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CONSEQUENCES OF UNCONTROLLED HUMAN ACTIVITIES IN THE BASIN OF LAKE VALENCIA

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I. INTRODUCTION

In the northern part of South America there is a lake about which much is being written and spoken. It is Lake Valencia, known in ancient times by the Indians as Lake Tacarigua. Located in the north central region of the Republic of Venezuela, it is the most important lake north of Titicaca.

What has happened to that lake over the past few centuries? Is it true that it is drying up? Is it true that it has become highly salinized? Such questions are frequently asked whenever the name of this beautiful adornment of Venezuela is mentioned.

The drying-up process of Lake Valencia is readily apparent to the eye. If you stand on the highway near Central Tacarigua, (a sugar mill located on the lake's western shore), and walk a short distance through the sugar cane plantations, or approach the shore from any point of the Maracay-Valencia highway (see map), it is apparent that, formerly, this body of water extended over a much broader area. One need not be an expert to appreciate that the fertile plains surrounding the lake used to be part of its bottom. Any peasant knows this. The myriad snail shells and other detritus of lake flora and fauna indicate it. In some places, the enormous quantity of snail shells is truly impressive (*) and invites research into the drying process.

In our investigations at the Institute for the Conservation of Lake Valencia we have sought answers to the following questions:

(1) Why is the lake drying up? Is this a natural phenomenon or an artificial one caused by man?

(2) If artificial, when did it begin?

(*) Among the various snails represented, the most abundant species is that of biomphalaria prona, of the PLANORBIDAE family, and its shells comprise almost all of these impressive layers. This mollusk is native to the area (12).

(3) What was the height of the surface of the lake prior to the beginning of the drying process?

(4) How did this phenomenon take place?

We will answer these questions one by one.

II. GEOLOGICAL RESEARCH

First, we will report the results of the most recent geological research on the lake.

Modern geologists tell us that, hundreds of thousands of years ago, there was a mighty river in the area now occupied by Lake Valencia. It was funnelled between the Coastal Range and the recently formed Interior Range and flowed in an east-west line. Naturally, this river did not have a name; at that time, there was no one around to name it. It was not until our times, much after it had ceased to exist, that it was christened "posthumously" by Armande Schwark Anglade (33), a Venezuelan geologist, and Lee Peeters (27), his Belgian colleague, who discovered its existence.

Subsequently, there was a geological change: west of the present lake, the subsoil rose and the ascending rocks formed a barrier. This phenomenon put an end to the ancient river and led to the formation of a lake. The lake was not the Lake Valencia of our times but an ancestral one which, following a series of changes, finally became the mirror-like body of water that we know today. Over thousands of years, this original lake changed considerably in both size and shape, as well as in the level of its waters. Because of several geological and climatological changes it alternately grew and shrank. However, one should not think in terms of abrupt changes or cataclysms. Generally speaking, geological changes are infinitely slow and the time factor plays the principal role. For example, if, in a given place, the earth layer is rising at the rate of one millimeter per year, after one million years a majestic one thousand meter-high hill will stand there.

We cannot see such changes obviously, because our life span is too brief. In the face of such phenomena, we are like butterflies and the solar cycle. Butterflies will never know that the seasons of the year renew themselves periodically, because their lives are ephemeral. In the eyes of these small adornments of Nature everything seems static -- and so it is with man in relation to the succeeding geological changes. It is as though we were small butterflies. We regard the mountains as symbols of strength and stability whereas, actually, such is not the case; they are formed, grow, and they disappear as does everything in this immense and marvellous universe.

Lakes, too, have their lives, are formed, and die; in Nature nothing is immutable. Generally speaking, lakes tend to dry because of the periodic accumulation of sediment on their bottoms. However, this is a very slow process. According to the estimates of Oswalde De Sola, a thousand years must elapse for the bottom of Lake Valencia to rise one meter from deposition of the solid substances poured into it from tributary rivers (13 and 14).

III. MEASURABLE CHANGES

But let us return to the world of perceivable happenings. We have stated that the size of the lake underwent great changes. But we also said that the geological and climatological factors that determine such changes are infinitely slow and consequently, invisible to us. Then how is it that we witness very evident changes at present -- changes that are readily visible and phenomena that unfold before our very eyes over so short a period of time as a few years? For example, there is the case of Club Náutico and the "Terminal del Lago" restaurant which are located south of Maracay. Constructed barely ten years ago on the waters, today they are in ruins and nobody thinks of rebuilding them because the lake has moved hundreds of meters away from their location. In 1953, when the project for the construction of Avenida del Lago, which connects Maracay with these installations, was initiated, the average lake level for that year was 408 meters above sea level. Today the level is less than 405 meters. A lake depth of over three meters was lost in 15 years! Another example: Alfredo Jahn (20), who initiated systematic studies of Lake Valencia, published a map during the closing decade of the last century on which La Culebra Island appears approximately three kilometers from the western shore of the lake. Today that island no longer exists because the receding waters left it high and dry, joining it to the land mass.

The conversion of Chambergo Island into a peninsula is an even more recent example. Nowadays, the "flight of the shore" -- an expression found in Humboldt's work (18) -- is so rapid that Chambergo still appears as an island on even the most modern maps. On the latest 1:100,000 map of Lake Valencia published by the National Cartographic Service in 1965, Chambergo appears as an island.

IV. THE HYDROLOGICAL BALANCE

What is the reason for this truly alarming phenomenon? In order to answer that question, let us analyze the hydrological balance of the lake briefly. Three situations may exist: A surplus, an equilibrium, or a deficit of water. Mathematically speaking:

$$A + B + C - D - E \gtreqless 0$$

In which:

A = the contribution of the tributaries

B = direct precipitation on the surface of the lake

C = the contribution of subterranean waters

D = the evaporation from the surface of the lake and evapo-transpiration from the

E = possible filtration outside of the basin

Where the volume of the positive components is greater than that of the negative ones, there is a surplus. In such circumstances, the watershed is not independent, and the surplus waters of the lake flow toward the sea.

When the outflow of water is equal to the input, the system is said to be in a condition of equilibrium. The level of the lake remains stable. In this case there is no communication with the sea; the watershed is endoreic.

In the third instance, the input is not sufficient to offset the losses. The negative elements are predominant; there is a deficit. Consequently, the level of the lake begins to drop.

V. ANALYSIS OF THE BALANCE

Formerly, the hydrological balance of Lake Valencia was positive. The surplus waters drained away toward the Orinoco River. Today, the very opposite situation exists; the drop in the level of the lake that has been observed for some time now indicates that the equilibrium has been upset and that the balance is negative.

Two questions arise: What caused the deficit? In which components have changes taken place?

Before answering these questions and analyzing the components one by one, we should make some general observations. First, in our time there has been no major climatological change. A few decades ago, when the above-mentioned La Culebra Island was three kilometers from the shore, the values for evaporation and annual precipitation were practically identical with those of today. Thus, if the values of the elements comprising the hydrological balance did change, it was not as the result of climatological changes. Likewise, since the region was first populated there have been no natural cataclysms. Furthermore, modern geologists discard the hypothesis that fissures in the base of the basin may be the cause. Consequently, the supposition that the present drying process of the lake is the result of natural causes may be discarded.

Let us first consider two negative components of the balance -- evaporation and possible filtrations of subterranean waters. With reference to the latter, research carried out by Tamers and Thielen (34) indicates there is no such leakage. Despite the fact that the basin is open on the eastern and western sides no water escapes. On the eastern side, the subterranean waters flow slowly toward the lake, while on the western side they have remained immobile for nearly 14,000 years, according to age measurements by Carbon 14. In the case of evaporation, the other negative element in the equation, the volume being lost at present, is less because the surface of the lake has decreased. Thus, if the balance is negative, there must be an even greater decrease in the input. Analysis of these components shows that the cause of the problem must be <u>the reduced contributions of the tributaries</u>, because the other two components cannot be blamed. The precipitation value has not changed, and if there has been a decrease in the surface on which rain falls at present, the also decreased volume of evaporation is offsetting that loss. With regard to a possible change in the volume of the subterranean waters that flow toward the lake, the general opinion among researchers is that this factor is secondary compared to the contribution of the tributary rivers, and that the cause of the imbalance does not lie there. Only Tamers and Thielen hold an opposite view. In their opinion, the drop in the level is due to a climatological change which took place in the region some 6,000 years ago. Prior to that time there was greater precipitation. Since the subterranean waters filter toward the lake very slowly, the last of the rain that fell 6,000 years ago reached the lake only a few centuries ago. Since there has been less rainfall, the volume of subterranean waters that reaches the lake is likewise smaller and, according to them, has caused the drying process. This theory is strongly contested at present.

VI. THE IMBALANCE CAUSED BY MAN

Adhering to the majority opinion, the Instituto para la Conservacion del Lago de Valencia believes that the drying process was not caused by some remote climatological change, but that it is due to the fact that the present contribution of the tributaries is only a fraction of what it was in ancient times. Actually, none of the tributaries today deserves to be called a river. They have become wadis which bring water to the lake only after torrential downpours, and are dry during the rest of the time or constitute pestilential sewers.

At this point, in answering the question "why has the contribution of the rivers decreased so markedly?", we see that we are actually accusing man. The deterioration of Lake Valencia is not of geological, but of human origin. The accusation is explicitly addressed to the careless and irresponsible heirs of the discoverers and colonizers of the region. The lake suffers from a decrease in the volume of the tributary rivers as a consequence of human activities carried out with neither planning nor control.

At this point we should like to quote what Alexander von Humboldt, the distinguished naturalist, wrote in 1800: "Until the middle of the last century the mountains that surround the valleys of Aragua were covered by wild forests. Mighty trees of mimosa, ceiba, and fig cast their cool shadows over the shores of the lake....With the growth of agriculture in the valleys of Aragua, the small rivers that feed Lake Valencia can no longer be considered as tributaries during the six months following the month of December. Downstream, their volume thins out because the planters of indigo, sugar cane and coffee have opened many irrigation ditches in order to water their lands."

Therefore, it may be stated that the "A" component of the equation -- the contribution of the tributaries -- has decreased because a) the waters are used in an unplanned manner for farming and industries; and b) indiscriminate deforestation -- a veritable pillage of Nature -- has destroyed a considerable part of the Lake's upper watershed.

Irrigation is necessary. Consequently, it is enevitable that the lake will be deprived of some of the waters which reached it prior to the expansion of agricultural activities. However, much of the present waste of waters can be avoided. Some irrigation systems operate with particularly great waste. These irrigated lands become swamps in which mud flourishes instead of corn. Thus the lake is deprived of waters while these same waters usurp farmlands, converting them into unhealthy wastelands.

VII. THE BEGINNING OF THE DRYING PROCESS

Having recognized the fact that the drying process is the result of artificial causes, we are no longer so bewildered in trying to determine when the process began, because we need not go back to nebulous pre-Columbian times. Furthermore, various quotations from scientific works on the region provide helpful guidelines. For example, there is the monograph of E.W. Berry (4) who studied the system of terraces and declivities molded by the waves of the descending lake on the La Cabrera Peninsula. On the basis of an analysis of human and animal remains found in the area, Berry concluded that the age of the soil here is at least four centuries. Other more precise indicators can be found in the descriptions of Humboldt (18) and Codazzi (9). Humboldt's comment is quite interesting. Despite the fact that the valleys of Aragua are among the areas of Venezuela that were populated from the earliest post-Columbian times, none of the ancient chroniclers mentions a drying process, and Humboldt wonders whether one should suppose that this was due to oversight. We doubt this, particularly if one considers the "History of the Province of Venezuela" by Oviedo y Baños (26), which contains a rather detailed description of the lake. The withdrawal rate of the shore is so remarkable and has given rise to so many comments in recent historical times that it surely could not have escaped the attention of "the First Historian of Venezuela" who spent almost his entire life in Venezuela.

The work of Agustin Codazzi, the noted geographer who explored the region from 1830 to 1840, has provided us additional guidance. Confirming the observations of Humboldt, Codazzi stated: "The experience of nearly a century has demonstrated that the level of waters is not constant and that the equilibrium between evaporation and the waters that feed the lake no longer exists."

These and other references indicated the desirability of finding an author who had made observations on the lake during the first half of the eighteenth century. Fortunately, we found one -- Antonio Manzano, an alderman in the city of Nueva Valencia del Rey. Apparently, Manzano was both an amateur natural scientist and a good observer. He explored the regions around the lake and left a geographical description of them. Manzano compiled the first data relative to the depths of the lake, data praised by Humboldt for their accuracy. However, neither these "soundings carried out with the greatest care by Don Antonio Manzano" nor those of Humboldt himself provide sufficiently accurate data for forming some idea of the topography of the bottom of the lake.

First of all, their measurements were sporadic and, secondly, the data that they obtained was often contradictory and inaccurate. For example, if we were to accept the maximum depth indicated by Humboldt -- 40 fathoms, equivalent to 67 meters -- we would be led to the absurd conclusion that in 1800 the level of the lake was six meters higher than the benchmark of the El Paíto gorge. The first accurate map of the bottom of the lake, which is based on the bathymetric survey carried out under the supervision of Roberto Alvarez in 1965 (1), appeared over 200 years later.

Now, in the "Prose Map" -- the title given by Manzano to his description -- we find a clear reply to our question. According to Manzano, the decrease of the surface area of the lake began in 1727, "because I saw its waters flow into the

Maruria River (alias El Pao)." Elsewhere (23) he states: " ... prior to 1727 it drained off in the same place and it was possible to sail as far as that river (Pao)." Acceptance of that date is strengthened by Humboldt's observation that Oviedo had not referred to the drying process. Oviedo's history was written in 1723, that is, 4 years prior to the observations of Manzano.

It is remarkable that, in Manzano's description, we find a criticism of human activities that were to profoundly affect the ecology of the lake. This keen observer complained about the large number of irrigation ditches which deprived the lake of much water. He stated that the mountains were being sterilized by land-clearing operations and that during certain months of the year "the rivers suffer because of the lack of water." These words were written two centuries before the beginning of the conservation movement in Venezuela! (*)

VIII. THE SALINITY OF THE LAKE

By accepting Manzano's information on the start of the drying process, the decline of the lake began two and one-half centuries ago. This finding has been well corroborated by the research findings of Oswaldo De Sola, which are based on the constant increase in the salinity of its waters.

Formerly, when there was a positive hydrological balance, and the waters of the lake flowed off through the El Paíto gorge, its waters were constantly renewed and were sweet and clear. Their saline content did not change and was equal to the average of the tributaries. However, following conversion of the lake into an endoreic system, the situation has changed radically. The salts reach the lake

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(*) At present, in behalf of the Institute for the Preservation of Lake Valencia (Instituto Para La Conservación del Lago de Valencia), Luis Auguste Arcay is in Spain, searching the archives for biographical data on this obscure personage.

in small quantities dissolved in the waters of the tributaries. In the lake the surface waters undergo the effects of evaporation. As the water evaporates, the salts remain and, in a closed system in which the waters cannot be renewed, this results in continuous salt storage.

According to De Sola, the salinity of Lake Valencia increases each year at a rate of 3.4 parts per million (13 and 14). By comparing total salinity and original salinity he concludes that the imbalance began approximately 250 years ago. Since that time, the salinity of the lake has increased eightfold.

A little over a century and a half ago, Humboldt found that the waters of the lake were still clean. He explored the region toward the end of February and the early part of March in 1800 and wrote: "The water of the lake is not salty as they claim in Caracas. It can be drunk without being filtered. When evaporated, it leaves a very light residue of calcium carbonate and perhaps some potassium nitrate. Even then it is surprising that a lake in the interior of the country should not be richer in alkaline or clayey salts drawn from the surrounding soil" (18). Humboldt's description is further evidence that the drying of the lake is a relatively new phenomenon; if the region had been endoreic for many thousands of years, the saline concentration of the lake would have been much greater by the time of Humboldt's visit. For example, the case of the Dead Sea comes to mind; in these waters, over the millennia, salinity has reached a level of concentration ten times higher than that of the oceans.

It is difficult to fully appreciate the changes in the salinity of Lake Valencia over the one and a half centuries since Humboldt. In order to do so, we present the following table which was prepared recently by researcher Octavio Jelambi on the basis of a study performed by Pérez Lecuna (28), which shows a constant increase of salinity in the lake:

Year	1920	1939	1950	1960	1966
Brackish solids, ppm	785	935	1,012	1,050	1,270
Sulfates, ppm	-	324	372	400	478

IX. THE LEVEL OF THE LAKE IN 1800

We have devoted a long section to this question in order to correct a series of confused ideas originating in erroneous data that appears in the books entitled "The Drying of Lake Valencia" (El Desecamiento del Lago de Valencia) and "Forum for Preservation of Lake Valencia" (Forum Pro Conservación del Lago de Valencia) (5 and 6). If we wish to know the level of the lake in 1800, we must consult Humboldt's work (18). The data are of two types: absolute levels originating in geographic descriptions and barometric measurements, and relative levels based on lake-level changes indicated by the scientist between the surface of the waters and certain points located on the shore, or on the elevation of one of the islands above the level of the lake.

The barometric data and levels originating in geographic descriptions are extremely inaccurate and contradictory and consequently should be discarded. In Humboldt's work we have found five items from that source which, when converted to the metric system, vary from 413.2 to 432.7 meters. This variation is understandable if we consider that even today, when we have more accurate instruments, the altimetric results obtained through isolated observations (without simultaneous readings at the two points being compared) may be subject to errors of the order of $\pm$ 20 m (32).

On the other hand, the data in the second group are absolutely reliable. Generally speaking, the measurements involved are small ones in which any error committed is of secondary importance. After having determined the absolute benchmark of these points and subtracting from them the aforementioned differences in levels, we can determine the benchmarks of the lake on the corresponding dates. Consequently, if the points indicated by Humboldt were clearly defined and are identified accurately, we can determine correctly the levels that existed in 1800.

Of the points whose relative levels were indicated by Humboldt with reference to the level of the lake, that of Las Piedras Island was the one that we found most noteworthy because of the accuracy of the absolute benchmark that it provides. On the basis of Humboldt's description we know that, in 1796, east of the island of Caigüire, three new islands emerged as a result of the drying process, which the people christened as Nuevos Peñones, Aparecidas, or Las Piedras. In 1800 when Humboldt explored the region they had an average elevation of one foot above the water level. In the course of our work we have become accustomed to referring to them as Peñones de Humboldt because he was the first one to mention them in the literature of science. Inasmuch as the error that Humboldt may have committed is insignificant, the Peñones seems the most appropriate point for placing the level corresponding to 1796 and 1800, without any error whatsoever.

With the help of Humboldt's work, plus the description and map of Jahn (20), we tried to identify these islands. We harbored some doubts because Humboldt referred to <u>three</u> islands and, in the place indicated by Jahn, we found only one. However, we felt this might be explained by the fact that, in 1800, when the top of the rocky island was barely level with the water, only three summits were visible, whereas today, with the further withdrawal of the waters, they form a single unit.

Our doubts vanished when, in determining the absolute benchmark of the apex of the island, we coincided exactly with the value found by Jahn. We then subtracted one foot from the top, thus reaching the conclusion that, in 1800, the surface of the lake waters was at the 416.5 m. level. Furthermore, knowing that in 1796 the level was one foot higher, we inferred that, at that time, the rate of descent of the waters was approximately 8 cm. per year. Unfortunately, through incurring the same error as Jahn, we were mistaken in our identification of this point (which was verified in 1951), and this led to a series of misunderstandings among researchers in subsequent years.

Some investigators, such as José Royo y Gómez and Octavio Jelambi, doubted the accuracy of the identification from the very outset, feeling that there was no possibility of three summits emerging in the form of the Peñones de Humboldt. Intrigued by this uncertainty and now acquainted with other data submitted by Jelambi (21), in 1967 we again explored the region. On the eastern shore, we found three small rocky hills located on the line that connects the islands of Tacarigua, Otama, and Zorro with the island we had erroneously christened as "Peñones de Humboldt." At present, these three small hills are on dry land, but the peasantry still refer to the point as "La Isleta" or "La Isla." This circumstance explains the error that we committed in 1951; we were seeking an island, and it never occurred to us that we might find it on dry land. On the map prepared by Antonio Nuños Tébar and published in 1919 by Vicente Lecuna, the Peñones still appear as an island called "La Isleta," located east of La Piedra.

These three small hills are located on a straight east-west line and are separated from one another by a distance of 60 and 290 m., respectively. Humboldt's description fits these small hills perfectly: there are three of them and their summits are "absolutely level." After determining their heights, we obtained the values of 422.77, 422.68 and 422.39 m. It would be a rare coincidence for three new natural formations to have practically the same heights as the islands Humboldt observed.

Taking the average height of the three hills and subtracting the data indicated by Humboldt, we may state that, in 1800, the benchmark level of the lake was approximately at 422 m. above sea level.

X. EL PAÍTO LAGOON - MAXIMUM ELEVATION

A study of the topography in the vicinity of the lake shows that the basin has an outlet to the west. The gap is located approximately 10 kilometers south of Valencia, at a place known as El Paíto (see map). Absolute elevation at this point is 426 meters, the maximum level for the current geological era. It could never have been any higher, since any excess drained off through this natural spillway.

Consequently, when the hydrological balance was positive and the lake was full, the water surface must have reached this point, and from this site the surplus must have flowed to the Orinoco River. Indeed, this is confirmed by the account of Manzano, who says, as we saw in Chapter VII, that of his own knowledge, up to the year 1727, the lake drained at this point into the Pao River.

At first glance, the El Paíto region appears to be a plain, but a topographic survey illustrates the actual configuration of the terrain, which is a pass with gently sloping sides, much like a flattened saddle. In the exact center of this pass there is today a lagoon known as El Paíto. Few bodies of water in the world are as strangely situated as this lagoon, for the ground formation is such that, on a north-south line, the lagoon occupies the lowest point, but in an east-west direction it is the highest point of the terrain. As a result, water flows into the lagoon from the north and south and runs out east and west. Water flowing eastward reaches the lake, while the runoff to the west flows through the Paíto, Pao, Portuguesa, and Apure Rivers to the Orinoco. Therefore, water from the Cabriales River flowing into this lagoon is divided between two hydrographic systems, that of the lake and that of the Orinoco, respectively. It may be incorrect to say that water from the Cabriales River flows into El Paíto Lagoon, since it actually spreads out or disperses upon reaching it, due to the fact that the river lost its outlet when the shores of the lake receded from this point.

But it is not only the unique topographic situation of El Paíto Lagoon that attracts our attention. It has another outstanding feature, and a very unfortunate one, as it happens. Flying over in a helicopter, we realize that it is a swampy, unhealthful area whose stench rises hundreds of meters above the ground. "Homo destructor" has transformed the Cabriales River, whose beauties in earlier times were a source of inspiration to painters and poets, into a sewer conducting the sewage of Valencia to El Paíto. This city of 250,000 inhabitants, in the midst of a population explosion (in 1948 it included only 50,000 inhabitants), still lacks a treatment plant. As a result, El Paíto Lagoon is now a vast "hothouse of microbes."

XI. THE OLD SHORELINE

As we have said, up to 1727 the level of the lake remained at the height of El Paíto Lagoon. Considerable evidence to substantiate this statement exists. Traces of the old shoreline found around the lake are all at approximately the same height. They lie between 426 and 427 meters above sea level, coinciding with the absolute elevation of the El Paíto opening. Here is some of the evidence:

a. Let us choose any flat part of the shore, for example, some place south of Maracay, north of Güigüe or south of Guacara. If we trace a line there, perpendicular to the shore, and take a grading along this line, it will provide us with a transverse section of the shore. Examining this section, we will observe a change in the slope at a height of about 426 to 427 meters. From this point to the lake, the incline is steeper than the slope from this spot inland. This point marks the height of the old shoreline. One of these contours is now outlined by the avenue running from Maracay to the abandoned Club Náutico. Traveling along it, the place where the slope changes can be seen at a glance.

b. There are lacustrine deposits along this former shoreline in a number of places. For example, layers of diatomaceous earth* have been discovered south of Guacara and on the peninsula of La Culebra (14). Again, we find that the upper edge of the layer ends at a height of approximately 426 meters in every case.

c. If we walk inland from the shore, at any place where there are many snail shells such as those mentioned in the introduction, we will find a place

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* Soil formed by accumulating layers of the remains of microscopic plants.

where the lacustrine deposits end. These deposits invariably reach to a height of 426 to 427 meters. None are to be found any higher. Again, this corresponds closely to the elevation of the El Paíto gap and offers further proof that the lake used to run off at that point toward the Orinoco.

d. Finally, we shall mention an argument put forth by Prof. Fritz Gessner (16), regarding the "Snail Zone." Gessner says that in every lake with a comparatively stable level, there is a much larger accumulation of dead snails at one certain depth than at any other depth. The depth at which this snail zone is found depends on a series of local factors; at Lake Valencia this depth should lie between 15 to 25 meters, or at an average of about 20 meters below the surface of the lake. However in 1952, Gessner located this belt at a depth of only four meters, indicating that, at the time the snail zone was formed, the water level must have been 16 meters higher than at the time he found it and must have remained there long enough to allow this belt to form. If we add these 16 meters to the 1952 level, we arrive roughly at the absolute elevation of El Paíto. The age of the samples gathered by Gessner was determined by the Carbon 14 method, indicating that this debris was deposited at the bottom of the lake around 250 years ago.

During the most recent (at the beginning of 1968) limnilogical studies conducted by Professor Gessner, at the invitation of the Instituto para la Conservación del Lago de Valencia, we became aware of a curious phenomenon. Gessner was taking temperature sections of the lake water at various sites. He discovered that the surface temperature averaged approximately 27° C. This is the normal value for an endoreic tropical lake. (Measurements by Octavio Jelambi recorded the following values for surface temperature: 1959, center of the lake, 27.1° C.; 1964, average value of 40 readings at various sites, 27.1° C.)

We recall that Humboldt gives a much lower temperature reading in his book. "The temperature of the lake surface," he writes, "during my stay in the Aragua valleys, was a constant 23° to 23.7° in the month of February." In order to ascertain the authenticity of this sentence, we have consulted the original French edition of Humboldt, published in 1814 (17), on the assumption that some error might have been made in the Spanish translation. But this consultation confirmed the fact: the figure is correct and given in centigrade not Reáumur degrees. This was further confirmed by the Geography of Codazzi (9). Page 90 of Volume I contains a table showing the temperatures in centigrade for various lakes, lagoons, and rivers of Venezuela, with the following important note: "The observations have been made at many points and for weeks at a time during various navigations of the rivers and lagoons, all at different hours and times of year, taking care to reconcile them in order to obtain the most approximate knowledge of the average temperature." This table gives 23 to 23.5° C. for Lake Valencia.

According to these data, the temperature of the lake has risen about 4° C. since the beginning of the last century. Further details would have to be known about the measurements made to be absolutely confident of this fact. But the data is substantial enough to start one thinking and to prompt further investigation. It must be taken into account that these historical measurements are not haphazard results; on the contrary, they carry considerable weight. On the one hand, there is the temperature indicated by Humboldt and confirmed by Codazzi, two world-renowned observers, and, on the other hand, the result of Gessner's measurements, confirmed by Jelambi, two internationally recognized scientists and no less meticulous in their observations than the first two. Furthermore, on both occasions, in the last century and now, these measurements were not sporadic but averages derived from a great many readings.

This data could be additional evidence that the drying up of the lake is a comparatively recent phenomenon. At the time when the balance of the lake was positive and its water was constantly replenished, the mitigating influence of the tributaries must have been greater than today. (Unfortunately, we have been unable to compile data on the temperature of the tributaries to date.) It would, of course, also be necessary to take into consideration the possible effect of forest destruction in the basin on any change in temperature.

XII. CONTRADICTORY OPINIONS

In recent years, especially after establishment of the Instituto para la Conservación del Lago de Valencia (2-4-1968), many new studies of various types have been carried out. (See the compilation entitled "Bibliografía del Lago de Valencia" (7), published in 1966.) These studies have supplied so much supporting evidence that today no one doubts that at one time the lake remained for many years at the height of 426 meters. The controversy begins when the questions are asked: "When?" and "In what era?" In our opinion, the arguments and proofs presented in this paper are more than sufficient to defend the thesis that the drying up began in the year 1727, as observed by Manzano. However, there were and still are opponents of this thesis. Yesterday they held the opinion that in the last century the waters of the lake still ran off to the Orinoco; today they set up a very remote date (thousands of years back) for the beginning of the desiccation.

The most authoritative spokesman for the first group was the late Puerto Rican agronomist Carlos E. Chardón, who, rejecting the evidence presented by Jahn (20), deduced from a series of historical accounts that after Humboldt's journey the lake returned to the level of the gap and remained at that height until the second half of the twentieth century (11). In our book "El Desecamiento del Lago de Valencia" (5), we have devoted two chapters to demonstrating the impossibility of this thesis. At the present time, no one is willing to defend this idea.

The other band of authors protests the existence of a level of 426 meters for the year 1727 and establishes a much more remote date for the start of desiccation. These authors belong to two branches of science: archaeology and edaphology. In the first group, we will mention José M. Cruxent, Irving Rouse, and Alfred Kidder, and in the second, Justo Avilán.

The bed of the lake contains a wealth of Indian relics. Many of the vestiges of the aboriginal settlers are found adjacent to the old shoreline, a few meters above the 426-meter elevation. The Los Cerritos mounds south of Los Guayos [where the Instituto de Antropología e Historia of the State of Carabobo, directed by Dr. Enriqueta Peñalver, is carrying out important excavations (19)] also follow this contour line indicating the ancient shoreline of the lake at its original high-water mark. But not all of the findings come from points located higher than the El Paíto gap. In some sites, archaeologists have found Indian traces below this height (10 and 22). And since the Indians whose remains were discovered in these sites lived long before Lieutenant Antonio Manzano, the archaeologists maintain that by 1727 the surface of the lake could no longer have been at the height established by us. This led Cruxent to form a poor opinion of our research with De Sola (10).

The other opposing argument is based on the edaphological studies conducted by Avilán (2). According to these, it is concluded that the soils lying below the 426-meter contour line down to a height of about 417 to 419 meters could not have been covered by water up to the beginning of the next-to-last century, since these soils required thousands of years in a dry location for their formation.

Avilán's thesis, that the process of desiccation of the lake must have been initiated thousands of years ago, was corroborated by a convincing diagram prepared in 1966 by Laura Montesinos, Julio A. García, Luis A. Rotundo, and Lorenzo Caldentey (24). The cornerstone of the argument accompanying this diagram is the height of the Peñones de Humboldt, which shows a level of 416.5 meters for the year 1800. According to this reasoning, it is difficult to believe that the lake dropped by 9-1/2 meters between 1727 and 1800 -- that is, a loss in the assumed first 73 years almost equal to the loss recorded in the subsequent 166 years (11 meters from 1800 to 1966) -- since the rate of drop during the last century was much less than at present, and it is logical to assume that in the next-to-last century it must have been even less. In other words, moving backward from our time to the era of the beginning of the drying up, the values of the rate of descent decline. Consequently, during the Manzano-Humboldt period, the drop must have been much less. Extrapolation of available data from 1966 to 1800 gives a height of 417.5 meters for 1727, which is consistent with Avilán's data. This line of reasoning concludes that Manzano's testimony in 1727 (that the water of the lake drained out at El Paíto) could be mistaken, since the topography of that area is difficult to interpret even now, despite the availability of much more accurate methods and instruments today than 250 years ago.

But we already know that this diagram supporting Avilán, and therefore Cruxent, Rouse, and Kidder as well, is based on an error for which we ourselves are responsible. For we indicated a mistaken elevation for 1800, as we explained in Chapter IX. With the correction noted in that chapter, the diagram is no longer valid and cannot serve as additional proof. However, the evidence presented by Avilán and Cruxent remains.

The arguments of the archaeologists and edaphologists cited are persuasive and contradict the existence of a level of 426 meters for 1727. But in that case, how are we to interpret the other group's confirmation of the opposite? Here we have arrived at some disconcerting contradictions. What are we to believe? What is the truth? The investigations of the geologist Leo Peeters provide an interesting answer to these questions and reconcile the contradictions. According to Peeters (27), there was a period during the Pleistocene age when the climate in certain areas of South America was semiarid. Consequently, the level of the lake was low at those times. During this period, which covered thousands of years, the soils examined by

Avilan were able to form. Then, as the climate gradually became more humid, the level began to rise. At that time, when the hydrological balance became positive, the first settlers appeared in the basin. The level continued to rise slowly, flooding the soils in question and annihilating the first Indian settlements cited by Cruxent, until the lake finally reached the El Paíto spillway, where it necessarily stabilized. At this height, within historical times, the present drying up of the lake began, caused by man the destroyer.

By 1800, as we have seen, the lake had already lost four meters in height. And the level continued to drop. Sixty-seven years later, in August 1867, a traveler from the United States, Henry Myers, found a 40 foot difference of elevation between the old outlet at El Paíto and the water surface at that time (25).

XIII. DIAGRAM OF LEVELS

The following chart shows the fluctuations in level from the beginning of desiccation to the present day (Fig. 1). In this diagram, the years are marked on the abscissa and the levels (their absolute elevations) on the ordinate.

The points utilized for this representation are presented in Table I.

TABLE I.

Year	Span (years)	Height s.n.m. (annual averages in meters)	Partial drop (meters)	Rate of descent cm/year	Notes
1727		426			Start of desiccation according to A. Manzano
1800	73	422	4.0	5.5	Journey of A. Humboldt
1867	67	413	9.0	13.5	Visit of Henry M. Myers
1892	25	413.5	-0.5	- 2.0	First year recorded by Jahn
1939	47	410.9	2.6	5.5	Last year recorded by Jahn
1949	10	408.5	2.4	24.0	Observation by A. Böckh
1967	18	405.6	2.9	16.0	Data of Ministry of Public Works

Total years: 240

Total descent: 20.4 m.

Rate of descent (average): 8.5

It must be stressed that this graph is no more than a sketch to demonstrate, in broad outline, based on historical sources and direct measurements in the field, the progressive ruin of the lake; this answers the question posed in our introduction: is it true that the lake is drying up?

As shown in the limnogram, up to 1727, the lake level held steady at an elevation of 426 meters, the height of the El Paíto gap. After that, the progressive decline of the lake began. Even omitting the data prior to 1892 (which continues to be a subject of discussion by some research workers) we see that what has happened in the last 75 years can only be termed catastrophic. For from the first gradings taken by Jahn in 1892, up to 1967, the level has dropped eight meters. And today no one can doubt the accuracy of Jahn's measurements. Here is an example of just how accurate they are: Jahn established a point of reference on the shore of the lake near Tapatapa, in Requena Park. To check its height, we chose a nearby point recorded in the Cartografía Nacional, whose absolute elevation was determined in 1963 by means of a highly accurate grading running from La Guaira to Puerto Cabello. Surveying from this benchmark to Jahn's point of reference, we found that there is only two centimeters of difference between the height indicated by him and that measured by us.

A detailed limnogram showing intermediate points between the dates appearing in our graph would demonstrate more clearly the fluctuations in level that have occurred. We would observe some fairly significant temporary recoveries, which, however, never succeeded in attaining the maximum elevation. With the diagram presented, we have sought merely to demonstrate the general aspect: a descending line illustrating the unmistakable trend toward progressive ruin of the lake.

And this "progress" is continuing. The most recent reading we have is 404.715 meters. (This was taken at Punta Cabito, at the Alfredo Jahn Station of the Instituto para la Conservación del Lago de Valencia, on August 14, 1968 by topographer José Royo González.)

XIV. SUMMARY OF THE CAUSES AND CONSEQUENCES OF THE DESICCATION

In summarizing the results of the research explained herein, we have reached the following conclusions:

a) The progressive destruction of the lake, which is going on before our very eyes, is not caused by natural phenomena. It is the result of uncontrolled human activities.

b) In pre-Columbian times, the water budget of the basin was positive, i.e., there was a surplus.

c) In a place called El Paíto, there was once a natural outlet for this surplus, by virtue of which the basin of the lake belonged to the Orinoco River watershed.

d) The absolute elevation of this spillway above sea level is approximately 426 meters. This is the maximum height which the level of the lake could have attained in the present geological era, and the lake remained at this height until the advent of historical, agricultural and industrial operations.

e) These destructive activities drew off an ever-increasing amount of water from the tributaries and aquifers, inverting the water budget.

f) By dint of the foregoing, the level of the lake began to drop in 1727. The shore receded from the outlet,and the basin was transformed into an endoreic system.

g) At present, the surface of the lake is 405 meters above sea level. In less than two and one-half centuries the lake surface has dropped 21 meters, the equivalent of a seven-story building.

h) On the average, the vertical lowering of the lake level has occurred at a rate of descent of 8.5 centimeters per year.

i) Once the watershed of Lake Valencia became separated from the Orinoco, salt began to concentrate in the lake. In the last two and one-half centuries, salinity has increased eightfold.

XV. DECREASING DIMENSIONS

By tracing a contour line at an elevation of 426 meters above sea level, the ancient outlines of the lake are obtained. (See the boundary lines on the map). Upon determining the area covered by this contour, we discover that in the early part of the past century, the lake had a surface-area of 643 square km. At present, it has an area only half that size. (Roberto Alvarez points out that in preparing the isobathic lines of the lake [maximum depth: 40.84 meters] in 1965, the figure of 369.8 square km was obtained through repeated integrations (1).)

De Sola is of the opinion that in ancient times, the lake contained approximately 16,650,000,000 cubic meters of water (14). Alvarez estimates that the figure for 1965 was 7,295,600,000 cubic meters. With these data, and accepting 1727 as the year when desiccation began, we reach the conclusion that in the last 238 years the lake has lost 1,500 liters of water per second, day and night.

Upon consulting our map, and comparing the ancient shore with the one existing in 1955, we see that in some places, e.g., the Yuma Peninsula where the shore is rocky and the land slopes steeply, the distance between the two levels is not very great. There are other places, however, such as the Central Tacarigua area, where land slope is almost nil. Consequently, for each meter of decrease in surface level, there is a corresponding strip of land half a kilometer wide, and the lake has receded nearly ten kilometers from the shore seen by Manzano.

Nowadays, the lake is nearly 30 km. long, with a maximum width of 18 km., and its perimeter measures some 125 km. According to our calculations, in Manzano's time these dimensions were approximately 40, 20, and 180 km.

XVI. POLLUTION, A NEW CALAMITY

To the problems already indicated, i.e., the lowering of the surface level, reduced size, decreased volume, and increased salinity, a new calamity has recently been added, namely, the growing state of pollution in the waters of the lake. This is due to the lack of sewage plants for the communities located in the basin, and to the fact that almost none of the industries are equipped to provide corrective treatment for their wastes. All of these effluents are dumped into the tributaries, and contribute to the progressive degradation of the water in the lake.

It should be pointed out that Maracay and Valencia, two of the most important cities in Venezuela, are located close to Lake Valencia. At the present time, the total population of the basin amounts to 500,000 inhabitants and is growing by leaps and bounds, in an exponential function. Along with this, the number of industries is also growing; despite such rapid development, there still are no measures to check water pollution. Ciudad Alianza, a new population center in the area, is the only community which has a plant to treat its sewage. We have already mentioned El Paíto Lagoon, where the stench is incredible. Similarly, we have discussed the advanced pollution already achieved along Guacara River.

According to the census taken by the Ministry of Development in July 1963, there were then 456 industries in the basin (automobile, rubber, glass, tanning, paper, cardboard, textile, vegetable oil, beer, animal feed, electrical appliance, etc.), and the number of new industries is increasing rapidly. This growth and its mounting effluents, together with the pollution caused by livestock-raising (which is also increasing considerably) produce great quantities of organic and inorganic residues which affect the tributaries, and thus the lake itself. (Pérez Lecuna, 28, 29 and 31). Tables II and III and the respective comments were taken from these papers.

TABLE II

CHRONOLOGICAL COMPILATION FOR PHYSICAL-CHEMICAL ANALYSIS VALUES OF THE WATER IN LAKE VALENCIA

Author	Date	Place	Depth	DBO5 mg/l	OD mg/l	S.U Mg/l	Temp °C	PH
Pearse	1918		0	---	7.00	---	27.6	
			15	---	6.86	---	27.2	
			25	---	6.29	---	26.9	
A. Bonazzi	1946	500 m de 0	3	---	5.18	---	----	
		300 m de 0	3	---	6.21	---	----	
		100 m de 0	7.60	---	6.89	---	----	
		300 m de 0	36	---	0	---	----	
F. Gessner Blohm	Sept. 1952		0	---	7.3	---	----	
			20	---	7	---	----	
			25	---	0	---	----	
O. Jelambi	1957 1958	Pta.Culebra 2 miles	Surface	1.0	7.9	---	----	---
		Idem	medium	0.7	7.8	---	----	---
		Idem	bottom	0.4	7.4	---	----	---
		Pta.Culebra 3 miles	Surface	1.3	7.5	---	----	---
		Idem	medium	0.8	7.3	---	----	---
		Idem	bottom	0.3	7.1	---	----	---
Study supply of water from Valencia (INOS)	(1959 (Mar.	East of Flor Amarillo	Surface	0.9	7.4	---	----	8.96
F. Gessner	Oct. 1963	East No.1 In front of Zorro Island	0	---	6.5	---	27.3	---
			15	---	6	---	27	
			20	---	0	---	24	
		East No. 2 half way between Otama and La Cabrera	0	---	6.9	---	27.5	---
			18	---	6.8	---	27	---
			20	---	0.5	---	24.5	---
		East No.3 In front of Chambergo	0	---	7	---	27.5	---
			10	---	6	---	27	---
			20	---	0	---	24	---
R. Perez Lecuna DAP. C.A.	Aug. 1964	Maracay Wharves 150 meters	Surface	4.23	6.02	226	30	8.7

TABLE III

CHRONOLOGICAL COMPILATION FOR PHYSICAL-CHEMICAL ANALYSIS VALUES OF THE WATER IN THE TRIBUTARIES OF LAKE VALENCIA

Author	Date	Place	Temp °C	PH	Volatile Solids	DBO^5 mg/l	OD Mg/l
R. Perez L.	May 1959	Quebrada	28	6.8	950	146	7.1
I. Guevara		Barrio	28	6.8	950	125	3.3
S. Tebet.C.		Lourdes ravine (gorge) of Maracay cemetary	30	6.9	---	160	2.0
		Guey river	28	7.8	520	83	6.5
		Maracay cross-roads	28	7.8	520	74	4.1
R. Perez L.	July 1963	Aragua River at La Victoria	25	7.8	150	12	2.0
R. Perez L.	Aug. 1964	Aragua River at Cagua highway	28	8.2	129	8.60	5.72
		Guez river across Boliv Mcy Ave	27.5	7.8	131	8.3	4.39
		Cabriales River at Valencia highway	26	7.6	82	61	4.69
		Stream across route to Guigue	25	8.2	68	4.79	5.00

Pérez Lecuna states that "obviously the value of the biochemical demand for oxygen as an index of pollution has increased to an alarming extent in areas near the mouths of these highly affected rivers. With respect to these quantitatively small DBO^5 factors, the volume of the body of water on the basis of which these samples have been taken should be considered. Moreover, we must not overlook the fact that our lake is located in an area which does not go through marked seasonal changes, which in other latitudes, because of the well-known thermocline phenomena that occur when the upset is produced, gives rise to the recovery of dissolved oxygen, thus increasing the self-purifying power of the body of water affected. Of special interest is the study by F. Gessner entitled "The Eutrophication of Lake Valencia"(15). In this regard, although we consider it (eutrophication) a direct consequence of the constant inflow of highly degradated waters into the lake, we feel that it would be timely to obtain samples on a methodical and prolonged basis, in order to confirm this phenomenon in a more exhaustive manner."

The following sentences were also taken from Pérez Lecuna: "The lack of adequate legal instruments at the present time makes it possible not only for the lake's surface layers to present conditions of obvious pollution and pathogenic contamination, but also for such degradation to be present in the lower layers; the latter are affected by domestic and industrial discharges which are arbitrarily poured into sewers, taking advantage of the natural permeability of the land along the shore of the lake. These effects have caused regrettable situations, such as those which occurred in past years in the towns of Los Guayos and Naguanagua (in the State of Carabobo) where the number of children who were the victims of water-borne infections caused considerable consternation in the area. In both cases, it was determined that water drawn from deep wells was highly contaminated by seepage from sewers which did not seem to be too close to the wells.

Similarly, numerous cases are known of industries which have had to invest large sums of money to purify the water from their wells because it was highly con-

3. Clean the beds of tributaries and canals, so that there will be no stagnant water. This procedure was utilized in colonial times.
4. Improve the channel of the Cabriales River and carry its water, which now spreads out to the south of Valencia, directly to the lake.
5. Drain swampy areas.
6. Reforest what was destroyed through lack of interest or ignorance, a suggestion made by Lieutenant Manzano 250 years ago.
7. Protect the headwaters of the tributaries. For this purpose, our Institute proposed to the Venezuelan Ministry of Agriculture and Livestock that the Henri Pittier National Park be lengthened and broadened.
8. Put an end to forest fires; and create an awareness of forestry resources, their values and proper management.
9. Avoid the unnecessary felling of trees, and prevent utilization of "arboricide."
10. Channel outside water into the basin. There are several interesting projects possible including those suggested by the Venezuelan engineer Lucio Baldó (3).
11. Take measures to prevent water pollution; build sewage treatment plants, and enact the ordinances recommended by Pérez Lecuna.
12. Study possible additional remedies for water-loss problems, including artificial rain-making, and the reduction of evaporation(from the reservoirs located in the basin) through the use of chemical substances and other means.

The critical moment is approaching, the last chance to remedy these environmental evils and to heed John F. Kennedy's call "to re-establish a sound relationship between man and nature, in order to protect our physical and mental health, and pass on to future generations our ancestral heritage: a land full of life and beauty".

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