHI
FILINGUE
OUALLAM
TILLABERI
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Banibangou
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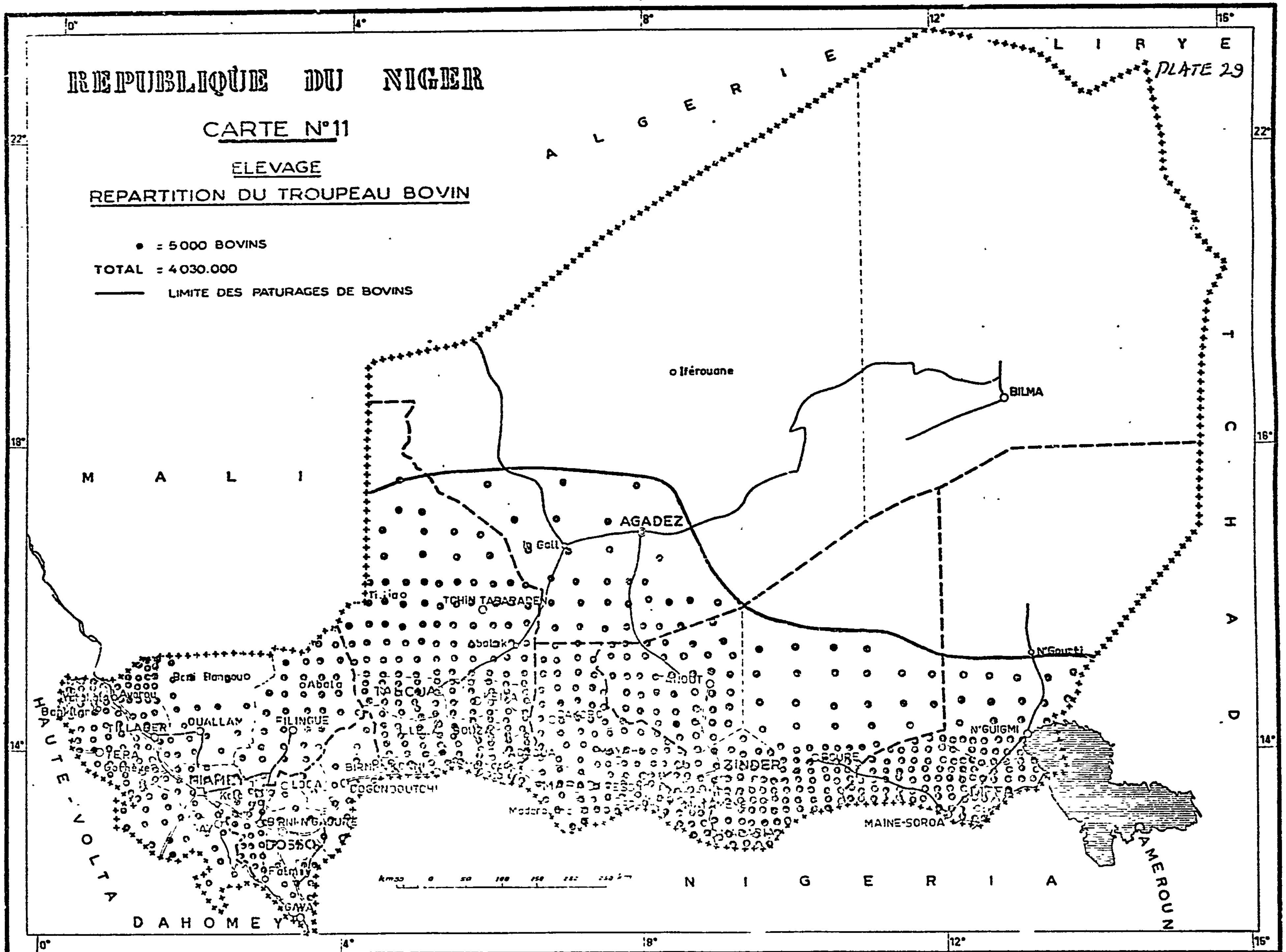

PLATE 29
REPUBLIQUE DU NIGER
CARTE N°11
ELEVAGE
REPARTITION DU TROUPEAU BOVIN
• = 5000 BOVINS
TOTAL = 4030.000
LIMITE DES PATURAGES DE BOVINS
ALGERIE
LIBYE
TCHAD
MALI
NIGERIA
HAUTE-VOLTA
DAHOMEY
CAMEROUN
Iférouane
BILMA
AGADEZ
In Gall
TCHIN TABARADEN
Tillia
Abalak
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N'Gourti
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GOURE
MAINE-SOROA
DIFFA
FILINGUE
OUALLAM
TILLABERI
Ayorou
Banibangou
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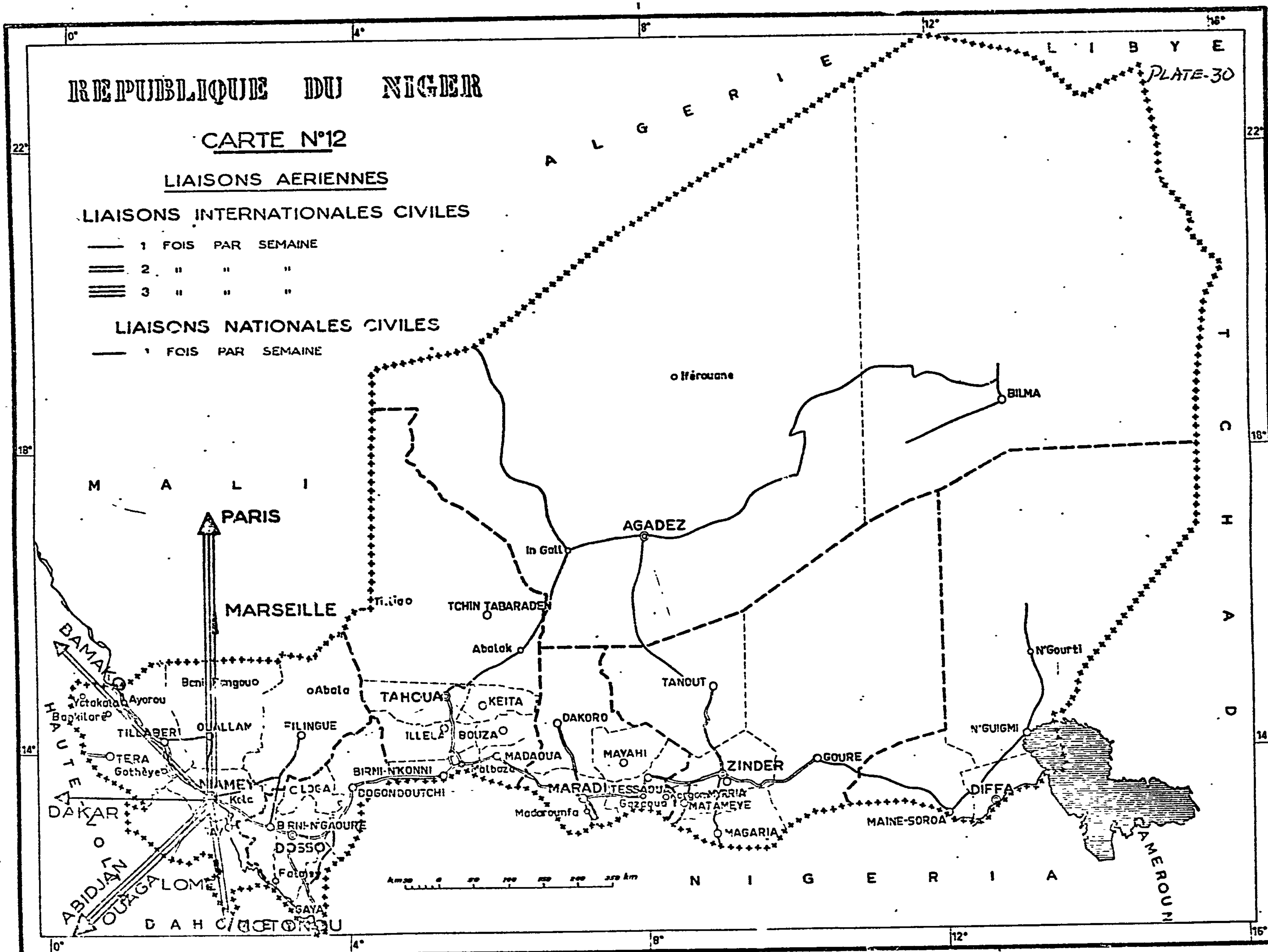
PLATE-30
REPUBLIQUE DU NIGER
CARTE N°12
LIAISONS AERIENNES
LIAISONS INTERNATIONALES CIVILES
1 FOIS PAR SEMAINE
2 " " "
3 " " "
LIAISONS NATIONALES CIVILES
1 FOIS PAR SEMAINE
ALGERIE
LIBYE
TCHAD
MALI
NIGERIA
HAUTE VOLTA
PARIS
MARSEILLE
BAMAKO
DAKAR
ABIDJAN
OUAGA
LOME
COTONOU
AGADEZ
In Gall
BILMA
TCHIN TABARADEN
Abalak
TAHOUA
KEITA
DAKORO
TANOUT
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N'GUIGMI
N'Gourti
DIFFA
MAINE-SOROA
MARADI
TESSAOUA
MAYAHI
MAGARIA
MATAMEYE
MADAOUA
BOUZA
ILLELA
BIRNI-N'KONNI
DOGONDOUTCHI
FILINGUE
OUALLAM
TILLABERI
Ayorou
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Madarounfa
Gazaoua
ASSAMAKA
oAbala
Tiltigo
o Iférouane

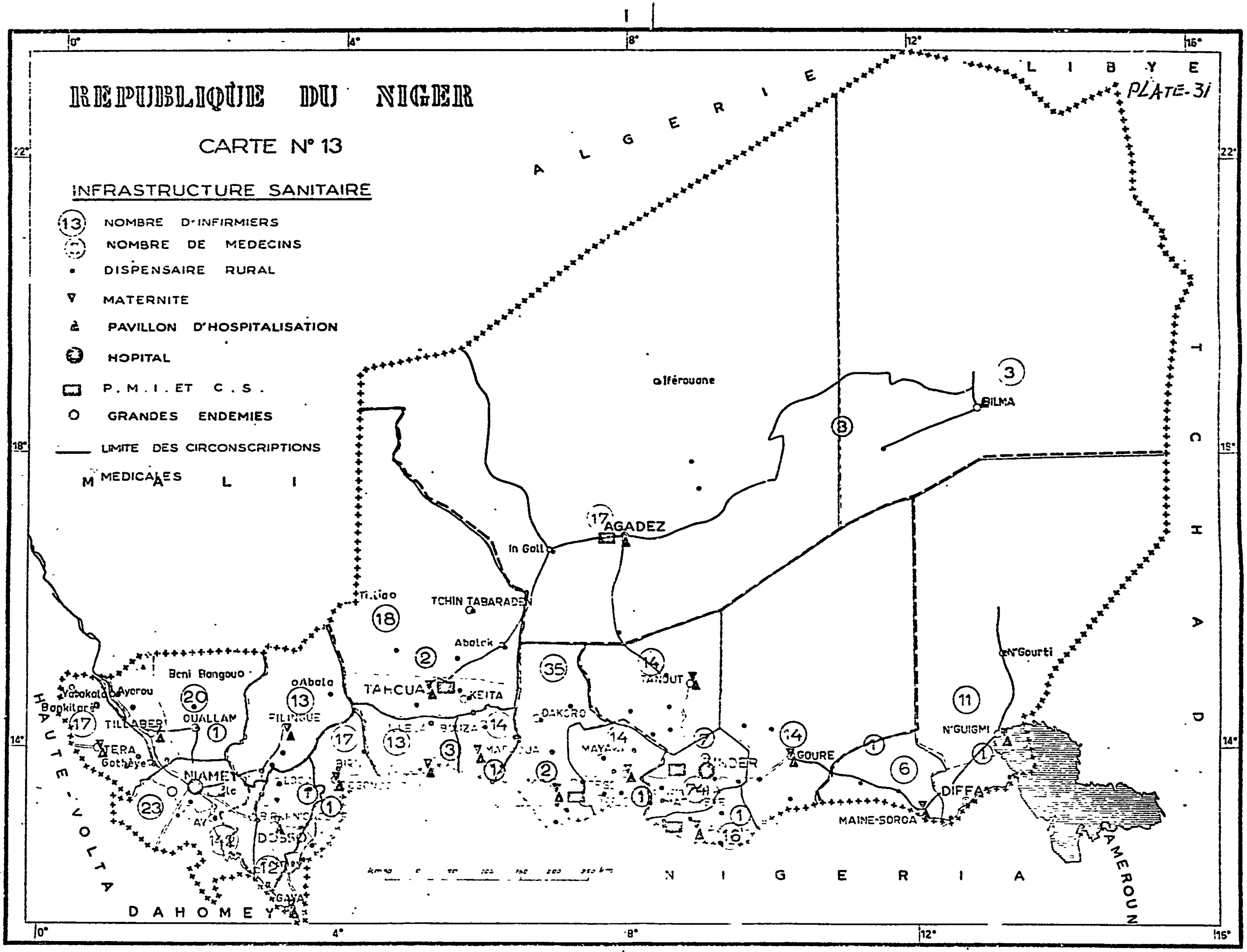
PLATE-31
REPUBLIQUE DU NIGER
CARTE N° 13
INFRASTRUCTURE SANITAIRE
NOMBRE D'INFIRMIERS
NOMBRE DE MEDECINS
DISPENSAIRE RURAL
MATERNITE
PAVILLON D'HOSPITALISATION
HOPITAL
P. M. I. ET C. S.
GRANDES ENDEMIES
LIMITE DES CIRCONSCRIPTIONS MEDICALES
ALGERIE
LIBYE
TCHAD
MALI
HAUTE-VOLTA
DAHOMEY
NIGERIA
CAMEROUN
AGADEZ
In Gall
TCHIN TABARADEN
BILMA
NIAMEY
TAHOUA
DOSSO
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DIFFA
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N'GUIGMI
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TILLABERY
OUALLAM
FILINGUE
TERA
Ayorou
Beni Bangoua
Abalak
KEITA
DAKORO
TANOUT
GAYA

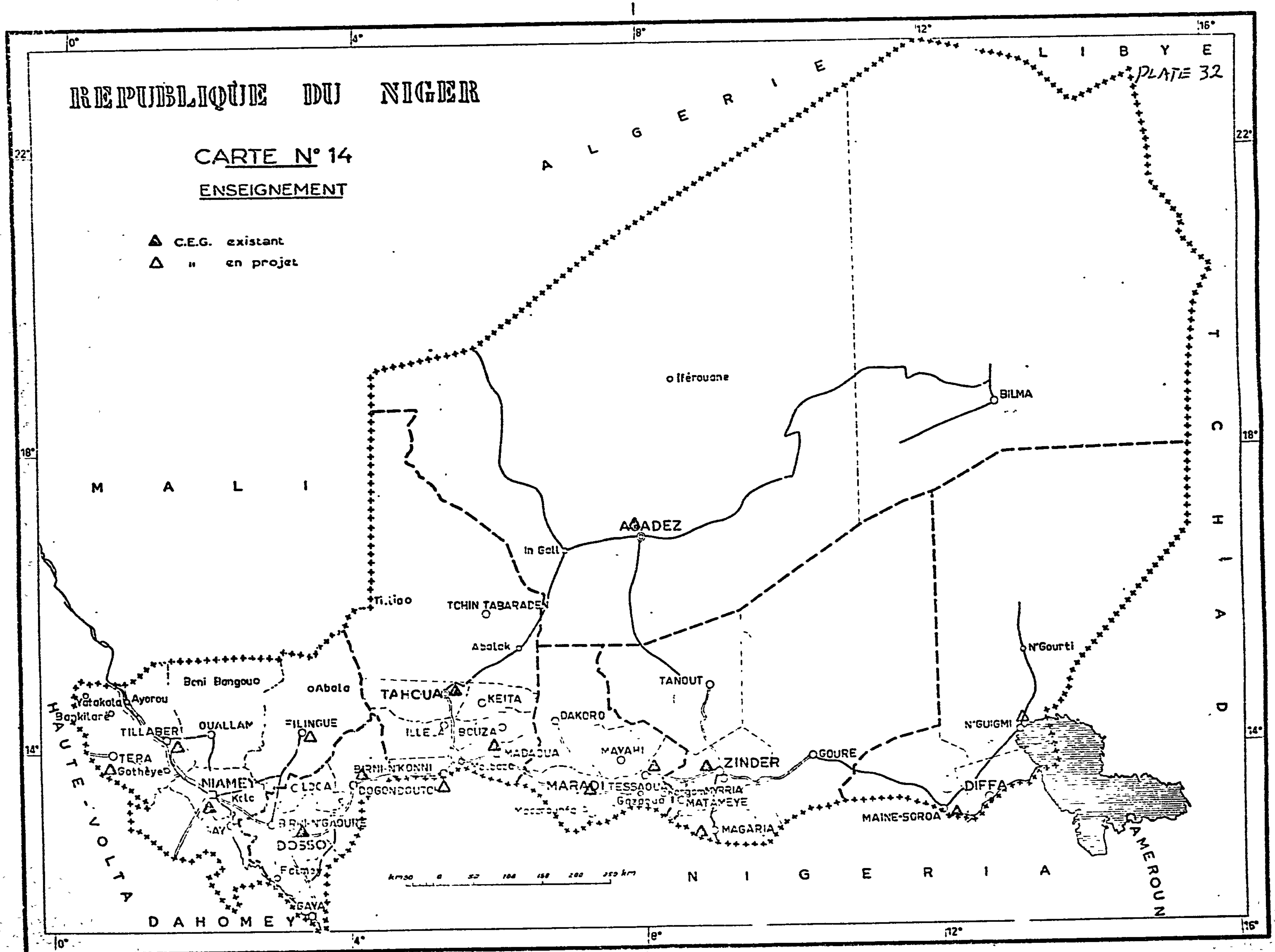
PLATE 32
REPUBLIQUE DU NIGER
CARTE N° 14
ENSEIGNEMENT
C.E.G. existant
" en projet
ALGERIE
LIBYE
MALI
TCHAD
HAUTE-VOLTA
DAHOMEY
NIGERIA
CAMEROUN
Iférouane
BILMA
AGADEZ
In Gall
TCHIN TABARADE
Abalak
TAHOUA
KEITA
TANOUT
N'Gourti
N'GUIGMI
Beni Bangou
Abala
Ayorou
Yatakala
TILLABERI
OUALLAM
FILINGUE
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Gothèye
NIAMEY
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GAYA
BIRNI-N'KONNI
DOGONDOUTCHI
BOUZA
MADAOUA
DAKORO
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MAINE-SOROA
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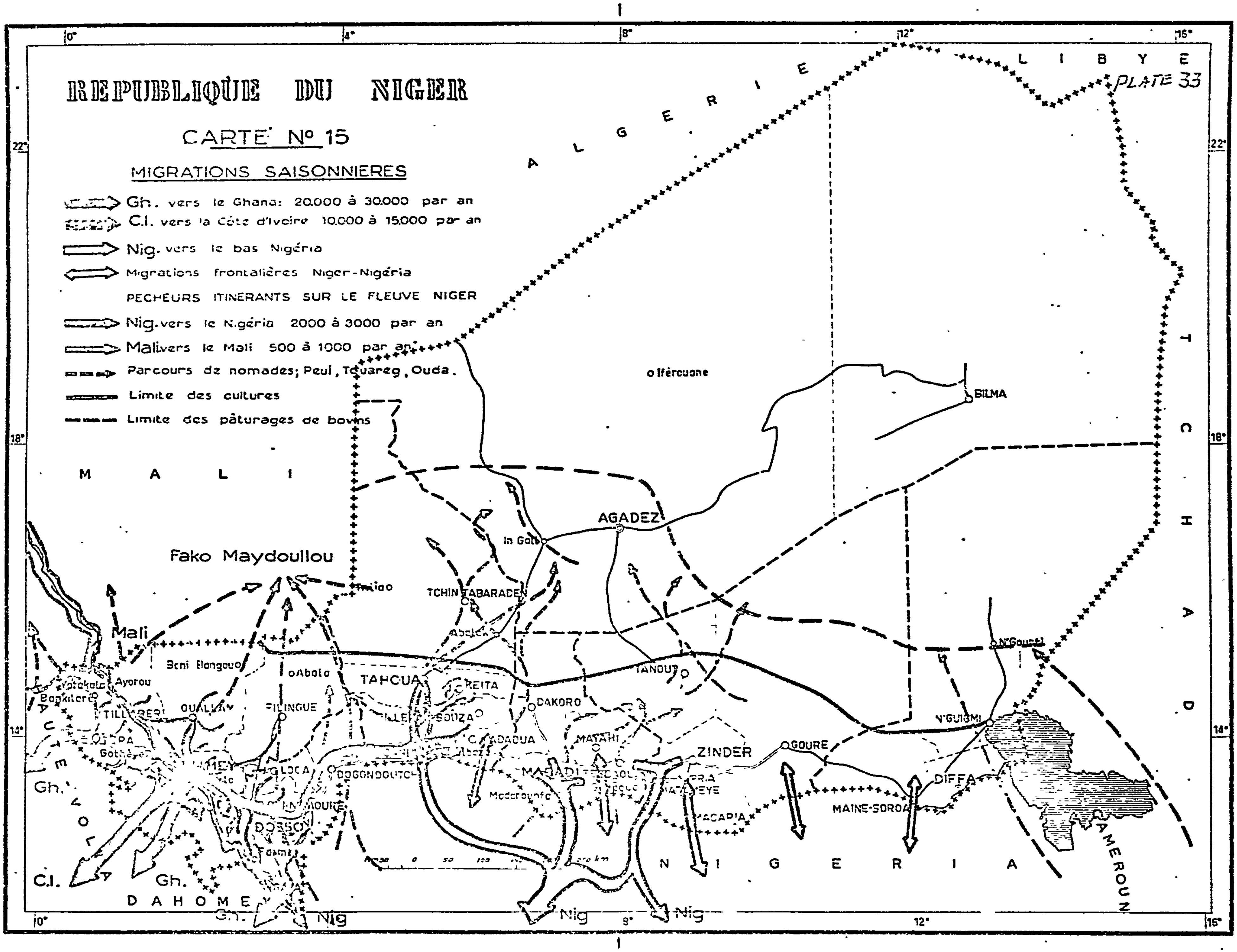
PLATE 33
REPUBLIQUE DU NIGER
CARTE N° 15
MIGRATIONS SAISONNIERES
Gh. vers le Ghana: 20.000 à 30.000 par an
C.I. vers la Côte d'Ivoire 10.000 à 15.000 par an
Nig. vers le bas Nigéria
Migrations frontalières Niger-Nigéria
PECHEURS ITINERANTS SUR LE FLEUVE NIGER
Nig. vers le Nigéria 2000 à 3000 par an
Mali vers le Mali 500 à 1000 par an
Parcours de nomades; Peul, Touareg, Ouda.
Limite des cultures
Limite des pâturages de bovins
A L G E R I E
L I B Y E
T C H A D
M A L I
N I G E R I A
D A H O M E Y
H A U T E V O L T A
CAMEROUN
AGADEZ
BILMA
In Gall
TCHIN TABARADEN
Fako Maydoullou
Mali
Ayorou
TILLABERI
OUALLAM
FILINGUE
TAHOUA
DAKORO
TANOUT
ZINDER
GOURE
N'GUIGMI
N'Gourti
DIFFA
MAINE-SOROA
MARADI
DOGONDOUTCHI
DOSSO
MAGARIA
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C.I.
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22°
18°
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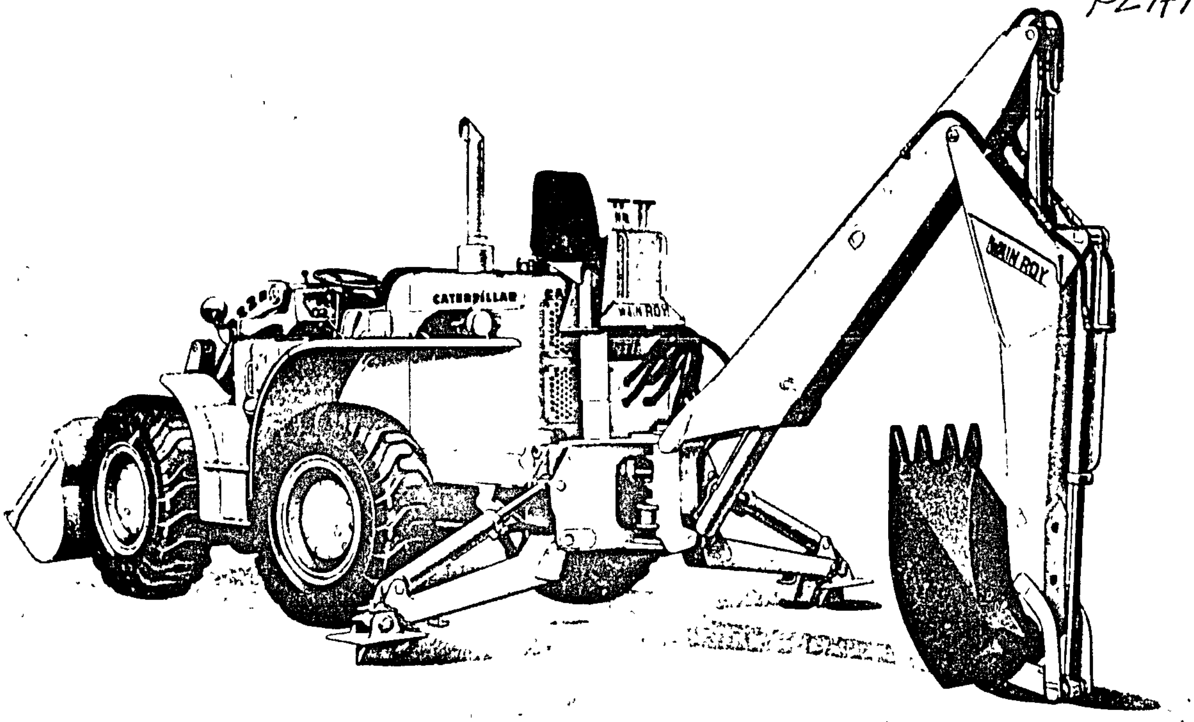
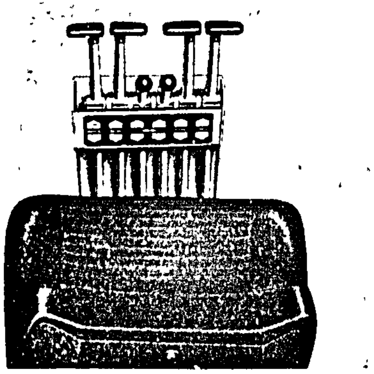
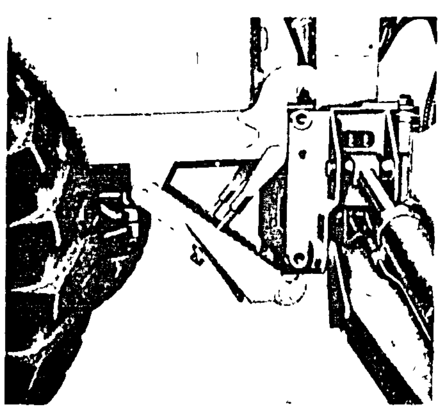
Wain-Roy

CATERPILLAR **922** Backhoe

PLATE 34







15′ digging depth (4572 mm) and 11′ 10″ (3607 mm) clearance height.

T-shaped control levers allow one hand operation of two levers.

Loader hydraulic system powers backhoe; oil return has separate full flow filter.

Less than 5 minutes hook-up and disconnect with simplified mounts and quick disconnect hydraulic lines.

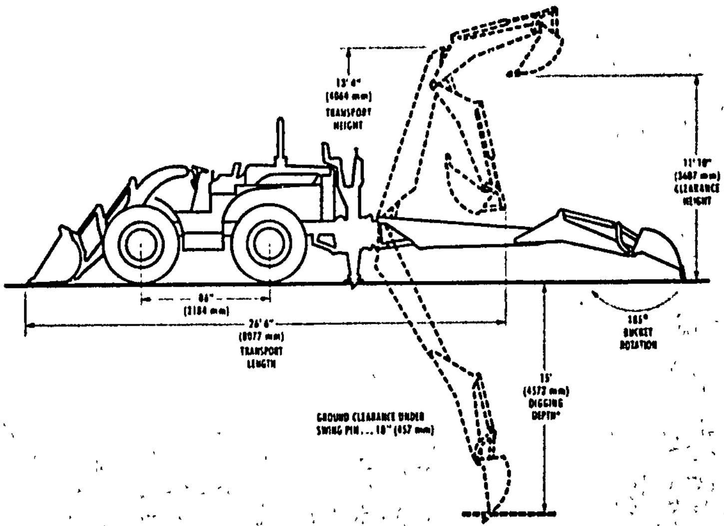
Center mounted adjustable seat remains stationary as boom swings, providing excellent visibility and operator comfort.

One source for parts, service and warranty.

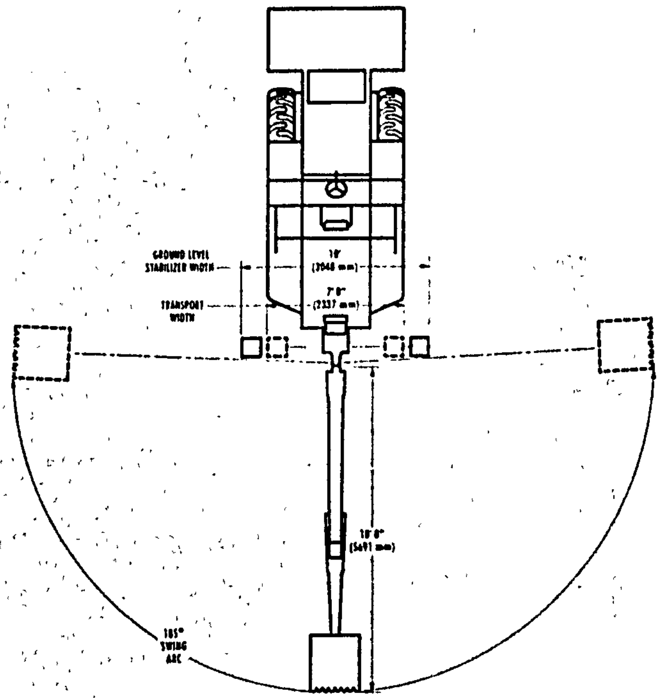
PLATE 35

922 Backhoe

Specifications are in accordance with I.E.M.C. standards (Industrial Equipment Manufacturers Council)



*Depth at which bucket without teeth will dig a flat bottom trench 2 ft. (610 mm) long.



BUCKET:

Struck Capacity .... 5.3 cu. ft. (0,15 m^3)
Width .... 24" (610 mm)
Number of Teeth (replaceable tips) 4

Bucket is detachable by removing two locks and pulling the pivot pins.

CONTROLS:

T-shaped handles for dipperstick, boom, bucket and swing levers. Operator can move two levers simultaneously with one hand. Control console remains stationary for constant control as boom swings.

Cam-actuated swing lever kickout prevents contact between boom and machine at extreme ends of swing. Kickout can be overridden with approximately 30 lb (13,6 kg) lever pull.

Engine governor within easy reach of backhoe seat.

SEAT:

Center mounted, foam padded, bucket type. Adjustable forward and back by lever to right rear of seat. Positive lock at any position during digging operations. May be tipped forward to keep seat dry and protect controls.

HYDRAULIC SYSTEM:

Included with backhoe are a diverter valve, relief valve, lines, return line full flow filter, and quick disconnect couplings. No additional parts are necessary to utilize the standard loader hydraulics for full hydraulic operation.

Hydraulic Oil Flow .... 22 GPM (83 lit/min)
Relief Valve Setting ..... 2000 PSI (141 kg/cm^2)

Cylinders:
- Boom, Double Acting (1) . 4" (102 mm) Bore
- Dipperstick, Double Acting (1) .... 4" (102 mm) Bore
- Swing, Single Acting (2) . 4" (102 mm) Bore
- Bucket, Double Acting (1) 3½" (89 mm) Bore
- Stabilizer, Double Acting (2) .... 4" (102 mm) Bore

MOUNTING:

Fixed and movable hooks on loader main frame engage trunnion pins on backhoe. Two clamping bolts securely fasten backhoe to loader. Time required to attach or remove backhoe — less than 5 minutes.

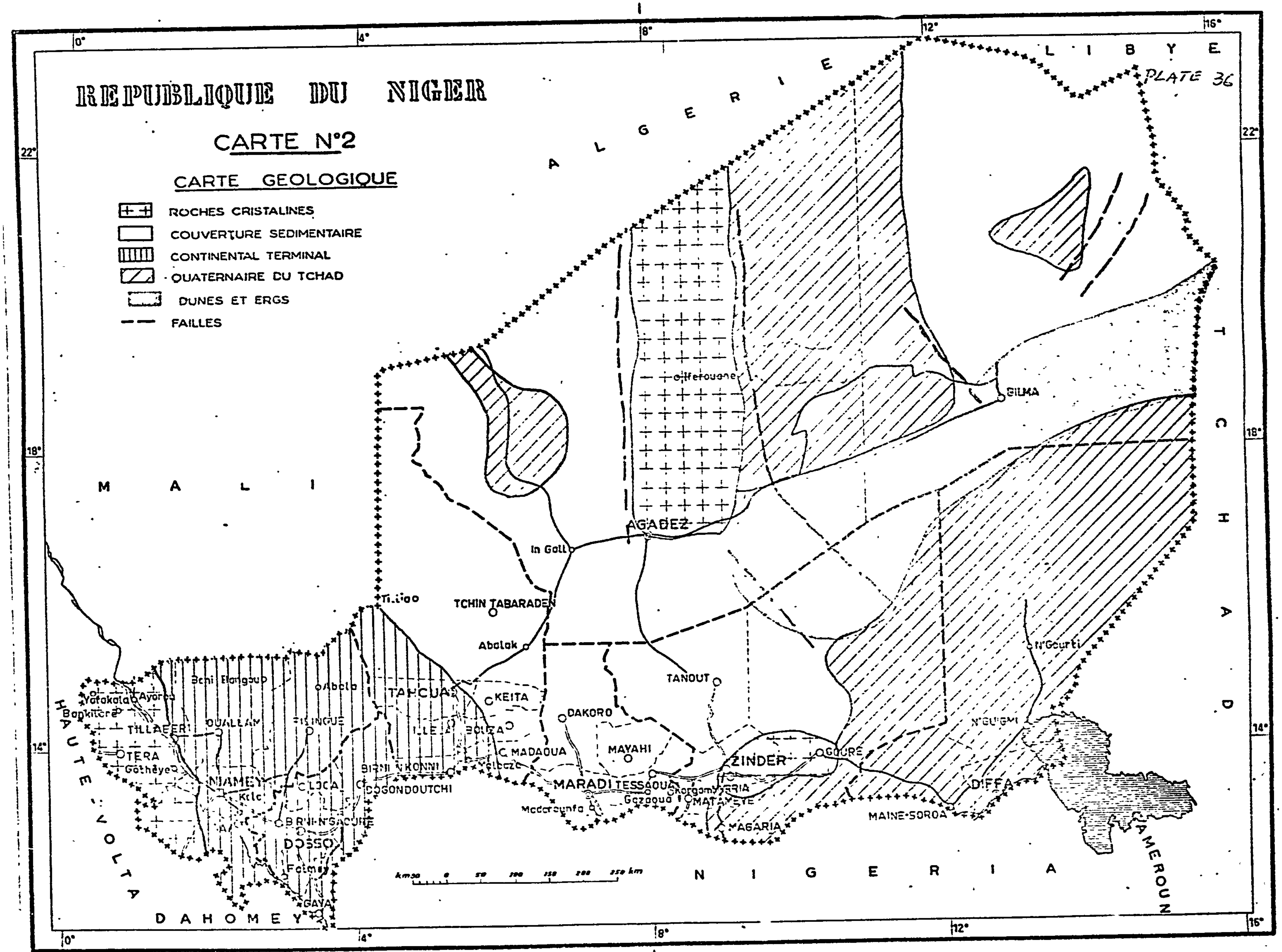
DIGGING FORCE .... 7,000 lb. (3200 kg)

WEIGHT, SHIPPING

(Not Installed) .... 3,300 lb. (1500 kg)

Materials and specifications are subject to change without notice.

CATERPILLAR



REPUBLIQUE DU NIGER
CARTE N°2
CARTE GEOLOGIQUE
ROCHES CRISTALINES
COUVERTURE SEDIMENTAIRE
CONTINENTAL TERMINAL
QUATERNAIRE DU TCHAD
DUNES ET ERGS
FAILLES
PLATE 36
ALGERIE
LIBYE
TCHAD
MALI
NIGERIA
CAMEROUN
HAUTE VOLTA
DAHOMEY
AGADEZ
Iferouane
BILMA
In Gall
TCHIN TABARADEN
Abalak
N'Gourti
TANOUT
TAHOUA
KEITA
DAKORO
MAYAHI
ZINDER
GOURE
N'GUIGMI
DIFFA
MAINE-SOROA
MARADI
TESSAOUA
Gazaoua
MATAMEYE
MAGARIA
MADAOUA
BIRNI N'KONNI
DOGONDOUTCHI
FILINGUE
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TERA
Gothèye
NIAMEY
DOSSO
GAYA
Ayorou
Abala
Madarounfa

PHOTOGRAPH NO. 4

Work in progress on a 1.5 m. diameter FED hand-dug water well 250 km. NE. of Niamey near Filingue. Access and egress is handled by a hand, windlass-controlled, steel cable and iron bucket.

The hole is excavated slightly wider than the diameter of a demountable circular metal mould one meter high. The space behind the mould is filled with gravel-bearing cement. After drying in about 24 hours, the mould is unbuckled and digging continues for another meter. Progress is slow and never exceeds 3 ft. per working day.

This hole, proposed as a cistern, will be sunk slightly below the piesometric level in an adjoining well drilled to an artesian aquifer. Through a horizontal connection the cistern will then be continually supplied. This innovation is locally termed a "forage-puits".

PHOTOGRAPH NO. 5

Women drawing water from a traditional hand-dug well lined with bent branches to retard or prevent caving. The hole is circular, and about one meter in diameter.

Note that the well mouth is reduced in size by rectangularly-placed logs, notched by many passages bucket ropes. Some wells of similar construction are about 0.80 meters across.

Buckets are constructed of circular-cut skins attached to strings, a design permitting them to lie flat on the bottom of the well.

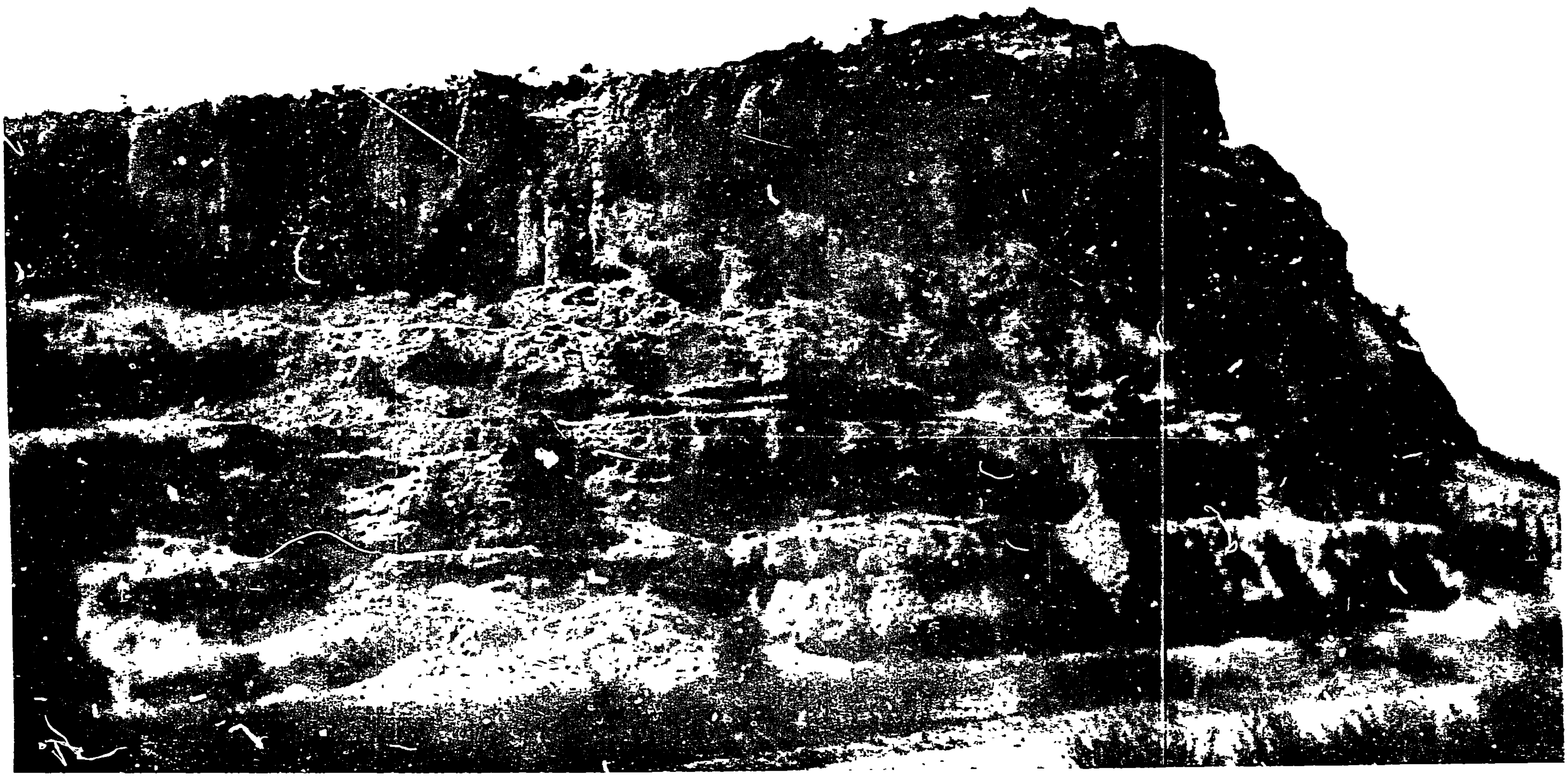
This universally-adopted design would permit water recovery when the level was very low.

PHOTOGRAPH NO. 6

Typical shale, sandstone, siltstone horizontal stratigraphy of the Upper Tertiary Continental Terminal formation between Niamey & Filingue.

Laterite development is widespread throughout Niger, Upper Volta, Mali, Ivory Coast, Dahomey and Nigeria.

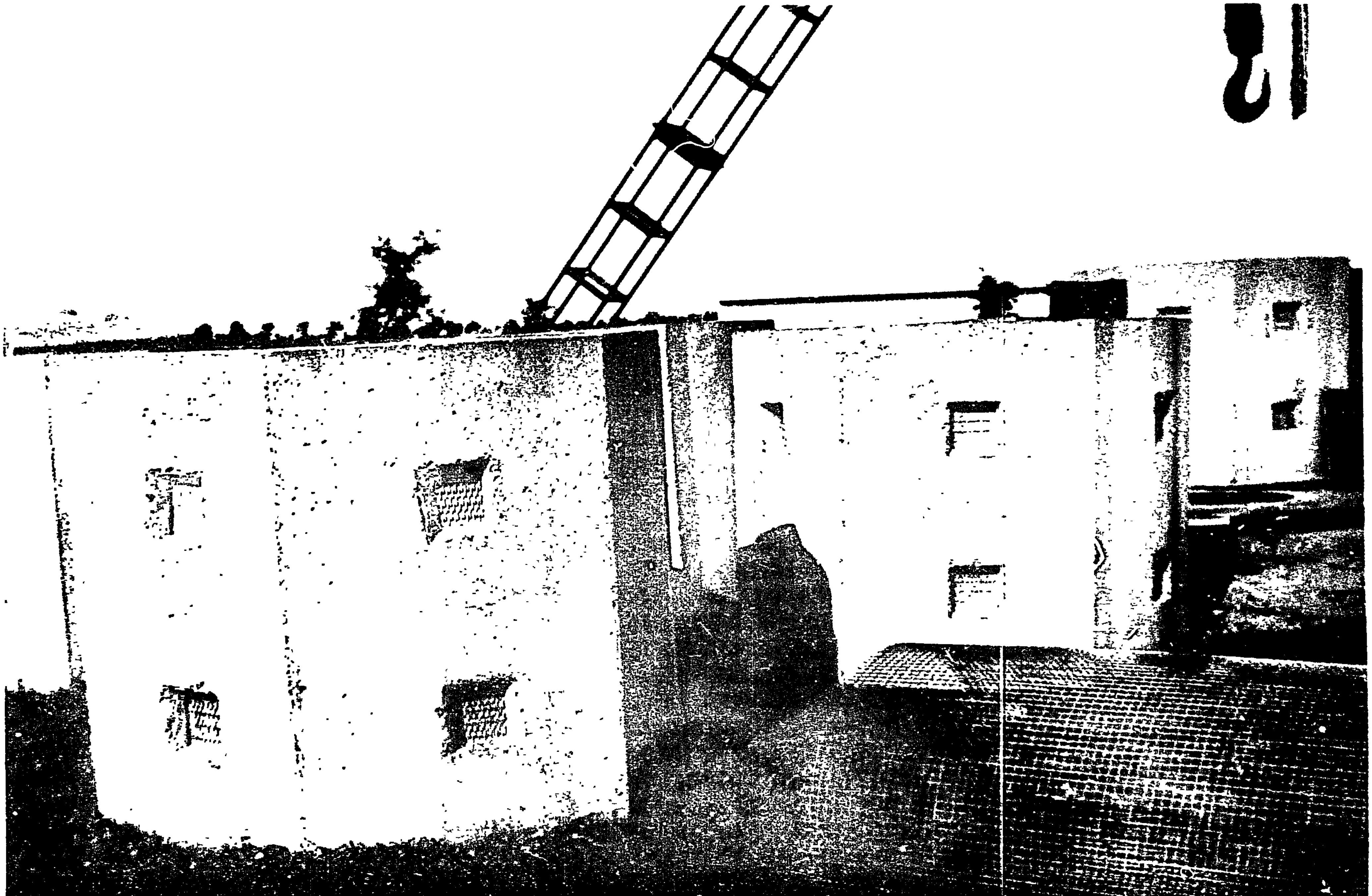
Where of sufficient thickness and texture, in relation to rainfall, it acts as a reservoir for ground water.



PHOTOGRAPH NO. 7.

Water-straining contrivance used in donor-constructed wells in the sedentary zone.

Twelve 10.8 x 10.8 cm. stainless steel screen insets occupy only 4% of the surface of the 1.0 to 1.4 m. diameter reinforced concrete ring placed opposite the producing interval at the bottom of cement-lined wells. In American practice 8% to 24% of the side-wall retaining filter screen is porous, depending on whether the hole is gravel packed (24%) or naturally developed (8%).



PHOTOGRAPH NO. 8

Same construction of well screen but of 40 cm. difference in diameter. Filling the annular space between the rock face of the hole and the well casing is called gravel packing.

The prevailing mechanics of well construction in Niger do not permit gravel packing behind the cement rings.

In American technology, screens are porous throughout their entire length as illustrated, in connection with gravel packing, as shown on Photograph 8A.

PHOTOGRAPH - 8A

INSTALLING WELL SCREENS

The methods of installing well screens thus far described apply primarily to well completions by natural development of the sand formation. The design features for naturally developed wells are detailed on pages 186 to 194.

Artificially Gravel-Packed Wells

Artificially gravel-packed wells differ essentially from naturally developed wells in that an envelope of specially graded sand or gravel is placed around the well screen in a pre-determined thickness. This takes the place of the hydraulically graded zone of highly permeable material which is produced by the conventional development procedure. Both types of wells, when properly constructed, are efficient and stable. The decision as to which to use must be based upon consideration of the conditions and the economics of each situation.

Procedures for installing well screens in artificially gravel-packed wells involve centering the screen in an oversize borehole followed by placement of the gravel-pack material.

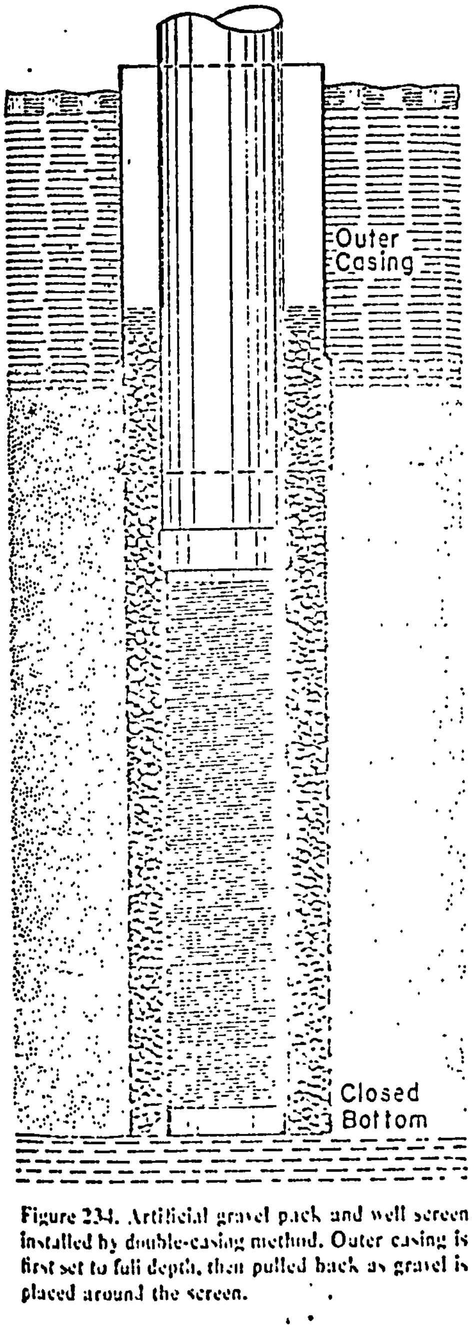


Figure 234. Artificial gravel pack and well screen installed by double-casing method. Outer casing is first set to full depth, then pulled back as gravel is placed around the screen.

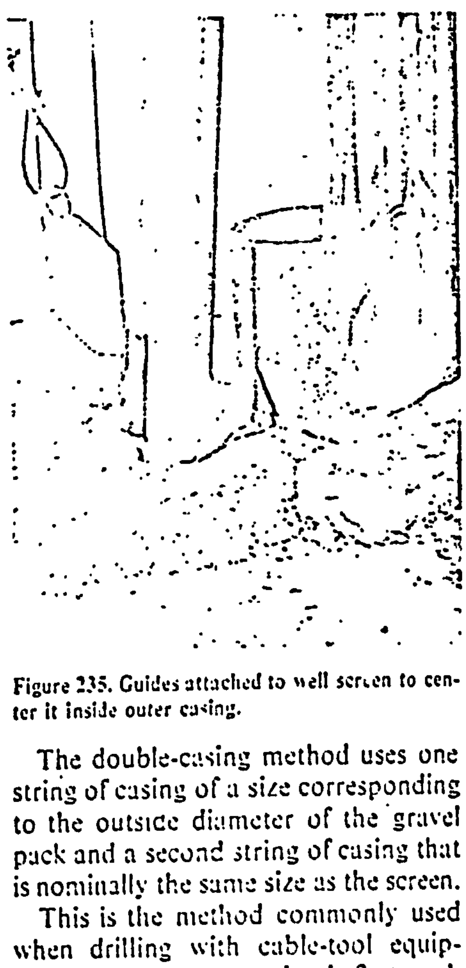
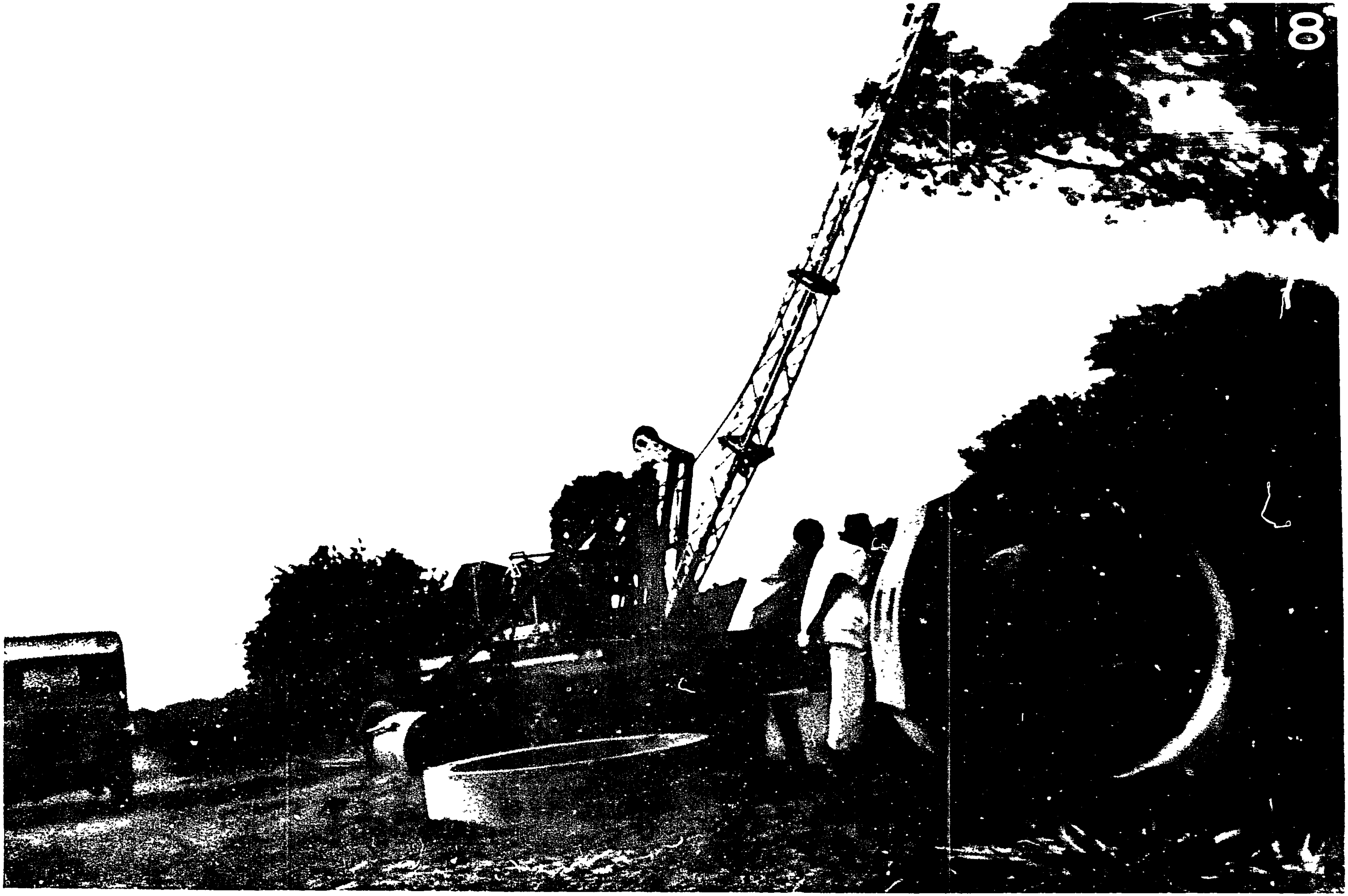


Figure 235. Guides attached to well screen to center it inside outer casing.

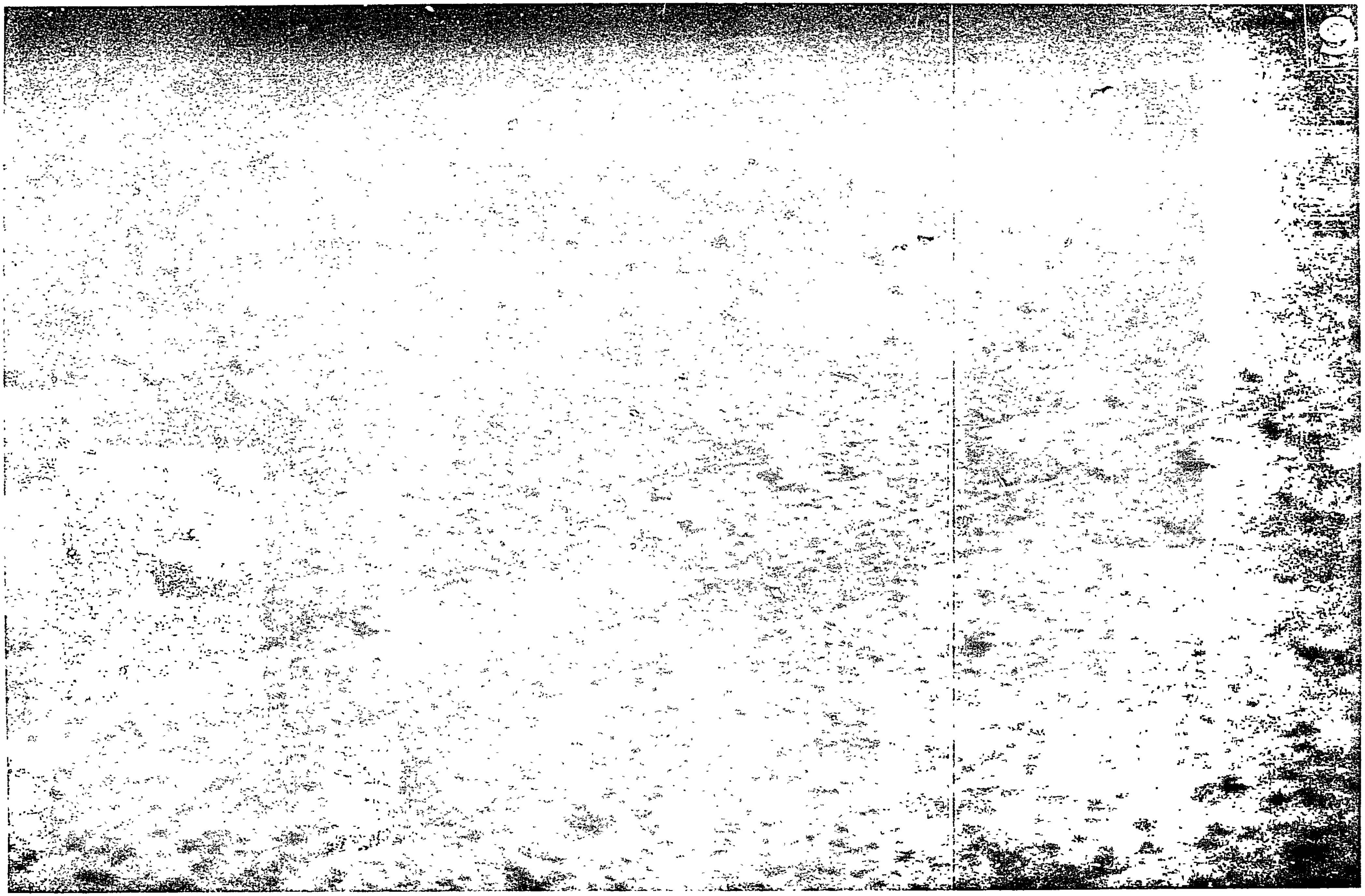
The double-casing method uses one string of casing of a size corresponding to the outside diameter of the gravel pack and a second string of casing that is nominally the same size as the screen.

This is the method commonly used when drilling with cable-tool equipment. A large outer casing is first sunk to the full depth of the well. The inner casing and the well screen are then


8

PHOTOGRAPH NO. 9

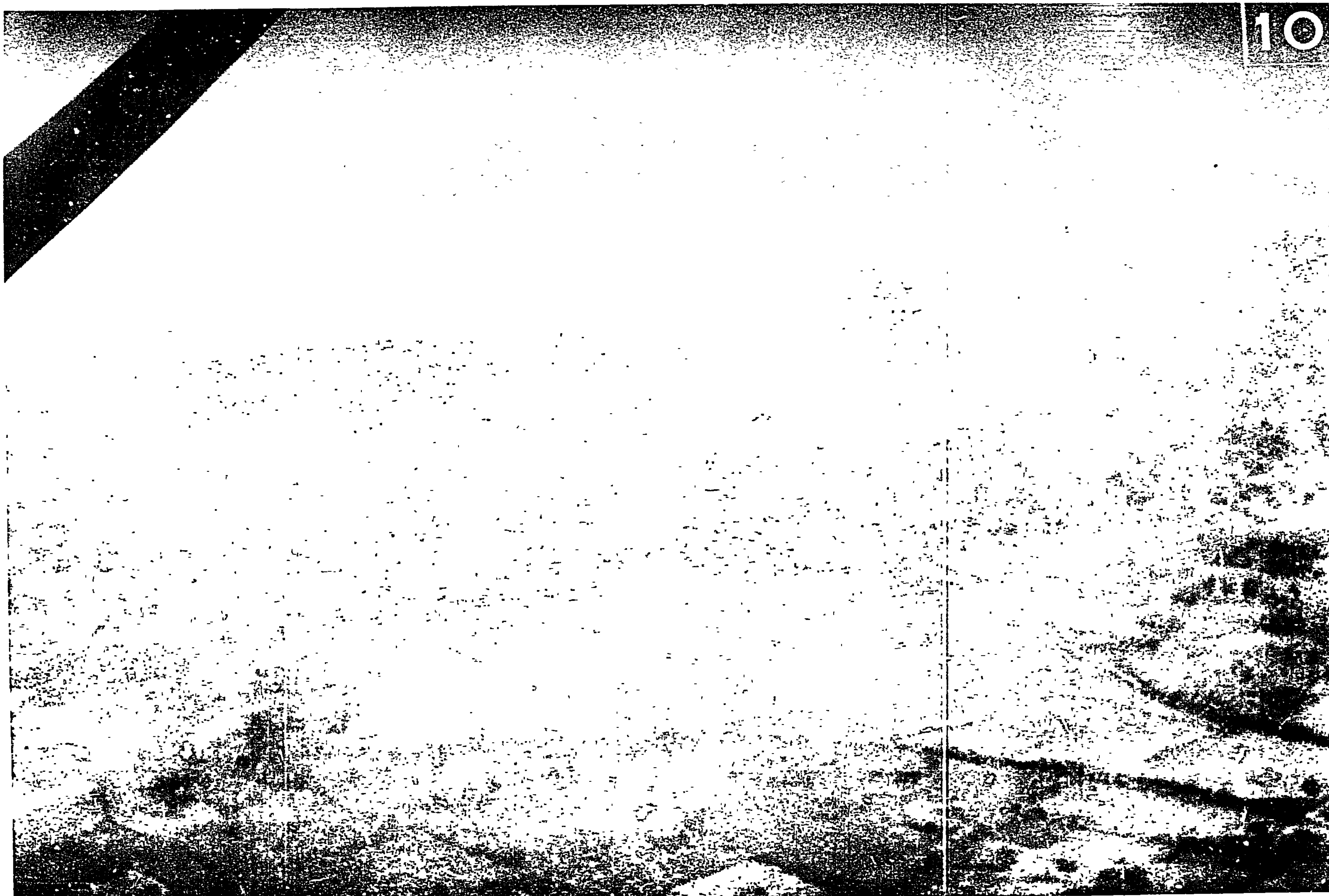
Aerial view of vegetation cover (yellow grass, bushes and scattered trees) at Dakoro, a settlement near 15° N. Lat. along what is customarily considered the boundary line between the sedentary zone to the south and the nomad zone to the north.



PHOTOGRAPH NO. 10

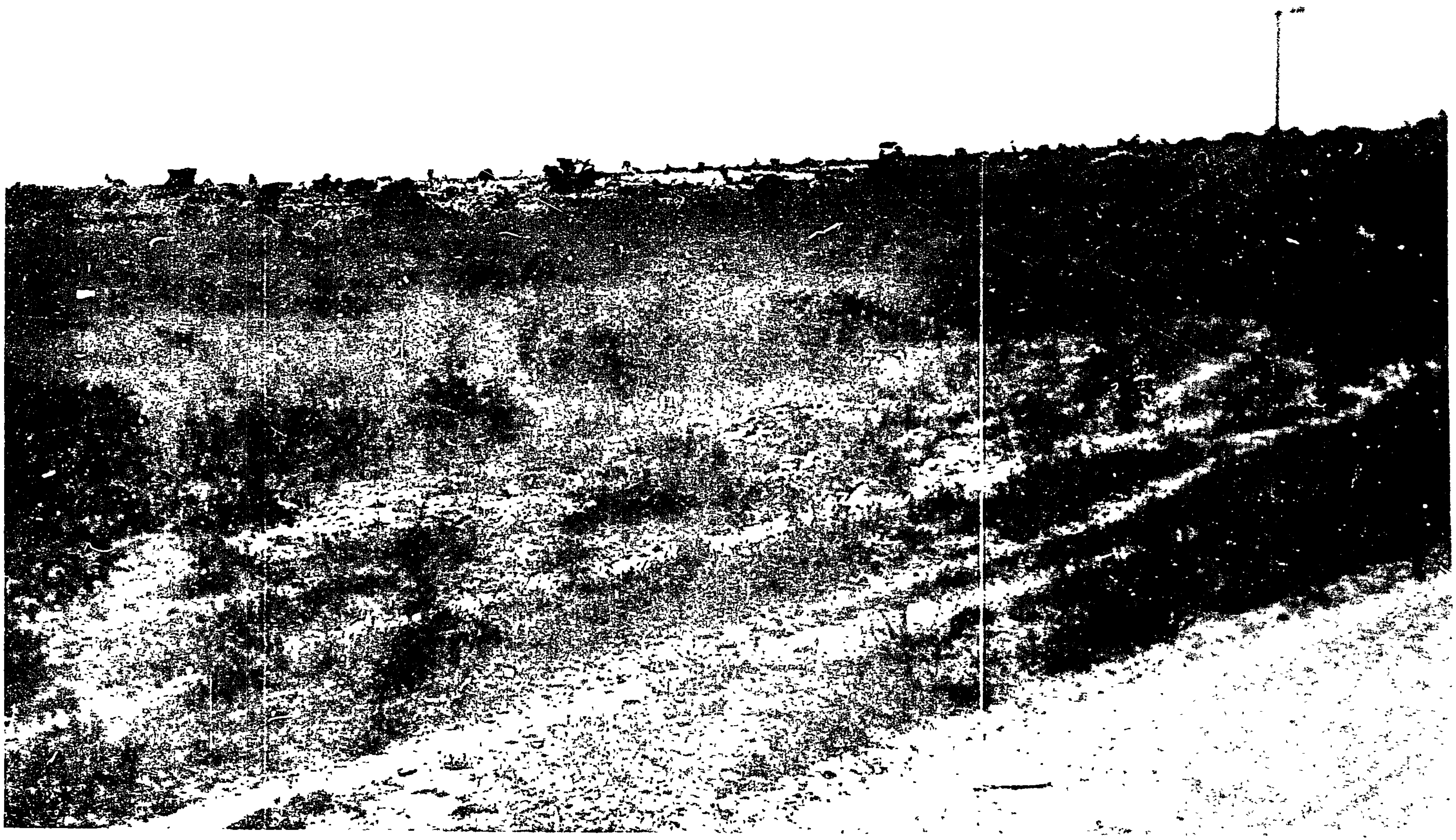
An aerial view of Maradi, one of the principal villages in south-central Niger on the main highway between Miamey and Lake Chad.

Being nearer to a railway (Kano) than any other settlement in Niger and on an avenue of seasonal migration between Niger and Nigeria, Maradi has been recommended as headquarters for both catchment and pilot drilling proposals.


10

PHOTOGRAPH NO. 14

This view of typical topography and vegetation in the sedentary zone was taken 25 miles from Niamey on the main east-west highway.



PHOTOGRAPH NO. 22

Wooden "home-made" pulleys used for drawing water with animals using larger skin buckets than may be manipulated by hand. The equipment is individually controlled and, therefore, removed when the owner leaves the well.

It can, therefore, be set up at another water hole.

PHOTOGRAPH NO. 23

A large capacity skin "bucket" used for hauling water.

This utensil is ingeniously constructed so that it can lie flat on the bottom of a well.

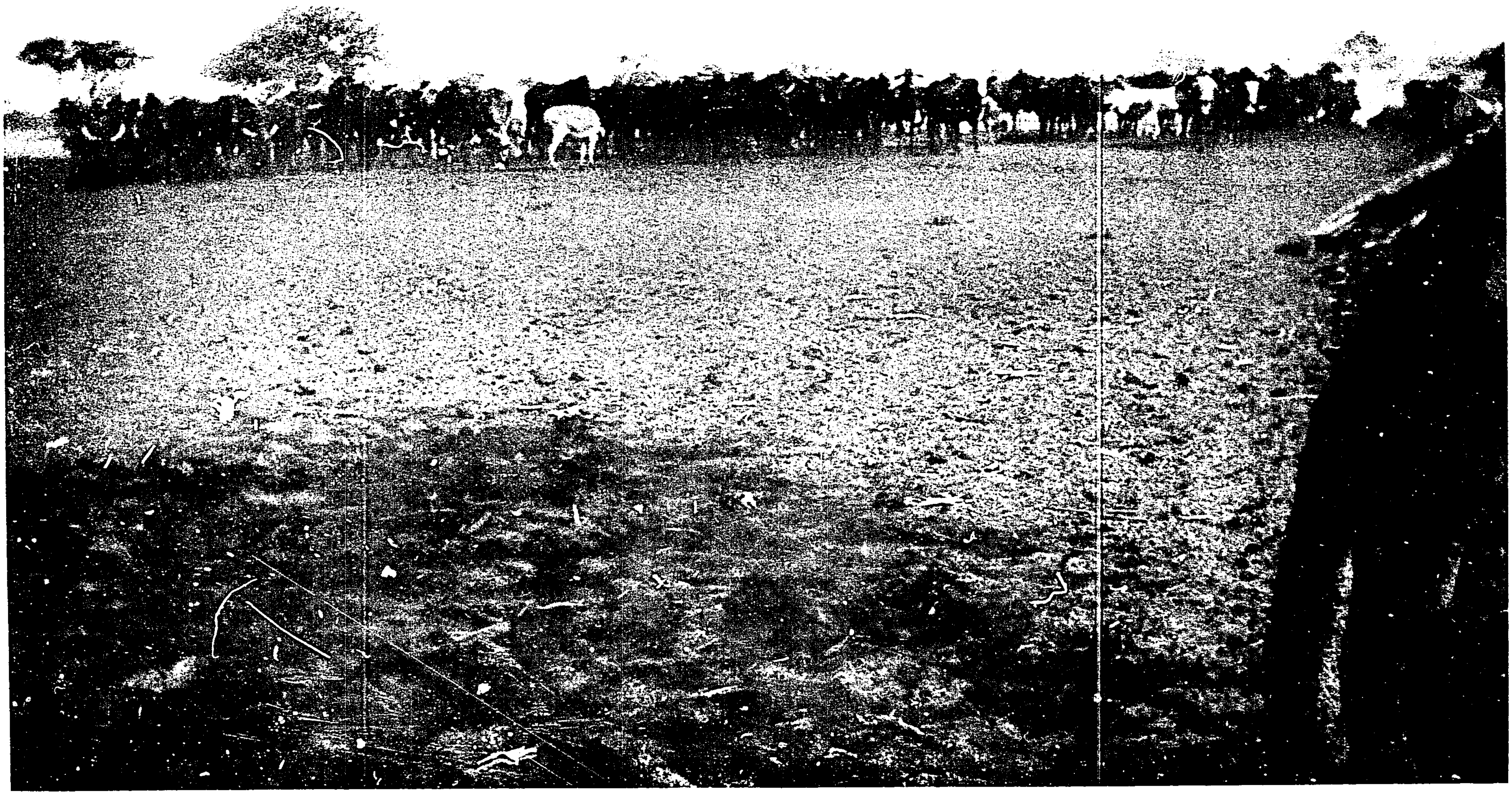
This universally adapted design permits water recovery when the level is low as in the dry season when the water table falls. The problem could be avoided if wells were deeper.

PHOTOGRAPH NO. 24

Concentration of livestock around a hand-baled well.

When large quantities of water are needed for stock, oversize skins, lifted by animal are used.

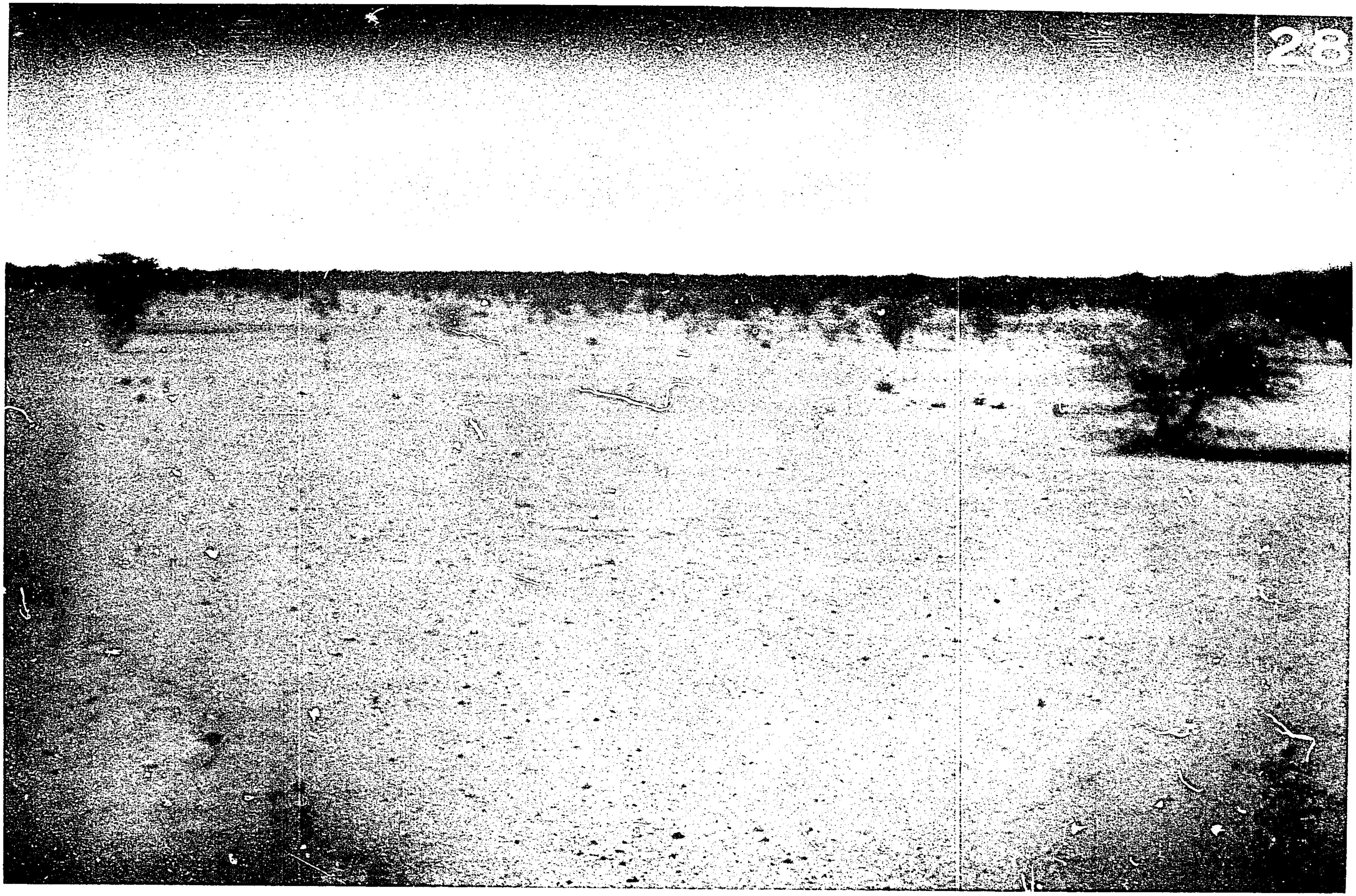
Capacity can be doubled over output achievable by human endeavor.



PHOTOGRAPH NO. 28

Grass cover, 20 miles southwest of Agades and near the northern grazing limit for livestock.

Comparison with photo 13 illustrates differences of grass cover that may occur within short distances and attributable to overgrazing


28

PHOTOGRAPH NO. 30

Compare with photo-28 for an indication of the degree to which the amount of rangegrass can vary over short distances.


30