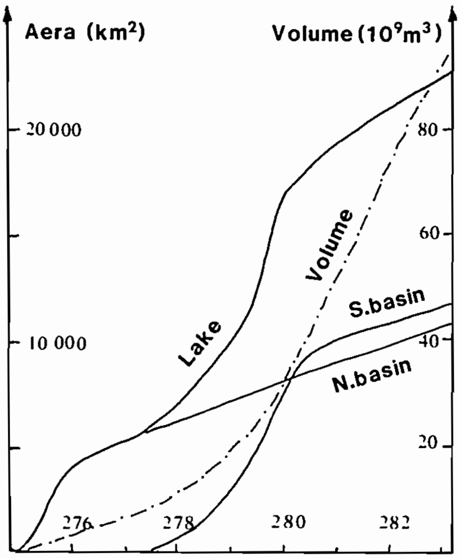


*Fig. 3* The morphometric curves of the lake.

Finally, though it is shaped by a sharper dune relief, the bottom of the south basin is flatter and higher than that of the north basin. This may result from lake sedimentation, which is more important in the south than in the north (Bouchardeau and Lefèvre 1957).

### 2.1.2 *Changes and development of the lake regions*

From 1967 to 1975, the water level continued to decrease each year from a mean of 281.9 m to 279–279.5 m and was followed by irregular changes in the lacustrine environment. Thus, until the level of 280.5 m, there was only a slight change in the different regions from 1967 to 1971. On the contrary, profound changes have been recorded below this level from 1972.

In the first case, we are dealing with a lake under average circumstances or 'Normal Chad' and in the second case, with a lake undergoing reduction or 'Lesser Chad' (Tilho 1910).

2.1.2.1 *The 'average' lake or 'Normal Chad'* (water level 281.9 m a.s.l.). Lake waters in the north and south basins occupy, respectively, 10 000 km$^2$ and 11 000 km$^2$ (Fig. 4).

In the north basin, dune crests above 282 m which are situated along the northern and eastern coasts create an archipelago landscape called the North-

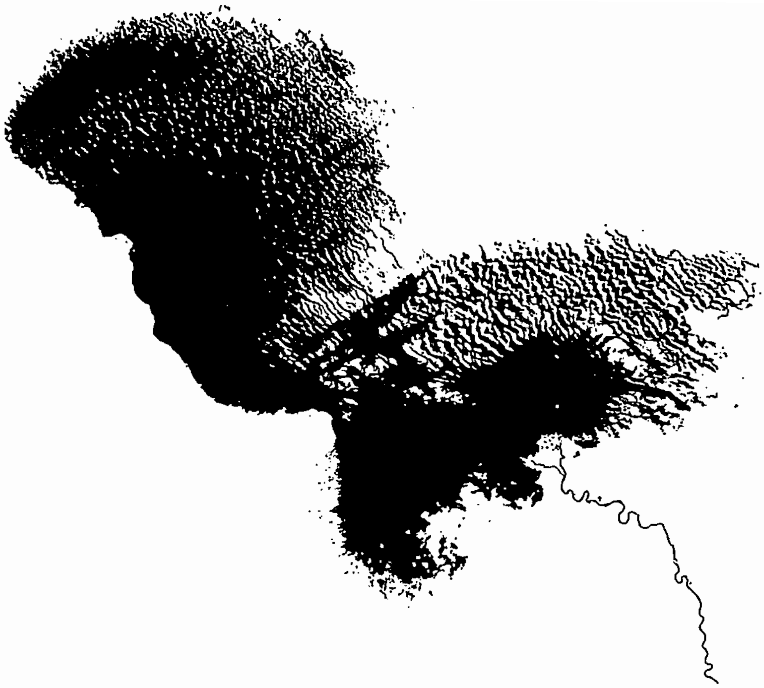

*Photo 5* Water surface of Lake Chad (January 1973) from a satellite photograph.

eastern Archipelago, along a stretch of about 25 km wide (Fig. 4). About 500 flat islands occupy 40% of the total area amounting to 2400 km$^2$, and are covered with herbaceous vegetation. They are often surrounded by a narrow stretch, a few meters wide, which is occupied by macrophytes, mainly *Phragmites* and sometimes extended by *Ceratophyllum demersum* and *Potamogeton demersum*. Depths range from 2.5 to 6.5 m.

Northwest of the archipelago, most of the dune crests whose altitudes range from 279 to 281.5 m are immersed and covered by macrophytes, mainly *Phragmites*. The archipelago zone is followed by a region of reed islands extending to the Nigerian coast. It has a total area of 3600 km$^2$, of which 17% is occupied by reed islands with an average area of 2.5 km$^2$. In some cases this region is divided into northern and northeastern reed islands (Fig. 4). To the east of Nguigmi, there is a small area with few reed islands forming a zone of open waters, with depths ranging from 4 to 7 m.

The southwest part of the basin with dune crests under 1.5 to 3 m of water is less influenced by the dune system. It also has a large zone of open water, the northern open waters, which is bordered to the west and the southwest by

*Table 1* Hydrological characteristics of the main natural regions for an average water level of 281.9 m (above sea level).

| | Z (m) | S ($km^2$) | V ($10^9$ $m^3$) | | Z (m) | S ($km^2$) | V ($10^9$ $m^3$) |
|---|---|---|---|---|---|---|---|
| Southeastern | 3.60 | 2000 | 7.2 | Southeastern | 3.30 | 875 | 2.9 |
| Open Waters | 3.20 | 1975 | 6.3 | Archipelago | 2.95 | 850 | 2.5 |
| | 2.75 | 1925 | 5.3 | | 2.55 | 825 | 2.1 |
| Southern | 2.75 | 2000 | 5.5 | Eastern | 3.10 | 1075 | 3.3 |
| Open Waters | 2.35 | 1975 | 4.6 | Archipelago | 2.70 | 1050 | 2.8 |
| | 1.95 | 1925 | 3.6 | | 2.40 | 1025 | 2.5 |
| Southern | 2.05 | 1525 | 3.1 | Great Barrier | 2.10 | 1700 | 3.5 |
| Reed Islands | 1.55 | 1475 | 2.3 | (southern part) | 1.80 | 1675 | 3.0 |
| | 1.10 | 1425 | 1.6 | | 1.55 | 1610 | 2.5 |
| Southeastern | 2.55 | 1800 | 4.6 | Southern | 2.75 | 10 975 | 30.1 |
| Reed Islands | 2.15 | 1750 | 3.7 | Basin | 2.35 | 10 750 | 25.3 |
| | 1.65 | 1700 | 2.8 | | 1.95 | 10 435 | 20.4 |
| Great Barrier | 3.40 | 1550 | 5.3 | Northeastern | 6.00 | 975 | 5.8 |
| (northern part) | 2.95 | 1525 | 4.5 | Reed Islands | 5.65 | 950 | 5.3 |
| | 2.55 | 1455 | 3.7 | | 5.15 | 925 | 4.7 |
| Northern | 4.90 | 3750 | 18.3 | Northern | 5.35 | 1475 | 7.9 |
| Open Waters | 4.40 | 3700 | 16.3 | Archipelago | 5.00 | 1450 | 7.2 |
| | 3.90 | 3660 | 14.2 | | 4.70 | 1400 | 6.7 |
| Northern | 5.35 | 2700 | 14.5 | Northern | 5.00 | 10 325 | 51.8 |
| Reed Islands | 5.00 | 2650 | 13.2 | Basin | 4.60 | 10 145 | 46.7 |
| | 4.60 | 2550 | 11.7 | | 4.15 | 9865 | 41.1 |
| | 3.85 | 21 300 | 82.0 | | | | |
| | 3.45 | 20 900 | 72.0 | | | | |
| Lake | 3.05 | 20 300 | 61.5 | | | | |

Z = depth; S = area; V = volume.
For a given region and parameter, three values should be noted: the upper number corresponds to the flood level (282.4 m), the lower number to the lower water level (281.5 m) and the intermediate figure to the average level.

Archipelago was composed only of some residual ponds (Fig. 6). From August 1972 to August 1973, the water level decreased from the average level of 280.1 to 278.4 m, i.e. by 1.6 m. This resulted in the occupation by the macrophytes of some newly emerged zones, especially those of the Great Barrier, the Southeastern Reed Islands and the Southern Open Waters. While the immersed or half-immersed vegetation around the islands or along the coastal zones had

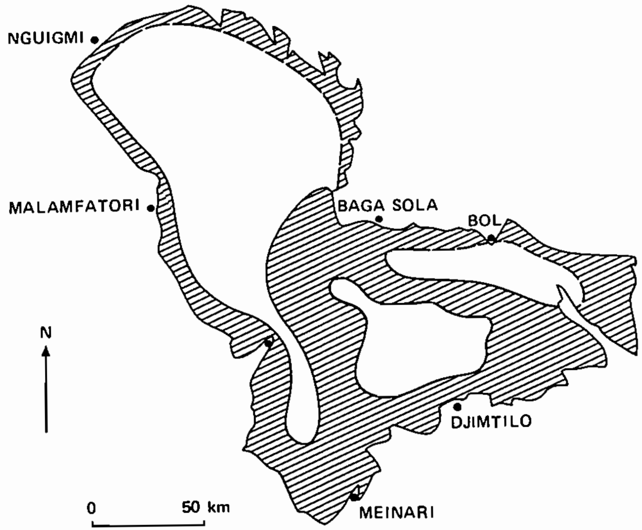


*Fig. 5* The 'Lesser Chad' in April 1973.

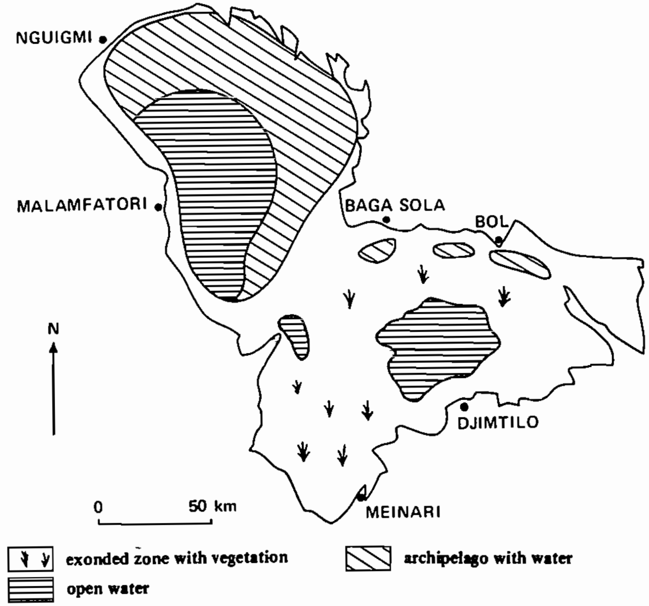


*Fig. 6* The 'Lesser Chad' in July 1973.

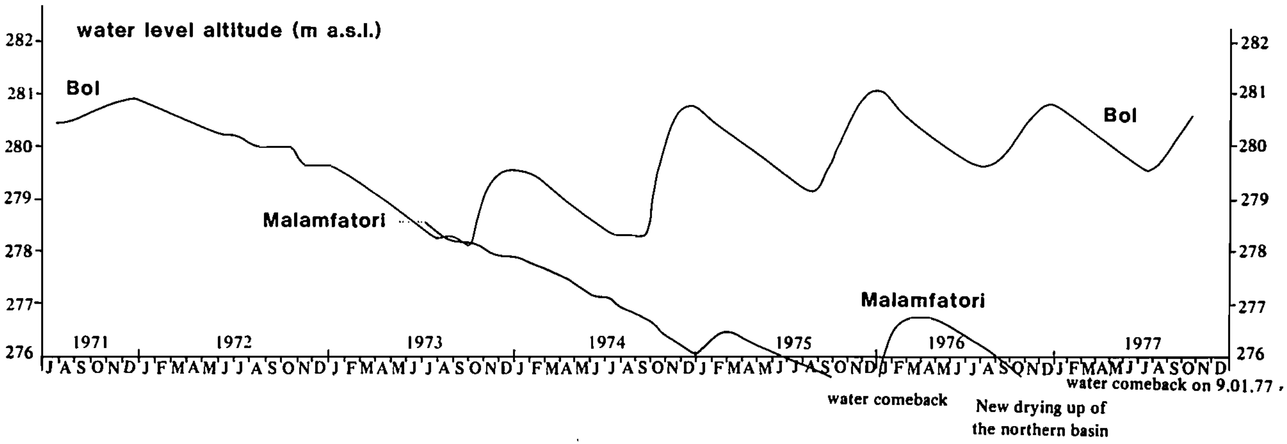


*Fig. 7* Water levels of the lake in the southeastern archipelago and the northern basin from 1971 to 1977.

virtually disappeared during the 'Normal Chad' period in 1972 as a result of the rapid contraction of the lake, the exposure of the above-mentioned regions made it possible for seeds in the surface sediments to germinate (Fotius and Lemoalle 1976). This vegetation which was mainly composed of *Cyperus papyrus*, *Typha vossia*, *Ipomea* and *Ludwigia* largely persisted until the water level increased again. The 'Ambadjs' (*Aeschynomene* ssp., *Sesbania* spp.) were equally prominent. In the south basin, the areas thus occupied were equal to about 5000 $km^2$.

In conclusion, apart from the reduction and the fragmentation of the water area, the second important phenomenon which occurred in 1973, was the development of a thick vegetation over a large part of the emergent areas in the southern basin.

2.1.2.3 *The development of the lake during the period of 'Lesser Chad' (1973–77)*. (a) *1973–74*: partial drying up of the south basin during the period of low water and the beginning of drying up in the north basin.

In 1973–74, the Shari flood was scarcely greater than that of 1972–73 ($18.4 \times 10^9$ $m^3$). Until mid-September, the Shari low waters flowed into the restricted Southeastern Open Waters that grew larger when the Shari flood occurred. From the beginning of October, the Southern Open Waters and a part of the Southeastern Archipelago, which were covered with abundant vegetation at that time, were filled up by water (Fig. 8). Although macrophytes were not entirely immersed, the rise of the water level was large and rapid (Fig. 7) amounting to about 1.30 m between early October and the end of November for the Bol region and to 1.00 m for the Baga-Kawa region.

The south basin reached its maximum water level in December (Fig. 9) and open waters of this basin occupied nearly the same area. In the Southeastern Archipelago, open water areas appeared, resulting in the total immersion of macrophytes and swampy zones were displaced southwards and northwards. At that time, water flowed through the thick vegetation of the Great Barrier towards the north basin, in a diffuse and minor way. As it received practically no water supplies, except those from the Komadougou Yobé and slight rainfall, the north basin underwent profound changes. The water level decreased by 85 cm in the central zone, dividing the open waters into two remnant large ponds separated by an archipelago of sandy islands without vegetation.

During 1974, the flood in the south basin was similar to that of the previous year with the decrease in water less marked during the first months (Fig. 7). Dune crests and shallows gradually reappeared but they were covered with vegetation before being exposed. Ambadjs developed to such an extent that in places they looked like forests. In July, the water level was nearly the same as that of the previous year at the same time, but with more abundant vegetation, especially at the level of the Great Barrier.

In the north basin, which had not been supplied with water since the

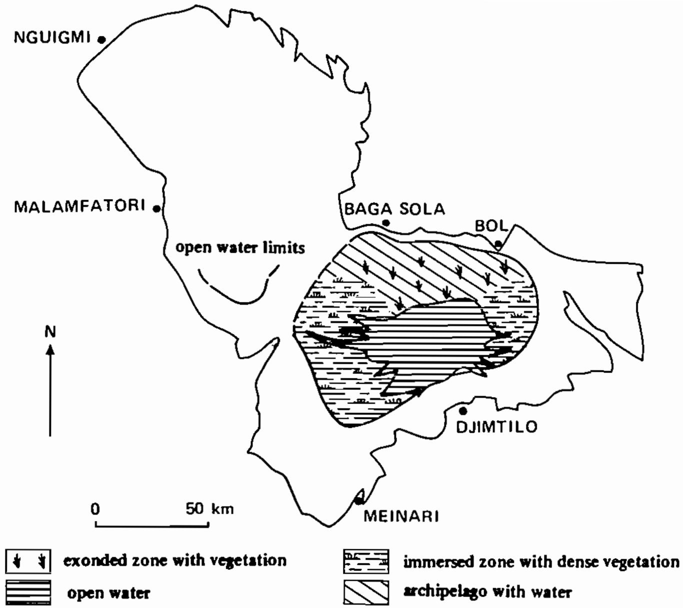


*Fig. 8* The 'Lesser Chad' in October 1973.

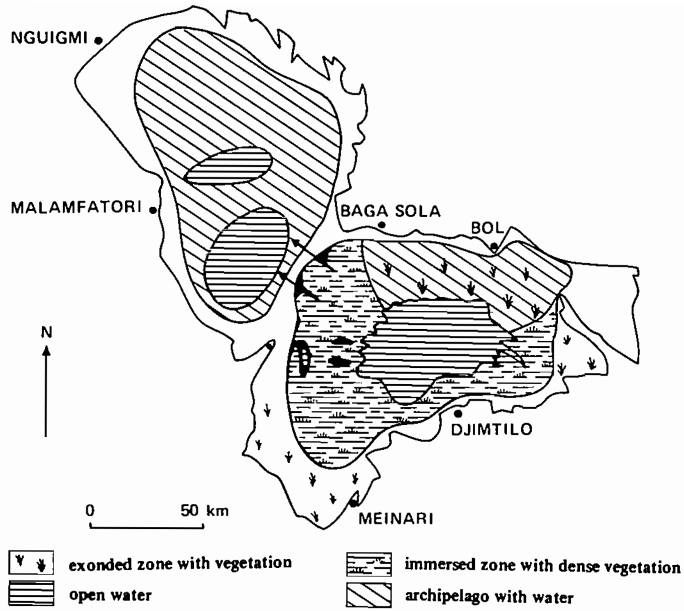


*Fig. 9* The 'Lesser Chad' in December 1973.

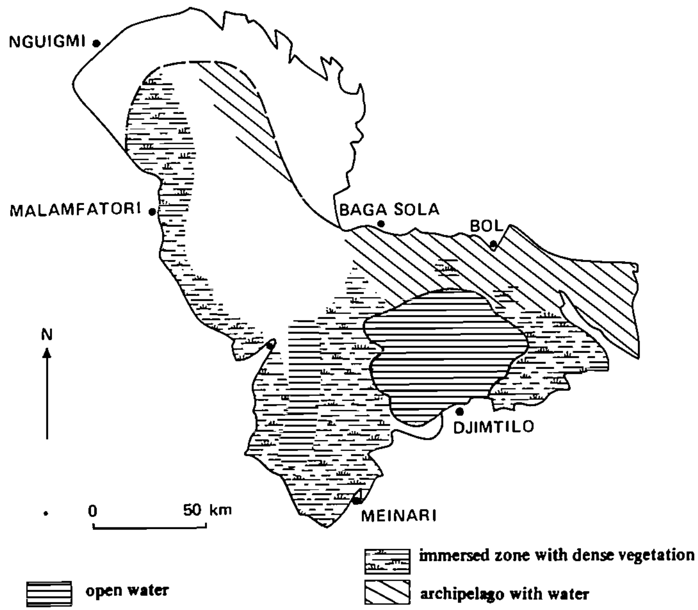


*Fig. 10* The 'Lesser Chad' in January 1975.

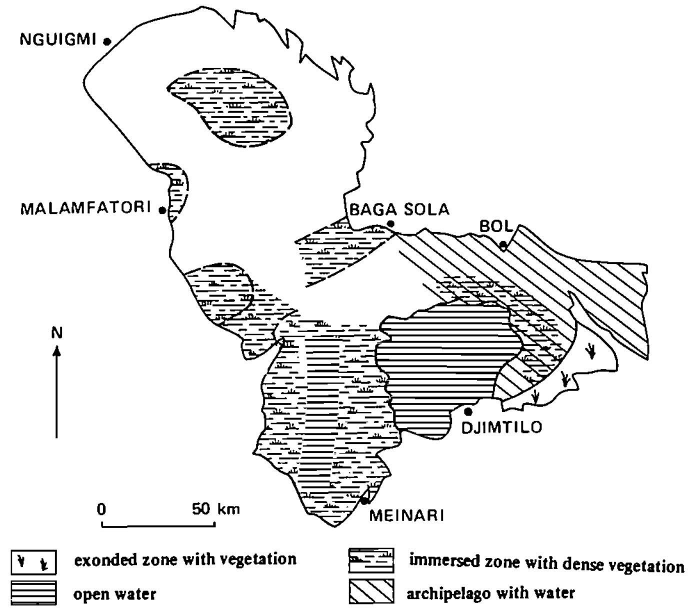


*Fig. 11* The 'Lesser Chad' in July 1975.

form, colour, degree of coherence, texture and organic matter content was reduced to four main types: mud, clay, sand and pseudo-sand, which are subdivided into varieties. In some zones of the lake, these materials are encrusted with limestone.

From 1970 to 1973, Dupont and Carmouze continued this study. A new map with surface sediments was drawn from 1500 observations that were uniformly distributed over the entire lake (Carmouze 1976) (Fig. 12).

2.1.3.1 *Materials with muddy clay facies.* Mud is a structureless material which usually appears in the form of a greyish-black, fine, homogeneous suspension and sometimes as big brownish flakes. Its water phase is always very important since it represents 250 to 500% of the dry weight. Its mineral portion, representing 80% of the average dry weight, is distributed approximately equally among three types of metric granules: clay up to 0.002 mm, silt from 0.002 to 0.050 mm and sand from 0.05 to 2 mm. Its organic fraction which is mainly composed of decaying macrophyte debris is relatively high usually ranging from 10% to 16% of the dry weight but reaching more than 30% when it is genuine peat. The average percentages of carbon and nitrogen are equal to 90% and 8% respectively of the dry weight; the C/N ratio is almost 11, indicating the leading part played by the higher plants in the accumulation of this organic matter.

The most abundant material, mud, is found particularly in the zones of reed islands and archipelagos (Fig. 12). Thus, the lake bottoms of the Southeastern Archipelago, the Southeastern Reed Islands, the Southern Reed Islands, the majority of the Great Barrier and finally the eastern and southern edges of the Northern Reed Islands and the Northern Archipelago are covered with flaky brown mud (flakes can reach 1 cm in diameter). The eastern half of the Eastern Archipelago is also covered with it. Peat like mud is found along the northern and eastern coasts of the north basin, as well as in some parts of the Southeastern and Eastern Archipelago arms.

Clay is a material with a variable consistency but always firmer than mud. It appears either in a homogeneous soft and structureless form or in a more or less structured form (cleaving into angular polyhedrons, a few centimeters in diameter and into smaller aggregates) or finally in the granular form (composed of thick particles resistant to manual weathering). Whatever the variety may be, clay is characterized by a mineral portion containing more than 50% of components less than 2 mm in diameter. It is usually composed of 10 to 40% slime and 10 to 20% sand. The water phase represents 120 to 130% of the dry weight when it is soft clay and 40 to 120% of the dry weight when it is structured clay. The organic portion is smaller in clays than in muds and does not exceed 5% of the dry weight. The average percentages of carbon and nitrogen in organic matter amount respectively to 25% and 2.5% and the C/N ratio of 10 is similar to that of muds.

in regions where highly saline waters cause flocculation, when the pH is higher than 8.8.

Unlike mud, clay is found in large amounts only in regions with few macrophytes such as the Southeastern Open Waters, the South Open Waters and the Northern Open Waters. From a distribution study of the different varieties a general interpretation (Dupont 1970) could be suggested. This author noticed that soft clay is found in the deepest zones where vegetation could generally not settle during lake recession; on the contrary, structured clay is found in shallower zones where macrophytes could occasionally grow during temporary drying up periods. Finally, granular clay is related to emergent regions either as a result of their shallowness or because of their isolation from the Shari delta, which exposes them to temporary drying up during large decreases in the lake. Dupont inferred that soft clay would have been the original material and could undergo a structural change resulting from the development of the root system as a result of macrophyte settlement. This would result in the isolation of polyhedrons and a decrease in water content. When sediments are exposed, this process would be accentuated leading to the formation of clay granules. Desiccation which isolates polyhedrons could be increased in certain cases by fires by farmers.

2.1.3.2 *Materials with sandy facies.* Fine and well-sorted sands originate from two different stocks. The first one corresponds to the eastern and northern edges of the submerged erg and is composed of aeolian quartz sand whose average diameter is about 0.250 mm. The second one derived from river sources is mainly situated in the coastal zones of the Southern and Southeastern Reed Islands. It is micaceous and the average diameter of its grains is about 0.16 mm. Both varieties are often mixed. Their organic matter content remains low, equal to or less than 1% of the dry weight (Dupont 1970).

It should be noted that sands are more abundant than is shown in Fig. 12, for, they actually cover the submerged periphery of the islands as well as most of the lake shallows where the reed islands are.

2.1.3.3 *Materials with granular facies (psuedo-sand).* These materials are composed of small granules which are variable in size and were first described by Guichard (1957) as 'marc de café'. Their unimodal frequency curves reach a peak around 0.250 mm (Dupont 1970) and in the samples under study, the median range is from 0.205 to 0.283 mm. Moreover, cumulative curves are very straight, thus showing that it is a well-sorted material (Fig. 13). There are also pseudo-sand samples smaller in average size in which the measurement* of granules cemented into clay or mud is difficult. They appear in different forms,

* The phylogeny of these granules is studied in Chapter 4.

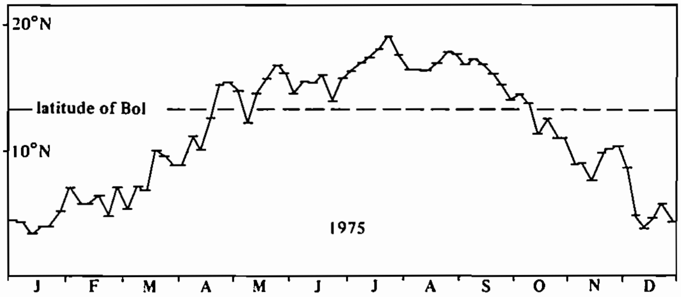


*Fig. 15* The displacements of the intertropical convergence zone.

## 2.2.1 *Winds*

The harmattan is a sry northeast wind that blows from October to April, while the monsoon is a humid southwest wind that blows from May to September. These rather strong winds blow mainly in the morning from 0600 to 1200 hours. The daily average at Bol (Southeastern Archipelago) was measured over the period 1965 to 1970. The frequency curve for velocity which is shown in Fig. 16 (after Billon et al. 1968) indicates that the average wind velocity is above 5 m/s for 6 hours a day. The two main winds are associated with local winds that result from anabatic winds and therefore blow from the land towards the sea in the night and in the other direction during the day.

Figure 17 summarizes the directions and average velocities of winds over ten days at Bol in 1969 and 1970 (after Roche 1973).

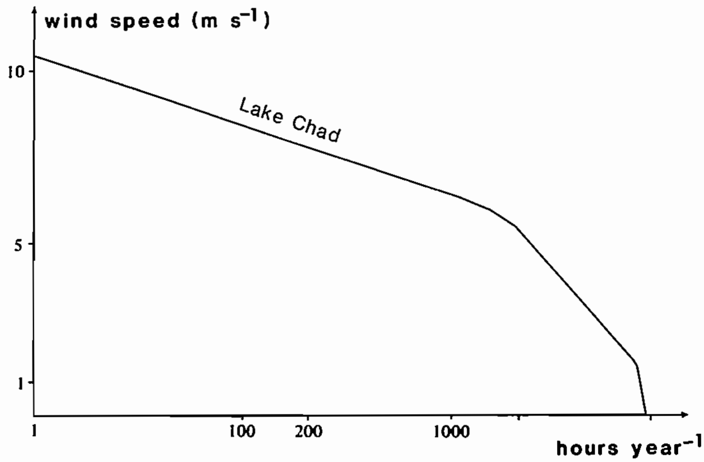


*Fig. 16* Wind speed frequencies at the Bol station.

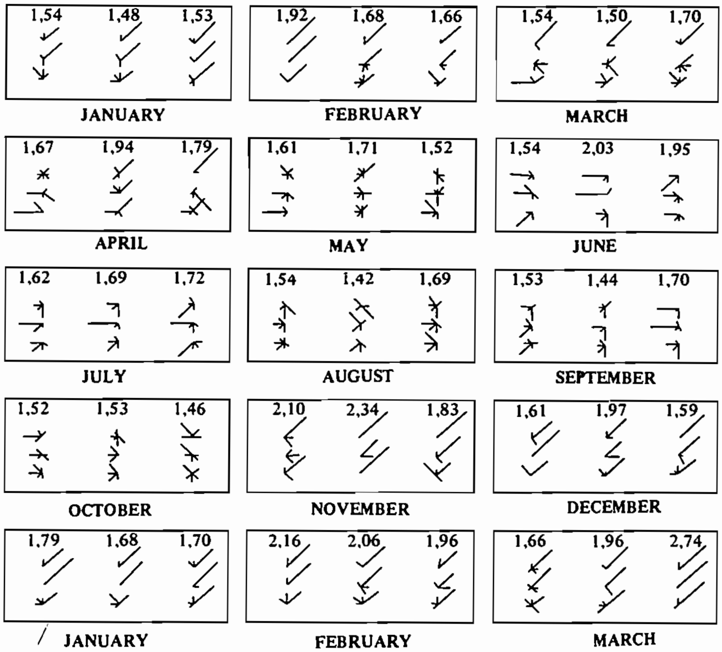


*Fig. 17* The winds: mean speeds and directions at Bol (calculated upon 10 years).

### 2.2.2 *Rainfall*

The rainy season begins in May–June and ends in October with maximum rainfall in August when the lake receives half the rainfall. The annual rainfall decreases considerably from the south to the north. The lake, situated between the isohyets 550 and 240 mm (Fig. 18), had an average rainfall of 315 mm at Bol from 1954 to 1972 with large between years variations (the extremes recorded were 125 and 565 mm)*.

### 2.2.3 *Air temperature*

The average annual air temperature is about 28°C. From 1936 to 1970, it was 28.7°C at N'Djamena and 28°9 at Bol from 1957 to 1970 (Toucheboeuf de Lussigny 1969; ORSTOM 1974a, 1974b). During the warm season, the average monthly temperatures vary from 29 to 32°C from March to October with a slight decrease in August (27.5°C). During the cool season, they range from 22

* Brunet-Moret (1968) undertook a detailed study on the frequency of rainfall intensity.

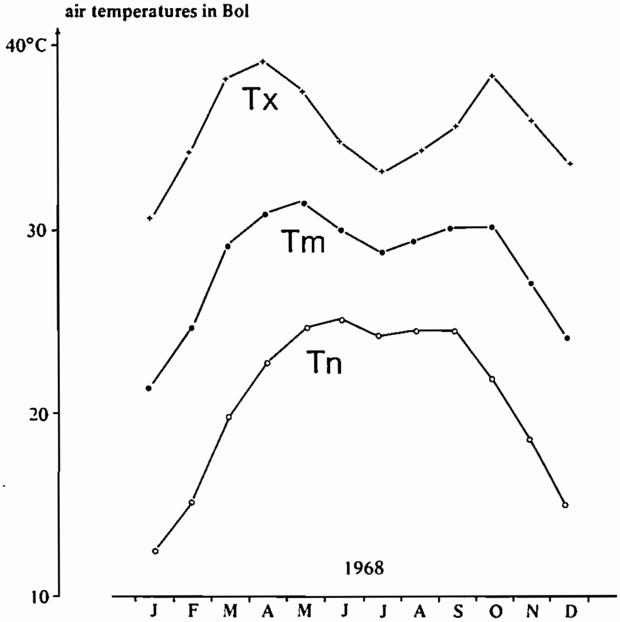


*Fig. 19* Air temperatures at Bol; Tx, Tm and Tn are respectively maximum, mean and minimum temperatures.

### 2.2.5 *The total incident radiation*

The annual average, the daily total incident radiation at the ground amounted to $2308 \times 10^4$ $Jm^{-2d-1}$ at N'Djamena from 1968 to 1973. It varies only slightly from one year to the other, and its seasonal variations are low in amplitude with a minimum of $2140 \times 10^4$ $Jm^{-2d-1}$ in January and a maximum of $2580 \times 10^4$ $Jm^{-2d-1}$ in March. Therefore, Lake Chad receives a relatively high irradiance with little variation in comparison with temperature zones (Fig. 20).

### 2.2.6 *Evaporation*

The different climatic parameters just examined lead to considerable evaporation through their characteristics of high wind frequency and intensity, high temperatures, low humidities and high insolation.

Evaporation, one of the main constituents of the hydrological balance was evaluated in numerous ways, according to different approaches. Annual estimations ranging from 2.10 to 2.20 m were made by Riquier (1963), Turc (1968) and Riou (1972) from theoretical formulae. Calculations from direct

Furthermore, the winds never lead to mixing of waters between the south and north basins.

The shape of the lacustrine basin, the arrangement of islands and shallows facilitate some movements and prevent others. Thus, the Great Barrier which is a shallow region covered with islands and reed islands acts against exchanges between the Southeastern and Eastern Open Waters and the Northern Open Waters. Similarly, in all the zones of archipelagos and reed islands, the islands and shallows which are generally aligned southeastwards and northwestwards act as a brake on water movements to the northeast.

Finally, the distribution of forces exerted on the major water movements (wind regime and river supplies) is practically the same from one year to another: the period of wind reversal occurs at the same time with a difference of 15–20 days and the period of the maximum Shari flood with a difference of 10 days. The occurrence of large water movements in the lake does not vary much from year to year but the sizes of the movements are variable and depend upon the strength of the Shari flood and the lake volume*.

These movements were shown by the study of distribution in space and time of sodium concentration in waters (Carmouze 1971, 1976) as well as that of the water conductivity (Roche 1973).

We will describe these movements over an annual cycle by taking as a starting point the period of June–July which is just before the abrupt occurrence of the Shari flood waters (Fig. 21).

### 2.3.1 *Water movements from mid-June to mid-August*

River supplies which are very low during this period (8% of the annual supplies) cannot cause water movements of great amplitude but their influence does become considerable at the end of July or at the beginning of August. The Shari waters enter the Southeastern Open Waters, however, without resulting in a major water renewal in the regions close to the delta.

However, water moves from the Great Barrier towards the Northeastern Reed Islands and Northeastern Archipelago. This water is pushed back by the water of the Southern Reed Islands and the Southern Open Waters which is driven by the southwest monsoon winds.

The other regions of the lake are not affected by large-scale water movements. In the Southeastern Archipelago, water penetration into the Southeastern Open Waters remains low. In the Northern Open Waters and the Northern Reed Islands, water movements are low in amplitude.

* During the period of 'Lesser Chad', the water circulation is totally modified as a result of the exudation of the shallows.

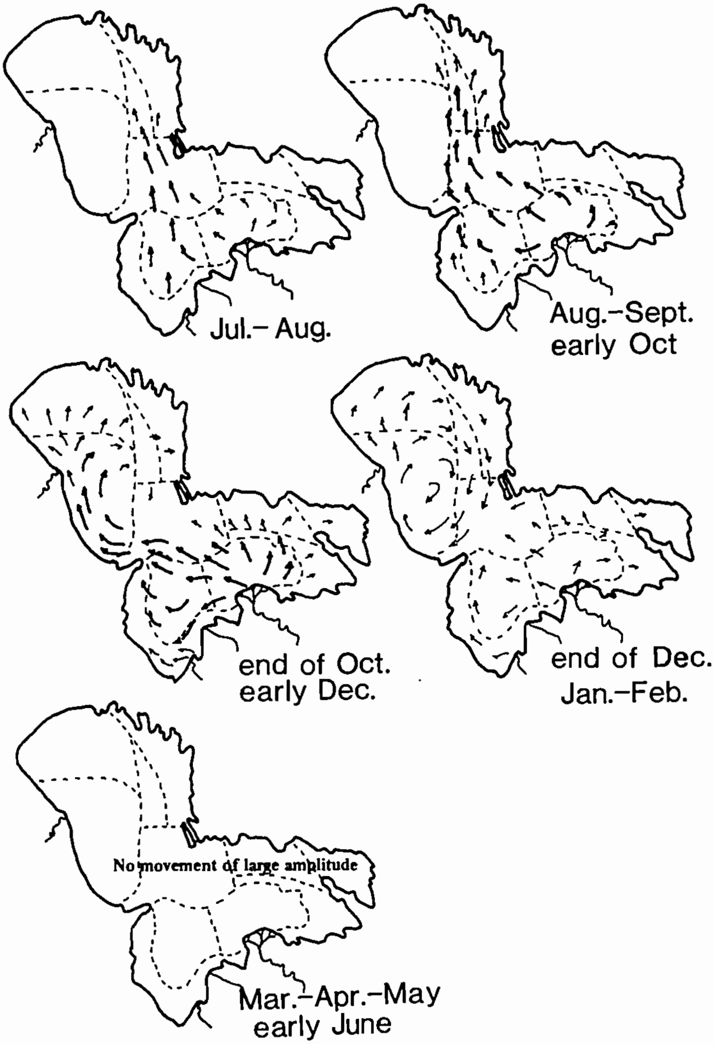


*Fig. 21* Water movements in the lake.

## 2.3.2 *Water movements from mid-August to early October*

During this period, the Shari water supplies, representing 15 to 20% of the annual river supplies, initiate a rise in the lake water level. The waters from the Southeastern Open Water pushed back towards the periphery without mixing new water with old one.

*Photo 6* General view of a saline lake in Kanem (northeast of Lake Chad).

water mass from the Northern Open Waters is pushed back towards the Northern Reed Islands, while water from the Northeastern Reed Islands mixes with newer water pushed the same way to the south of the Northern Open Waters.

So, in the Northern Open Waters, new waters take a circular course, while mixing with residual waters. This is favoured by environmental topography of the Island Barrier and Reed Islands of the Northern and Northeastern Reed Islands and the Great Barrier and by the influence of the harmattan.

### 2.3.5 *Water movements from March to early June*

At this time, water supplies become very low, representing 4 to 5% of the annual supplies, water movements are very reduced and the wind regime is unstable. This is a transitional period since the harmattan is gradually replaced by the monsoon.

Partial mixtures of waters from contiguous regions are caused by the Northern Reed Islands waters mixing with those from the Northern Open Waters, the Northeastern Reed Islands waters with those of the Northeastern Archipelago, the Southeastern Open Waters with those from the Southeastern

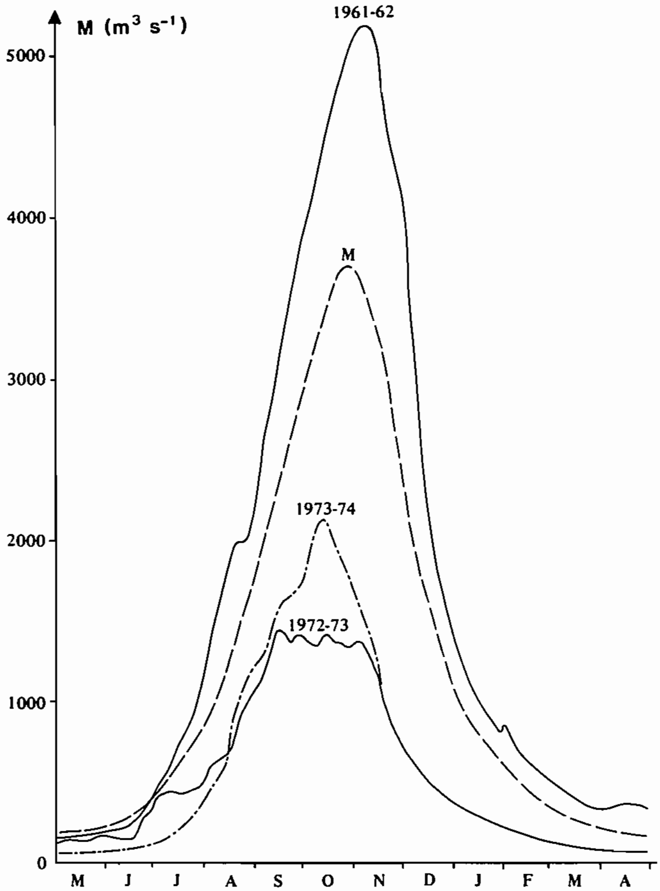


*Fig. 23* The Shari floods in N'Djamena.

## 2.4.2 *The Logone*

The hydrological regime of the Logone is different from that of the Shari, for the degradation of its bed in its lower course allows side discharges and distributary emissions on both banks during the flood period. On the right bank, there is a considerable discharge only upstream from Bongor, contributing to inundation of the plain between the Logone and the Shari mainly through the 'Grand Courant' which has its source downstream of Laï. Part of the water returns towards the high water bed slightly upstream of Logone Gana. During the period of high water, the Logone and the Shari are connected through the Loumia.

On the left bank, there are considerable discharges: the Logomatia brings back only a small part of the discharged water to the Logone forty kilometers further.

Thus, profound changes occur in the regime of the Logone because of the large losses along its course, resulting in a decrease in flow from upstream to downstream and a corresponding decrease in the peak of the flood is recorded (Fig. 24). The average flow of 578 $m^3 s^{-1}$ at Bongor decreases by 125 $m^3 s^{-1}$ at Kaboa and by 103 $m^3 s^{-1}$ from Kaboa to Logone Birni in an average hydrological year. It is obvious that in the case of low floods, these differences are less while they are increased in the case of high floods.

The result is an extraordinary stability at the junction of N'Djamena where the Logone flow varied from 47 to 360 $m^3 s^{-1}$ between 1953 and 1971 with an average of 387 $m^3 s^{-1}$, half that of the Shari.

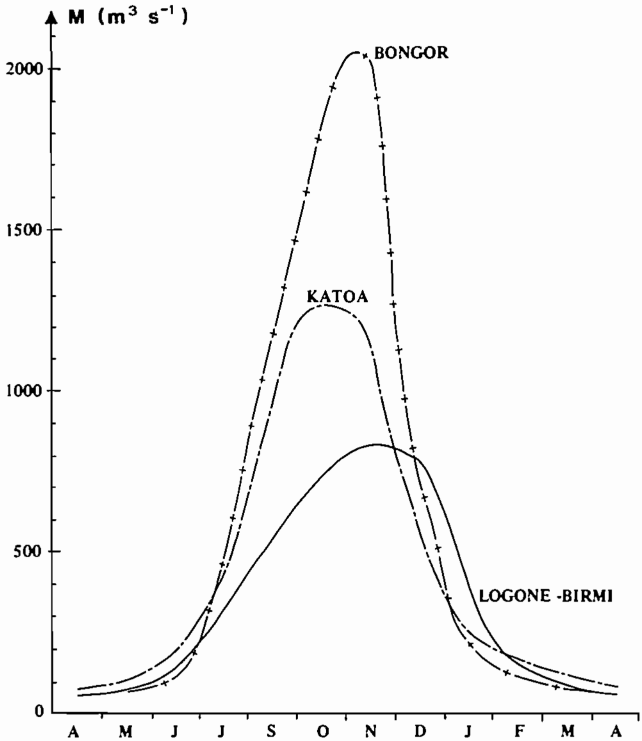


*Fig. 24* The Logone floods in Bongor, Katoa and Logone-Birni.

2.4.3 *Temporary environments*

(a) *The great flood plain in the North Cameroons.* A very large flooding zone or 'Yaéré' extends over about 5000 $km^2$ from the Logone and the Shari on the east to the Mandaras Mountains in the west and south and runs into Lake Chad on the north (Fig. 22). This plain is very vast, covered in places with hillocks that are usually artificial and occupied by Kotokos villages where the vegetation is mainly herbaceous. During the period of the river floods, it is immersed under 0.70 to 1 m of water. By mid-July on the average, the flooding regime begins with rainfall which, a month later, increases the water level by about 30 cm. Generally, the Logone inundation appears only in September. In December, waters subside and are collected by the El Beïd which flows into the southernmost region of Lake Chad.

(b) *The El Beïd and Yobé rivers.* Although the water supplies of these two intermittent rivers to Lake Chad represent only 5% of the total, they are important, especially the El Beïd, for the migrations of numerous species (Durand 1970, 1971, 1978; J. Hopson 1969, 1972) (Fig. 22).

The El Beïd flows only five to eight months in a year and is supplied by water from the plain in the North Cameroons. Its bed is 40 to 60 m in width and is composed of only a string of muddy ponds during the period of low waters from April to July. The first runoff from the Yaéré occurs during August and September and the flood reaches its maximum in December, when the El Beïd overflows its bed. It then subsides until the end of March. From 1953 to 1976, the average flow was 46 $m^3 s^{-1}$. The annual variations of 87.5 $m^3 s^{-1}$ in 1954–55 and 19.5 in 1955–56 and 1965–66 were great.

Throughout the periods of flood and subsidence, the transparency and the conductivity vary to a great extent according to the mixture ratio of two water masses of different origin. On the one hand, water from the first flood corresponds to the rainfall in July and August. This water is highly mineralized, resulting mainly from the dissolution of salts accumulated during the dry season. On the other hand, the Logone water has a lower conductivity of about 60 $\mu S\ cm^{-1}$ (Roche 1973).

The first ones prevail at the beginning of the humid season, the second ones at the end of the humid season. Transparency measured with Sacchi disc is never high and ranges from 65 cm at the beginning of the flood to 10 cm in February and 3 cm in May. This abrupt change corresponds to the arrival in the El Beïd of the last drainage water from the flood plain which is very rich in clayey materials.

The Yobé river whose flood occurs generally at the end of July and ends in April—May (Hopson 1972) also has an intermittent regime. The annual flow, very variable, is of about $0.6 \times 10^9\ m^3$ (Toucheboeuf de Lussigny 1969).

general water circulation is such that the renewal of water is increased by proximity to the Shari delta and by the river going through a period of flood from September to January. The first flood waters move towards the archipelago under the influence of the southwest winds up to mid-October. At that time, the harmattan, a northeast wind, takes over and changes the movement of the Shari flood waters towards the zones of open water. This change in direction allows a more thorough mixing of 'new' and 'residual' waters.

According to the rate of renewal of waters, it can be said that *the northern basin has a proper lacustrine appearance while the southern basin or at least its central zone has a more riverine appearance.* From this point of view the northern basin is more stable than the southern basin as long as the lake is not divided. This is not true during a severe contraction of the lake when the Shari no longer supplies the northern basin. It can then dry up either partially or totally over a short period of time, while the region connected to the Shari delta is always occupied by water.

The nature of the lake bottom varies considerably from one zone of the lake to the other. It is dependent mainly upon the distribution of solid suspensions from the Shari, which is itself dependent upon the general water circulation as well as the distribution among the macrophytic vegetation. Generally, the deposited materials are a clay facies in the zones of open water, a muddy facies in the zones of reed islands, and a clay-muddy facies in the archipelago zones. These three main types are subdivided into varieties. *Therefore, the nature of sediments is far from being regular and it leads to a strengthening of the spatial heterogeneity of the environment.*

In short, before dealing with the physical as well as chemical features of the waters, it is observed that Lake Chad is composed of a mosaic of biotopes, each of them likely to undergo profound modifications in time, even disappearing and reappearing according to the lake floods and recessions. Only the open waters of the southern basin do not disappear during the drying up periods.

All these environments are subject to the influence of a tropical climate. Rainfall, winds, air temperature, air humidity and evaporation are determined by the Intertropical Convergence Zone (ITCZ) which moves along a south–north line throughout the year. South of the ITCZ, a humid climate prevails and north of it, a dry climate. Continental winds such as the northeast harmattan blow over the entire lake in winter leading to the occurrence of drought from October to February–March, while the marine winds such as the southwest monsoons blow from June to September and are associated with rainfall. The lake is situated between the isohyets 550 mm in the south and 240 mm in the north and receives 50% of its rainfall in August. At that time, evaporation falls to a minimum of 16–17 cm per month, while in October–November, it increases up to 21–23 cm per month. The mean monthly air temperatures range from 29 to 32°C from March to October (with a minimum of 27°C in August) and from 22 to 24°C from December to February. Diurnal

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