The Qattara depression

By Dr. Ing. Giuseppe De Martino*

Reprinted from WATER POWER January 1973

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This report presents, and discusses briefly, the main schemes proposed by various engineers for the development of the Qattara depression in the northern region of Egypt in order to produce electrical energy

IN RECENT TIMES, West Germany undertook a programme of technical aid to the United Arab Republic, and reconsidered the idea of utilizing the natural depression at Qattara in northern Egypt, so as to generate electric power.

The aim of the project is to convey water from the Mediterranean Sea in an open channel or tunnel, utilize the natural head, and allow the water to be continuously removed by the high degree of evaporation from the surface of the salt lake that would be thus formed within the depression.

This particular type of hydroelectrical station, also known as a hydrosolar power station[1], would be made possible by the combination of such factors as the existence of a vast depression at a distance not too far from the sea, and the region's characteristically scarce rainfall (with the resulting high degree of evaporation).

The production of energy from the waters of the River Nile is, in fact, subordinated to the demand for water to be used for agricultural purposes, and this does not correspond generally to the demand for electrical energy. Moreover, the firm electric power that these waters can produce is used mainly in the production zone, and so there is only a fluctuating energy supply available for the northern industries[2,3,4].

Consequently, a project in the region of Qattara is even more significant, since with its potential hydroelectric energy output, it could satisfy the peak-load requirements of an electricity-supply system that would be aimed mostly at the northern region of Egypt.

Jointly with other Egyptian hydroelectric and thermal plants, such energy could satisfy the country's demand for about 4000MW of capacity, as predicted for 1975 by experts of the United Arab Republic.

The depression

The utilization of the Qattara depression (discovered at the beginning of the 20th century in the northern part of the Libyan desert) for the purposes mentioned here, was suggested for the first time by the Berlin geography specialist, Professor Penk in 1912, and later[5] by Dr Ball in 1927.

They were ambitious ideas since in those times the depression was not completely known and therefore only a simple orientation sketch could have been drawn.

Later on, by using the measurements taken by the Survey of Egypt, it was possible to study the depression in more detail and provide the particulars from which Dr Ball in one of his authoritative studies (published in 1933) could define better the utilization of the depression[6].

In about 1950, due to the demand mentioned before, the problem was again reconsidered (especially in West Germany), and other schemes were proposed.

As the possibility of the development of Qattara is once again a topic for discussion, and (as will be described later on) since it is feasible from an economic point of view to develop the scheme, it is worth looking again at the outline of the principal proposals made to date.

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Ball's researches

Limited to the north and west by deep escarpments and becoming comparatively flat towards the south and the east (Fig. 1), the depression has a length of about 300km at sea level, a maximum width of 145km and an area of 19 500km^2.

The lowest point is found at a level of about 134m below sea level.

The floor of the depression is covered, over the main area of 5800km^2, by Sabakha, a mixture of sand, salt and water, whose formation cannot have been caused by the evaporation of sea water that has reached the depression. In fact, borings carried down to some 20 and 30m below sea level at a distance of more than 20km from the coast were completely dry.

The material was probably formed by the continuous seepage of underground water flowing below the Libyan desert, which by contacting pervious rocks had its salt content concentrated before it reached the depression.

Therefore, the fact that the sea once had access into Qattara can be discounted.

In the remaining part of the ground surface in the depression are found sand, clay, gravel and limestone.

Having described the depression, Dr Ball studied in particular the possibility of utilizing it for hydroelectric purposes by the formation of lakes at final levels of 50, 60 and 70m below sea level, to which the corresponding surface areas were 13 500, 12 100 and 8600km^2, respectively.

Moreover, he indicated the most convenient water inflow routes (lines D, E, F in Fig. 1) with reference to the formation of the three lakes.

Ball then made a detailed study into favourable and unfavourable conditions for the lake's possible plant life, including such considerations as rainfall, evaporation, and the inward and outward seepage flows.

With regard to rainfall, by considering it an adverse factor to the existence of the lake, Ball made a conservative estimate that the actual daily average rainfall of 0·06mm would double after the salt lake had been formed.

By taking into account the rainfall that would not precipitate directly into the lake but would find its way into the depression (he thought that only half of this water would reach the lake), he assumed for the three lakes at sea levels −50, −60, and −70m, daily average rainfall depths of 0·15, 0·16 and 0·18mm.

Then he considered the evaporation, an essential factor in the lake's life, and in order to evaluate its possible volume, he referred to the process that occurs in the brackish Birket el Qarum Lake located in the nearby depression of Faiyum.

Keeping in mind that the new lake that might be formed would tend to be saturated with salt and would therefore alter the evaporation environment, and considering observations made in the Karabugas (an enclosed gulf almost saturated with salt at the east of the Caspian Sea) he concluded that the average rates of evaporation from the surfaces of the three lakes would be 4·6, 4·3 and 4·0mm/day, respectively.

Then he studied the seepage flow inwards due to the

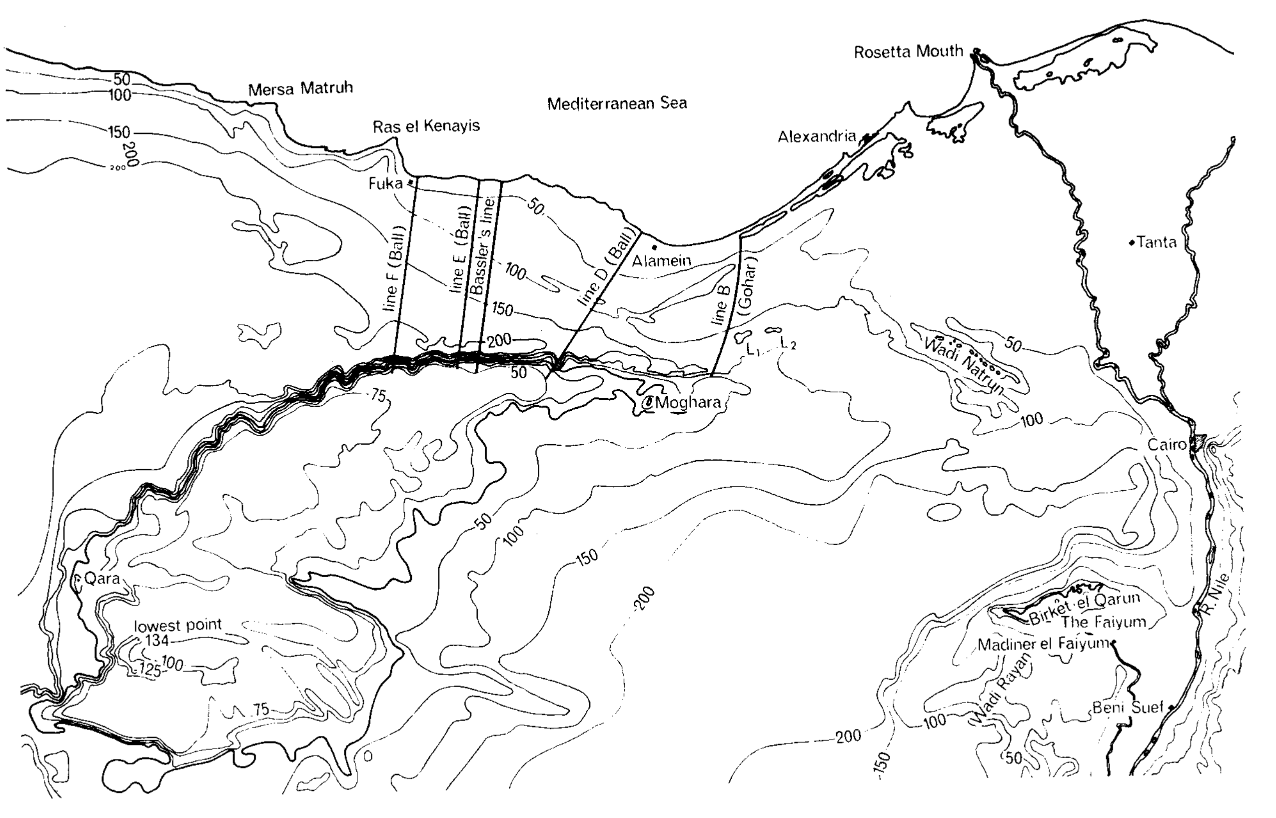

Fig. 1. The Qattara depression, showing the different routes chosen over the years by Ball, Bassler and Gohar to conduct water to the depression from the Mediterranean Sea

rainfall in the Ennedi Highlands of French Equatorial Africa, which is partially diverted into the depression, and succeeded in evaluating the quantities by using the evaporation data of the salt marsh (sabakha) that balances inward seepage and the local rainfall.

Granting that for safety purposes the volume of the future seepage into the lake would be equal to the present, he estimated that the daily volume would be equal to depths of 0·21, 0·24 and 0·33mm for lakes at levels −50, −60 and −70m.

Finally, Dr Ball gave no quantities for the eventual volume of water that might leave the lake due to outward seepage, as he considered such flows as being substantially a positive factor in the lake's plant life.

Having studied these factors in great detail, Ball concluded that the daily volume of sea water that could continuously enter the depression would be the product of the final lake area and the average depth of water that would be removed by evaporation, from which could evidently be subtracted the sum of the average depth of rainfall and the seepage inflow.

He put the discharges that might, in this case, be channelled into the lakes at 656, 546 and 348m³/s, respectively.

Pursuing his researches further, Ball evaluated approximately the time necessary for the formation of the lakes at the levels considered (−50, −60 and −70m) and calculated that, supposing right from the start the maximum inflow were admitted into the depression, after 150, 60 and 30 years, respectively, the levels in the lakes would still be 1m below the final level.

Then he studied the progressive increase of the salinity and calculated that the maximum concentration would be reached after 160, 120 and 100 years.

Longer periods of time would be necessary for the lakes to be completely full of salt, in fact 1230, 940 and 780 years.

Dr Ball made further detailed researches to find the most convenient level for the lake, bearing in mind the electric power to be generated, the minor transmission losses between the central power plant and the Delta area, and the lowest cost per kW installed.

Having pointed out the necessity of putting at least two-thirds of the length of the conduit in tunnel due to the height of the land intervening between the sea and the depression, and having proposed to divide the flow into three circular tunnels so that construction could take place in three successive stages, Ball showed that the most convenient solutions were those relating to lakes at −50 and −60m below sea level.

He left the final selection to be based on the best solution for the geological and topographical conditions. However, it is clear that he preferred the lake with a final level at −50m, with the supply system along route D in Fig. 1.

Along such a line, about 72km long, he put forward the geological section shown in Fig. 2, deduced from measurements taken every 5km at depths greater than those along the other tunnel routes.

Such researches pointed out that at distances of more than 20km from the Mediterranean coast it was impossible that any seepage of sea water could take place towards the South.

Finally, he suggested that an open channel be con-

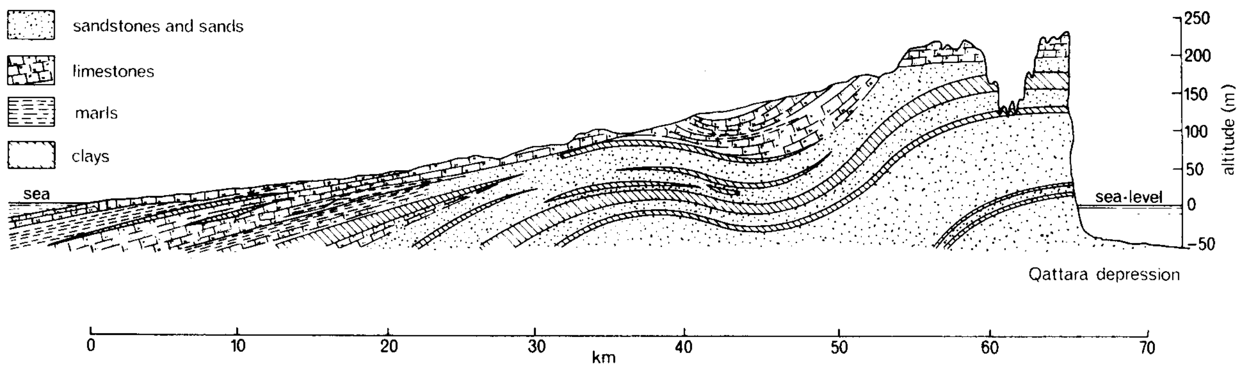

Fig. 2. Cross-section along Ball's pipe line "D", showing the geological conditions he reported

structed for the first 20km (it too could be carried out in three stages), and that three tunnels with a diameter of 11m be built to supply the lake at a level of −50m.

The resulting firm power potential would be about 175MW.

It must be observed that the construction of the tunnels in three stages, and therefore with initial flows being considerably less than the final discharge of 656m³/s, the time necessary for the lake to reach a level of −50m would be significantly longer.

Moreover, the direct observations that could be made of actual levels of the lake during the first and the second stages could provide more accurate data on evaporation and could therefore result in new criteria for designing the third tunnel.

Dr Ball, moreover, anticipated the possibility of using a power surplus during periods of low demand to pump some part of the inflowing water into a high-level reservoir on top of the escarpment around the depression, and using the 200m head to generate power to meet peak-load requirements.

He suggested that such a reservoir could probably be located at some point along the lines E and F and therefore near the conduits feeding into the lakes at levels −60 and −70m.

He concluded his study by predicting other benefits that the formation of the lake could bring to the region, including the possibility of extracting salt for commercial uses.

Further developments

It was only at the end of the 1950s that the question of developing Qattara was raised again due to the economic expansion of the United Arab Republic. At this time Siemens proposed a scheme involving the creation of an artificial balancing reservoir on the edge of the depression, continuously fed by two conduits from the Mediterranean.

The estimated power potential was about 100MW, and the turbines were to function for only six hours a day.

In 1964, a commission of experts took a favourable point of view of the possibility of a plant to produce peak load energy, and Professor Bassler was appointed by the West German Ministry of Economics to study possible development schemes in greater detail.

Bassler refers to such studies in an article published[4] in December, 1968, in which he presented the scheme shown here in Fig. 3, whose relative conduit route is indicated approximately in Fig. 1.

After detailed geological and engineering research aimed at examining the technical and economic feasibility of a plant in the Qattara depression, which was carried out in 1964 and 1965 by expert technicians, Bassler, who was responsible for the research, proposed a possible scheme.

In it, the most convenient solution was said to be the formation of a lake at level −60m, with a corresponding area of 12 000km². In this case, the volume of water that would disappear annually due to evaporation was estimated at 19 000 million cubic metres, taking into account the inward seepage flows. (Dr Ball estimated an annual evaporation of about 17 000 million cubic metres for a lake at this level.)

It was also anticipated that such a lake would have to be fed by a flow of 600m³/s (546m³/s according to Ball) from the Mediterranean to compensate for the evaporated water.

This discharge would be carried through tunnels having a length of about 80km to an underground power plant at level −54m (Fig. 3).

During the hours of low load demand, the energy produced could be used to pump the water into a high-level natural reservoir having a capacity of about 50 million cubic metres. Such a basin is located at the edge of the depression and was discovered during the topographical and geological research works.

Therefore, during peak load hours a valuable head of water would be available, and in addition, by not allowing the pumps to work during these periods, the low head

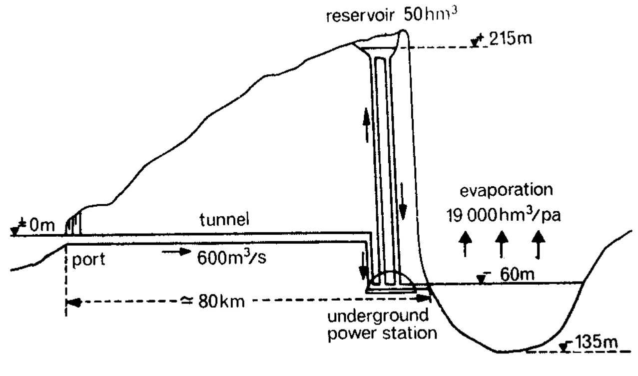

Fig. 3. Cross-section showing the outline of the power scheme proposed by Professor Bassler

system would be able to generate much useful power.

To sum up, this scheme is a combined high and low head system, capable of producing peak power up to 4000MW and adaptable to a varying demand pattern.

Moreover, the proximity of the plants to the main centres of electricity consumption would give a definite reduction in transmission costs.

On the question of energy costs, Bassler claimed that no estimate could be made at the time as the determining factor for the technical and economic feasibility of the plant would be the cost of tunnel construction (he agreed with Ball that three were necessary).

These might be undertaken today by means of nuclear excavation or other advanced techniques and preliminary experience in the USA has indicated that higher construction speed would lead to lower construction costs compared with traditional methods.

A third proposal

In 1961, the Cairo University Professor, Kamal Gohar, referring to the studies conducted by Dr Ball, observed that this scheme would encounter great difficulties in construction and would be of little value from an economic point of view.

He then suggested an alternative scheme, Fig. 4 (whose supply conduit route is indicated by the letter B in Fig. 1) which, he said, would be more advantageous.

The author pointed out that along the route he indicated, the highest point of the land between the sea and the depression was to be found only 11km from the Mediterranean coast, and he suggested that the sea water could be pumped up to a convenient point and then carried in an open channel (*ab* in Fig. 4).

This design could result, according to Gohar, in a simpler and more economic scheme than the three tunnels previously proposed. At the end of the channel, the water could be directed from point *b* to a suitably located underground power station at *C*.

A continuous 24h daily power output equal to $(P_2 - P_1)$ would be obtained, where P_1 is the power necessary for pumping and P_2 is the useful generated power.

However, it would be possible to have the whole output P_2 available for some time (7-9 peak hours per day) when the pumps were shut off and the turbines supplied by the volume of water retained in the channel *ab*.

In accordance with these proposals, Professor Kamal Gohar suggested that the best solution among the various possibilities studied, was the formation of a lake at a level of -75m, together with a discharge of 266m^3/s and a channel at a level $+80$m.

The continuous net power available would be about 100MW, while the maximum peaking capacity was about 345MW.

The cost per kW installed would be less than that corresponding to Ball's scheme, and it is significant that the project would not need compensation reservoirs since the channel could be used for such a function.

If necessary, two small lakes (L_1 and L_2 in Fig. 1) located very near to the channel *ab* could be used as pumped-storage reservoirs.

Gohar predicted that about 70% of the power generated could be utilized in the Qattara area, with the remainder being transmitted to the Delta area during peak-load periods.

Finally, the author pointed out the advantages of the simpler maintenance of an open channel compared to the tunnels, and the shorter distance from the plant to the Alexandria area than in the scheme put forward by Ball.

Conclusions

As far as Gohar's scheme is concerned, it must first of all be said that the author has not specified how the sea water is taken to the depression from the underground station (point *C*).

Looking at the project outline, it is noticeable that to reverse the water in the lake, there would have to be a tunnel at least 60km long, and thus the advantages of an open channel compared to the tunnels proposed by Ball are cancelled out.

In addition, the use of artificial lakes L_1 and L_2 as compensation reservoirs is not made clear.

Therefore, the Gohar scheme does not seem very satisfactory and it cannot be accepted that there would be cost savings when comparing the scheme to the tunnels proposed by Dr Ball in 1933, and later confirmed in recent studies conducted by West German experts.

Moreover, the scheme proposed by Professor Bassler, following the researches conducted under his direction, confirmed Ball's predictions that had in 1933 already anticipated the possibility of intermediate pumping during times of low load, resulting in the combined high and low head system.

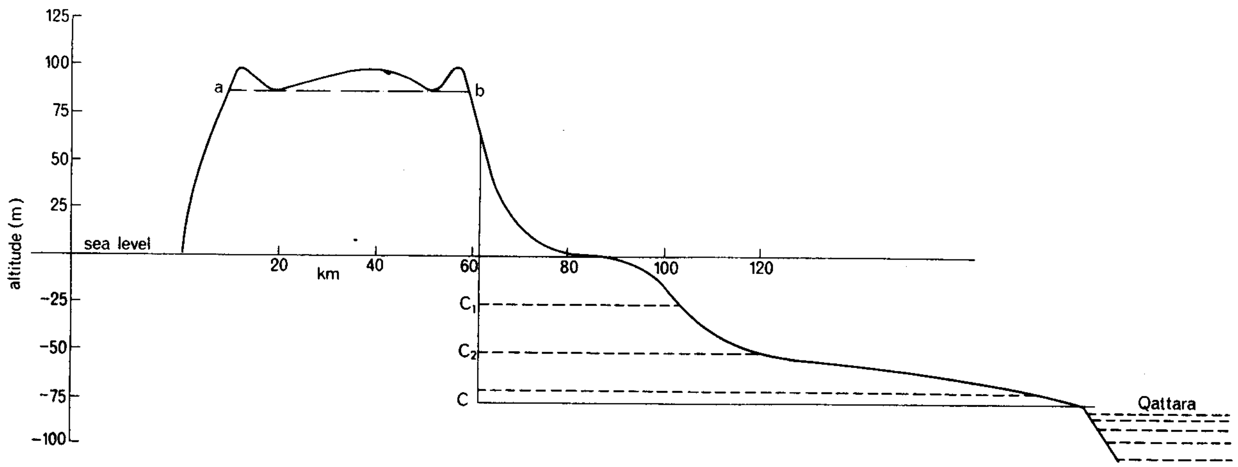

Fig. 4. A profile of the levels of the various features of the scheme suggested by Professor Gohar

Estratto dal fascicolo n. 7, Volume L, 1973
della Rivista mensile « L'Energia Elettrica ».

L'UTILIZZAZIONE DELLA DEPRESSIONE DI QATTARA

(G. De Martino: *The Qattara Depression,* « Water Power », gen. 1973, pagg. 27-31).

L'Autore riferisce dei principali schemi finora proposti per l'utilizzazione della naturale depressione di El Qattara, ai fini della produzione di energia elettrica, consistenti nel riversare, mediante la costruzione di una galleria o di un canale aperto e utilizzando il salto disponibile, l'acqua del Mare Mediterraneo nel suddetto bacino, dal quale, dopo l'uso, sarebbe poi continuamente dispersa per effetto della forte evaporazione dalla superficie del lago salato che si formerebbe (fig. 1).

Si realizzerebbe così un particolare impianto idroelettrico detto pure idro-solare, che potrebbe risolvere i problemi elettrici egiziani. Infatti la generazione di energia dalle acque del Nilo è subordinata alle richieste per l'agricoltura, le quali generalmente non corrispondono con le domande di energia elettrica ed inoltre la potenza garantita da queste acque è usata principalmente nella zona di produzione per cui solo l'energia fluttuante si rende disponibile per il Nord Egitto.

Scoperta agli inizi del secolo ventesimo nella parte settentrionale del deserto libico, la depressione (fig. 1) presenta, alla quota del livello marino, una lunghezza di circa 300 km, una larghezza massima di 145 km ed un'area di 19 500 km^2. Il punto più depresso si trova a circa 134 m sotto il livello medio del mare che non trova accesso nella depressione stessa. Il suo fondo è coperto in gran parte da Sabakha, una miscela di sabbia, sale e acqua.

I principali schemi proposti sono dovuti, nel tempo, a Ball, alla Siemens, a Kamal Gohar e Bassler. E' però il primo a descrivere in dettaglio la depressione, in un suo notevole studio del 1933, e a suggerire i primi concreti schemi di funzionamento.

Schema Ball.

Dopo aver studiato il bilancio degli eventi tanto favorevoli che sfavorevoli per la vita del lago salato (quali le piogge, la evaporazione, le infiltrazioni verso l'esterno e verso l'interno), il dott. Ball indica tre possibili soluzioni (formazione di laghi a quote finali — 50, — 60 e — 70 m) con i relativi tracciati riportati in fig. 1 (linee *D, E, F*). Calcola le portate di adduzione pari rispettivamente a 656, 546 e 348 m^3/s e valuta i tempi necessari per la formazione dei laghi alle quote suddette (150, 60 e 30 anni) ed i tempi occorrenti perchè i laghi risultino completamente riempiti di sale (1 230, 940 e 780 anni). L'Autore si orienta per un lago a quota finale — 50 (linea *D*) e suggerisce la realizzazione di un canale aperto per i primi 20 km e quindi tre tunnel di 11 m di diametro. La potenza continua è prevista di 175 MW. Prospetta inoltre la possibilità di pompare, con energia disponibile durante i periodi di minore richiesta, parte dell'acqua affluente dal mare in un serbatoio ad alta quota, al contorno della depressione, utilizzando altri 200 m circa di salto, per coprire, con turbine supplementari, le richieste di punta.

Indica pure che un tale serbatoio potrebbe essere consentito relativamente ai tracciati *E* e *F*.

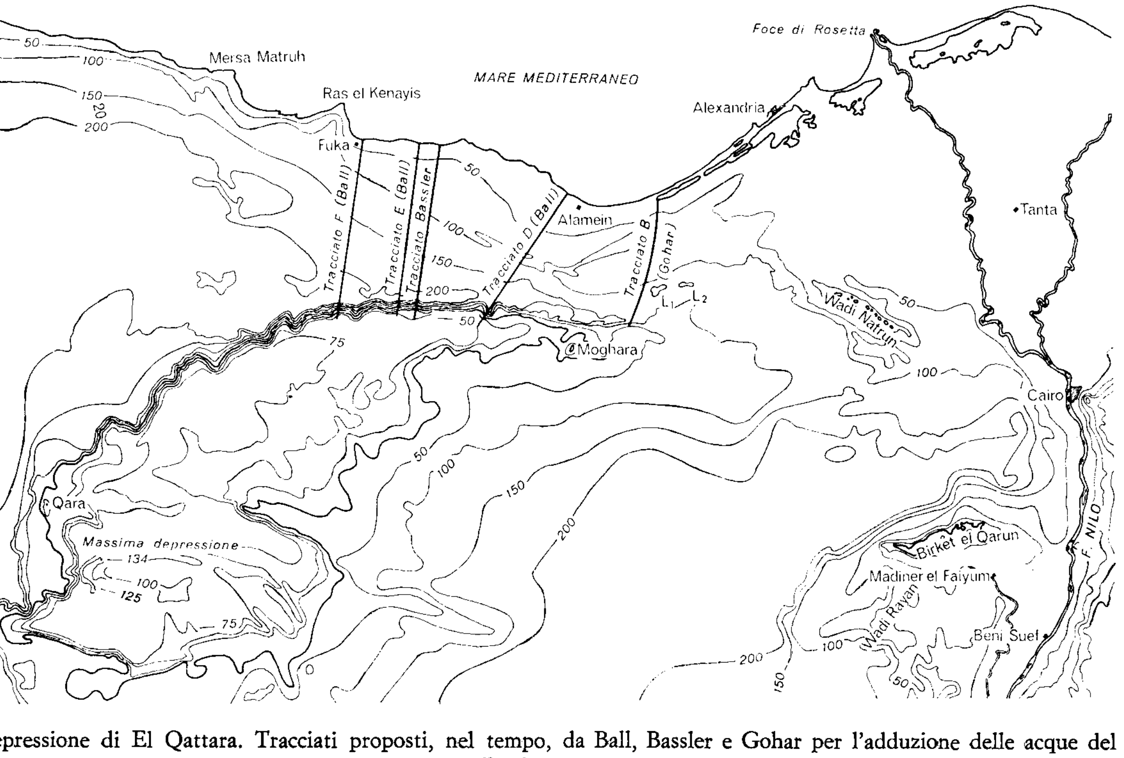

Fig. 1. - La depressione di El Qattara. Tracciati proposti, nel tempo, da Ball, Bassler e Gohar per l'adduzione delle acque del Mediterraneo alla depressione.

Schema Siemens.

Tra gli anni 1960 e 1962 la Siemens, sempre rifacendosi agli studi del dott. Ball, proponeva, come possibile e conveniente soluzione, uno schema costituito da due tunnels, convoglianti complessivamente una portata di 550 m^3/s, da un serbatoio artificiale di compenso giornaliero posto al termine dell'adduzione e una centrale di potenza di 1 000 MW. Il funzionamento delle turbine era previsto per sei ore al giorno.

Schema Gohar.

Con riferimento agli studi di Ball, Kamal Gohar nel 1961 suggerisce uno schema alternativo alla soluzione proposta dal dott. Ball (figg. 1 e 2). Tale schema consiste nel pompare l'acqua marina ad una conveniente quota, farla defluire in un canale all'aperto (*ab*) di adduzione ad una centrale sotterranea, ubicata ad una opportuna quota *C*. Suggerisce la formazione di un lago a quota finale — 75, una portata di adduzione di 266 m^3/s ed un canale (*ab*) a quota + 80.

La potenza continua sarebbe di 100 MW, mentre quella di punta, che si potrebbe ottenere per alcune ore al giorno, utilizzando, in assenza di pompaggio, il notevole volume di acqua invasato nel canale *ab*, di circa 345 MW.

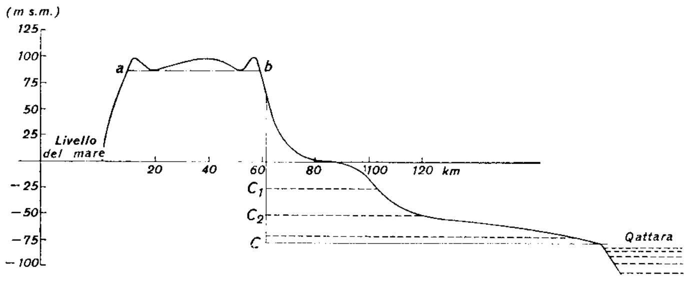

Fig. 2. - Profilo dello schema di utilizzazione proposto da Gohar.

Schema Bassler.

Dopo una campagna di rilievi eseguiti tra il 1964 e il 1965, Bassler indica quale schema più conveniente per l'utilizzazione della depressione quello rappresentato nelle figg. 1 e 3: precisamente un lago a quota finale — 60, una portata di scarico di 600 m^3/s ed una centrale in caverna a quota — 54. Indi, durante le ore di minor richiesta, l'energia prodotta potrebbe essere utilizzata per sollevare l'acqua in una bacino naturale ad alta quota, esistente al margine della depressione, avendo così a disposizione per le ore di punta un notevole salto. Non facendo inoltre funzionare le pompe durante le suddette ore, il sistema a bassa pressione potrebbe a sua volta produrre potenza utile. Trattasi cioè di un sistema combinato ad alte e basse pressioni, capace di produrre potenza fino a 4 000 MW.

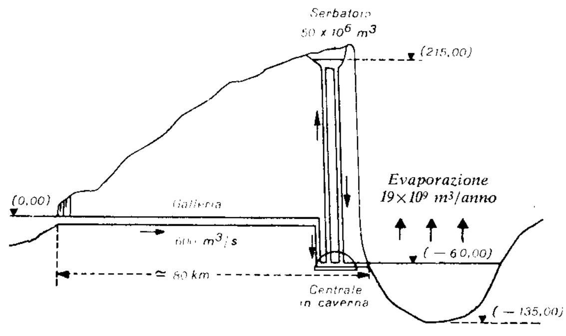

Fig. 3. - Schema proposto da Bassler.

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L'Autore discute quindi gli schemi di cui sopra e indica che il più conveniente dal punto di vista tecnico ed economico, ai fini della utilizzazione predetta, è quello proposto da Bassler, schema che in definitiva non si allontana da quello concepito, nel lontano 1933, dal dott. Ball.

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