DAMS

GEOLOGY AND LARGE DAMS IN ALGERIA
(A translation)

Savornin, J. (Professor of Geology and Mineralogy at Algiers University, Assistant-Director, Service of the Geologic Map of Algeria) - La Géologie et les Grands Barrages en Algérie (Geology and large dams in Algeria); Bulletin du Service de la Carte Géologique de l'Algéria, ser. 3rd, Fig. 8, pp. 6-18; 29-32; Algiers 1941.

Translation by Mrs. Severine Britt, U. S. Geological Survey, 1947

On the occasion of the last International Fair in Paris in 1937, a splendid illustrated pamphlet was devoted to the arts and techniques applied to modern life in Algeria. Eight large river dams are described in this remarkable work, with pictures showing the dams either completed or, in most cases, under some stage of construction. Now, all of them are practically ready for use. /

/ The number for May 1938, which treats of the Algerian economy (supplement to No. 57 of the Bulletin de l'Association des Anciens Elèves de l'Ecole Supérieure de la Métallurgie et de l'Industrie des Mines de Nancy (Bulletin of the former students' Association of the College of Metallurgy and Mine Industry of Nancy)) contains valuable information for the technician's use, on the same large hydraulic works.

The eight dams referred to are:

1. Oued Fodda, height 89 m. (visible section)
2. Oued Chelif (Le Ghrib), height 65 m.
3. Oued Mina (Bakhadda), height 45 m.
4. Oued el Hamman (Bou Hanifia), height 54 m.
5. Oued Tafna (Beni-Bahdel), height 47 m.
6. Oued Gueiss (Foum-el-Gueiss), height 23 m.
7. Oued Kcob (no other name), height 35 m.
8. Oued Safsaf (Le Zardezas), height 35 m.

The first two dams are in Algiers Department, the following three in the Department of Oran, and the last three in the Department of Constantine. Only the Oued Fodda, the Ghrib on the Chelif and the Beni-Bahdel are discussed here.

About 15 other locations were studied for projects that were not put into execution (most of them were definitely given up following geological investigations, which gave conclusions that were altogether unfavorable).

Five or six other dams, generally of small size, are located on the oueds (streams) Sig, Fergoug and El Abd, in Oran Department; Meurad and Hamiz in the Department of Algiers. The first two and the last one had to be strengthened, repaired, and even restored. No mention will be made of them in the following descriptions which describe the main geological characteristics of the recently erected dams.

If some details regarding the structure of the subsoil are of importance to the technicians of public works only, other details are not without interest to economic science and even to general geology. In this respect, the outstanding results of an occasional collaboration between engineers and scientists have to be recognized.

Oued Fodda

The dam of Oued Fodda did not give any difficulties in regard to the geological problems.

It is situated in a typical deep, narrow gorge, steeply cut in the rock mass. The rocky slopes of the gorge eroded by rain water and almost deprived of soil except in a few irregular areas are practically homogeneous. The stratification is hardly noticeable due to the prominence of diabase beds. Thick, steeply dipping calcareous beds belonging to the Lias stages, or Lower Jurassic, constitute the core of a folded "dome" which is remarkably isolated in the middle of the Cretaceous Atlas Mountains.

This exceptional arching of the underlying rocks is located on the same meridian as the folds of the Ouarsenis (20 km. south) and of Vauban (15 km. north), although the latter are quite different in structure. Such a gradation of zones of elevation in the Atlasic foldings, extending toward the east or northeast, leads one to think of the general tectonic pattern of the mountain chain located in the Algerian Tell; but this is not the place to draw theoretical conclusions from it.

If one refers to the detailed geologic map (sheet Orleansville, published in 1925), the "dome" of Oued Fodda would be cut into sections by three faults which form the sides of an isosceles triangle. The stream nearly follows one side about 1 km. downstream from the dam.

This is probably only a first approximation of the truth. Many stratigraphic and tectonic details have to be added to this plan, however, and no meticulous geologist has ever been called to undertake the necessary study on this subject.

The dam site is in the Jurassic limestones (south limb of the dome with a Liassic core).

In the confined space covered by the site, it did not appear necessary to be concerned about any structural problems. The case must have appeared exceptionally simple. It was sufficient to restore a strong pre-existent rock-bar by building up on the same place a mass of concrete which formed a gravity dam having a rectilinear crest and an ordinary cross-section.

If it had been a question of massive rocks such as granite or calcareous deposits of organic origin, an arch dam of small thickness could safely have been built. But in the presence of stratified, folded, vertically fractured rocks, this solution must have seemed too dubious. The technicians, who were responsible for the construction, could not leave anything to chance. Construction is such that no other mechanical work than resistance to crushing is required of the rocks which support and anchor the dam.

The two lateral spillways are independent of the dam. The spillway of the right bank, however, touches the crest. It is a concreted open cut in the rock and is provided at the inlet with a floodgate. It ends in the open and is liable, eventually, to give rise to a waterfall of considerable height. The spillway on the left bank starts much farther upstream. It penetrates immediately under the road into an inclined underground tunnel in the limestone. At its outlet downstream, it runs through a picturesque crevasse where a second waterfall may occur in case of exceptional floods.

These public works are completed by an underground passage for the road from Lamartine village which crosses the crest of the dam by means of a small bridge over the spillway on the right side and then goes upstream following the left bank of the artificial lake.

The basin of the lake is underlain almost entirely by impervious marly shale Cretaceous formations (except where the Jurassic core is crossed).

To sum up, the excellent firmness of the rocks allowed an unusual amount of tunneling; moreover, it was possible to give to the concrete mass a great simplicity of line which harmonizes with the severe and bare scenery.

It is schematically the most simple example which may be found in Algeria. Two or three other sites could perhaps be found, namely at the "Guergour of Bou Sallam" and at the "Foum el Kreneg of the Rummel" in the Department of Constantine, but those locations, that have not been used, are of less interest.

This explains why the most important and the first of all the dams to be built was erected at Oued Fodda. At no time during the construction, did it require detailed geologic reconnaissance.

The only appreciable difficulties concern construction techniques mainly to assure that the structure would be watertight. The unavoidable fissuring of the calcareous rocks left numerous and sometimes large crevasses which necessitated injections of large volumes of cement. These operations were carefully conducted and have been completely effective.

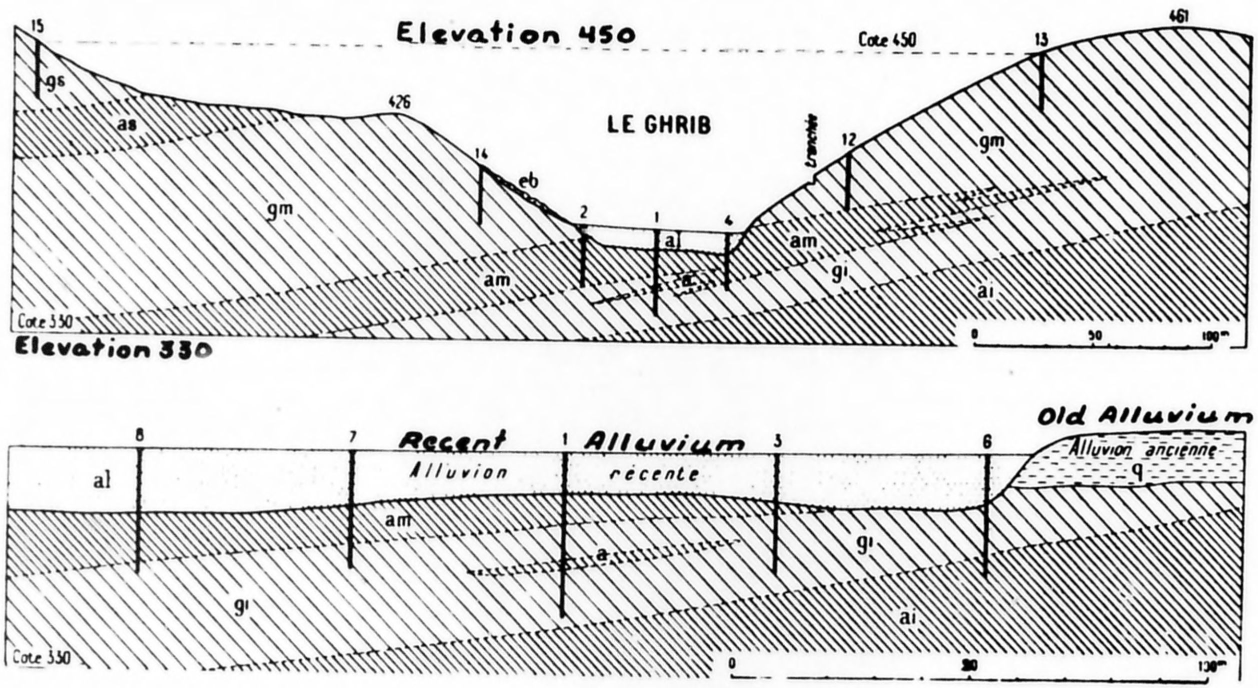
The capacity of impounded water is estimated at 225 million cubic meters.

Ghrib Dam

The natural dam site where the "Chelif" enters a Miocene Basin situated in the Cretaceous mountains was deemed suitable for the construction of the Ghrib dam.

Figs. 1 and 2 show cross sections which were drawn up from the interpretation of borings made during the preliminary investigation. A section of the 1/50,000 map (sheet Sidi-Mahdjoub) (fig. 3) completes the illustrations.

The penetration of the Chelif into the Miocene Basin was made easier by a downwarping of the edge of the basin, which is underlain by alternating clay and sandstone. The general attitude of these beds in a cross section 5 km. long (fig. 5) does not exclude small localized deformations.



Figs. 1 and 2. GHRIB DAM

Cross-sections along the first line of bore-holes

al, recent alluvium; gs, upper sandstone of the Miocene; as, upper clay; gm, middle sandstone am and a, middle clay; gi, lower sandstone; ai, lower clay (base of Miocene).

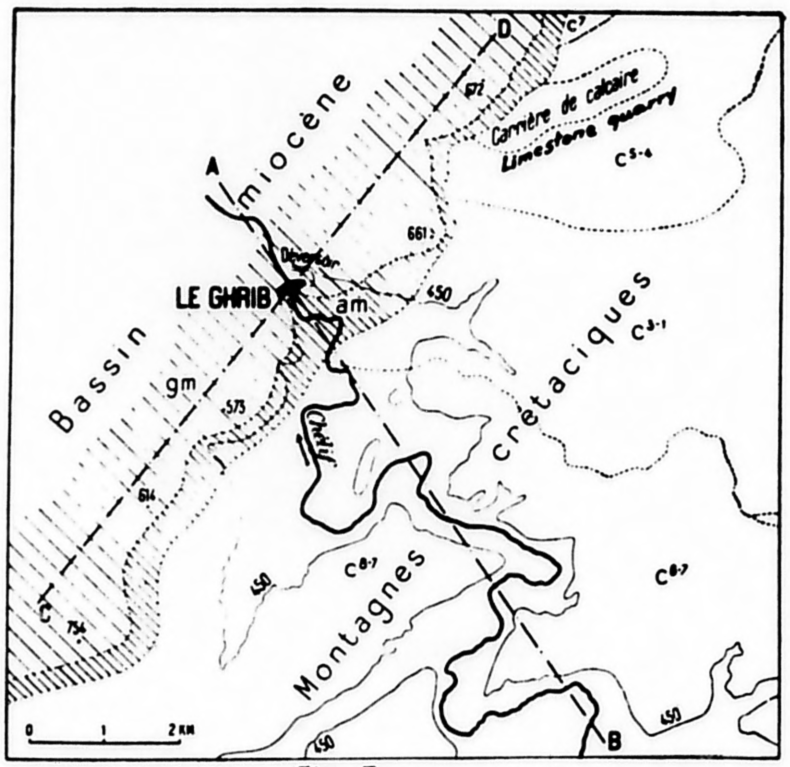


Fig. 3

The Ghrib and its artificial lake (elevation 450)

gm, Miocene sandstone; am, Miocene clay; C^{8-7}, Senonian; C^{5-4}, Cenomanian; C^{3-1}, Albian.

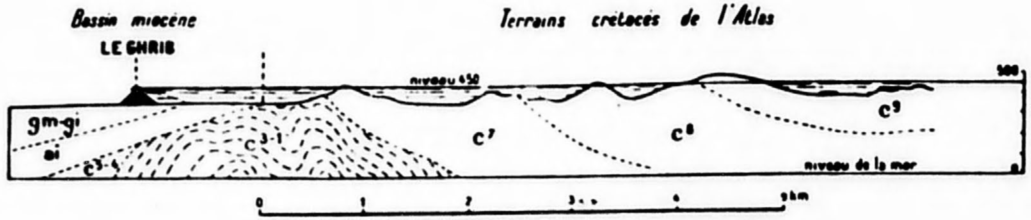


Fig. 4

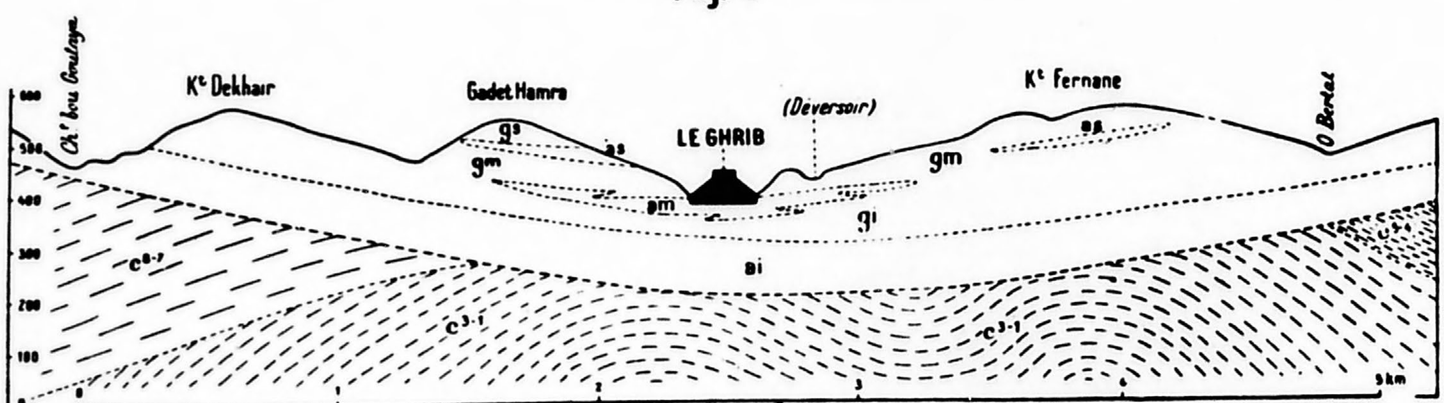


Fig. 5

GHRIB DAM

Cross-sections along the lines AB and CD of fig. 3.

gs, gm, and gi, Miocene sandstone; as, am, ai, Miocene clay; C^9 C^8 C^7 and C^{8-7}, Senonian; C^{5-4}, Cenomanian; C^{3-1}, Albian.

The bedding planes are not absolutely level due to their "lenticular" or "half-lenticular" arrangement. The outcrops of the clay and sandstone are ocher or yellowish in color (due to oxidation of the pyrite), but retain their original gray or bluish color in depth. Also, according to lithogenetic or diagenetic peculiarities, this clay is more or less marly (calcareous) and the sandstone is more or less friable (sandy).

These geological and physio-chemical variations of the rocks hold the attention of the designers, builders and those engineers concerned with the watertightness of the dam and reservoir, but it is practically without interest for the geologist.

A gravity dam with a large base was erected at the Ghrib without manifest difficulty but not without various precautions. The dam is uncemented masonry made of large limestone blocks, in places "cyclopean" in size, arranged with great care.

More than 700,000 m^3 of this limestone was used. The blocks were taken from a quarry of Cenomanian limestone having large regular benches. The volume of the quarry was calculated as having several million cubic meters available from working faces located at a higher level than the dam crest. The removal and transportation for a distance of 4 to 6 km. to the dam site were thus made easier by the topographic location. One could not hope to find, even at a much greater distance, such a quantity of practically homogeneous material. Some of the quarried blocks weigh as much as 10 tons.

The watertightness of the structure was assured by construction of a grout-curtain (injection of cement in vertical borings into the underlying and lateral permeable rocks) in front of the cofferdam which was built upstream from the rock-fill dam. The face of the dam, which is in contact with the water was protected with a simple flexible bituminous concrete cover. The down-stream face is bare from top to bottom, and it shows the "cyclopean" masonry, the appearance of which calls to mind the monuments of ancient Egypt.

The valley walls to the right of the dam are not very high. The rocks are of medium firmness and show some of the usual fractures or joints. All these characteristics of this location may be considered as very normal in Algeria in spite of the serious difficulties which severely tried the ingeniousness of the constructors.

The spillway was placed laterally at the best topographic location. It was dug in friable sandstone which had to be protected by thick concrete to keep it from eroding in case of exceptional floods. This precaution is probably not superfluous although the artificial lake is not completely filled every year._/ The bottom and the sides of the reservoir itself give every guarantee of watertightness as they are of marly shale (Albian) and marly (Senonian) chalk formations, which are known to be generally watertight.

For a while consideration was given to using the Ghrib dam to provide the town of Algiers with an additional supply of drinking water and perhaps to doing away with the expensive pumping plants upon which the large town depends. A serious difficulty was encountered, however, because of the heavy concentration of salines (chlorides and sulphates) in the Chelif water, particularly at the time of floods which bring to the artificial lake the products of the leaching of salt soils located

_/ The average annual discharge of the Chelif approaches 120,000,000 m^3; but during the construction of the Ghrib a minimum of 20,000,000 and a maximum over 500,000,000 m^3 were registered. The dam is high enough to maintain an impounding reservoir of 280,000,000 m^3, which will provide a regular distribution of the water.

mainly upstream from Boghari. This should be taken in consideration even when using water only for irrigation. Since the large reservoir is more than 10 km. long and will be subject to an active evaporation, the saline concentration should be kept under control.

Under the present circumstances, the construction of a hydroelectric plant seems to be required at the Ghrib, as in many other places.

It seems that in the future the "policy of water", which was aimed at making the irrigable sections of some valleys available for agriculture, will have to give place to a larger scale "policy of rural electricity". Large regions, now considered nonirrigable due to their geographic location, may become irrigable at the time when the expenses of pumping ground water will be considerably reduced, thanks to a general distribution of electric power.

It is not necessary now to go into the related considerations which may be suggested by the future rational utilization of the water power reserves not only in the principal rivers (large volume, slight changes of level) but also in mountain streams (small volumes, high changes of level). In both cases, this utilization is made by means of appropriate installations, dams or channels, for which the geologist's help is called upon in the preliminary planning stage as well as in the construction stage.

Beni-Bahdel

At Beni-Bahdel on the High Tafna, a group of regularly stratified marine beds of the Upper Jurassic (Sequanian stage) forms the foundation of a peculiar, widely hollowed-out concrete dam (multiple-arch type) made up of eleven semicircular elements, with two massive wings extending from the main body of the dam to each bank.

The irregularities of the hilly terrain surrounding the reservoir and dam sites made it necessary to build two accessory dikes across low passes where the altitude was less than the desired reservoir level. The level which had first been set at 652 m. was lowered 5 m., however, so that these accessory structures became considerably less important than in the original plans, thus allowing a considerable reduction of the importance of the complementary constructions.

One of these low passes is a former river bed, 33 m. higher than the nearby stream of Oued Khemis. This abandoned channel is evidence of an earlier drainage system quite different from the present one, and is also proof of the phenomenon of "stream capture" in the evolution of the system.

The spillway is located in a third pass between the two accessory dikes. Here there is no old alluvium; instead the spillway area is underlain by very fine sandstone and marly limestone with characteristic impressions of Cancellophycus. These rocks belong to an older Jurassic stage than that of the Sequanian sandstones, or even of the Callovo-Oxfordian sandstones which are also present in the area.

The generalized cross section (fig. 9) shows the regular superposition of several Jurassic stages in the Beni-Bahdel region and on both sides of a fault located far away from the dam (this fault deserves the name of "thermal fault" for it explains the presence of the "Ain-Skrouna" (Skrouna spring) on the side of the Oued Khemis (Khemis stream)).

In fact, the geologic sketch map (fig. 10) of the Beni-Bahdel region, shows a large complex field of fractures; but these do not concern the dam itself.

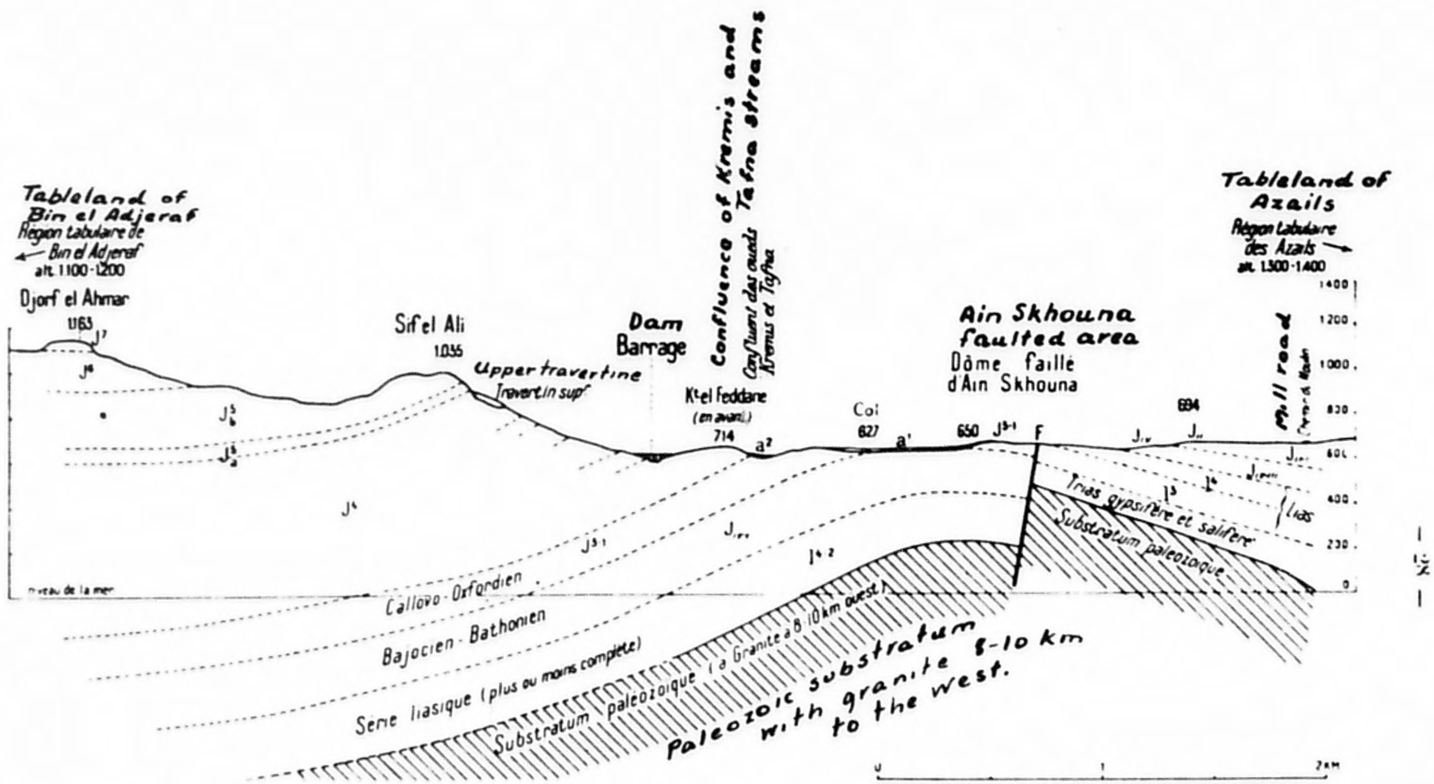


Fig. 9

BENI BAHDEL DAM

Cross-section passing through El Ahmar Djorf, the dam and the confluence of the Tafna and Khemis streams

a^2 recent alluvium; a^1 old alluvium; J^7 to J^4 upper Jurassic; F, thermal fault

A wide cut in the Jurassic plateau of Tlemcen exposes beds of numerous stages, down to the Lias, and even to the Trias. The underlying Paleozoic substratum with its granitic core appears a short distance to the west. It is the easternmost extension of the large fold of Ghar Rouban. The Moroccan frontier is 30 km. west-southwest of Beni Bahdel.

For the location of the dam site, things must be considered on a different scale.

A line of five borings marked the vertical plan containing the crest line of the future work. The alternation of gritty and marly shale layers, which were first recognized from actual outcrops, were easy to correlate with precision from one boring to the others nearby, although the beds identified in the first hole sometimes pinched out at an angle in the second and vice versa.

For example, bore-hole No. 14 on the left bank (almost under the buttress No. 7 of the multiple-arch construction) penetrated the following succession of rocks, from the top (conventional elevation 600.64 m) to the bottom:

3.30 m. compact siliceous sandstone
7.60 m. schistose marl
8.80 m. sandstone, more or less fissured
13.20 m. schistose marl
16.60 m. gray or yellow sandstone, more or less fissured
21.20 m. schistose marl
23.60 m. sandstone and shale with fissured sandstone at the base
29.15 m. yellowish sandstone, more or less compact
30.00 m. gray sandstone.

The strata, uniformly inclined, dip to the north at angles of 18° to 20°. The dip is of the same value in a perpendicular azimuth which corresponds to the local direction of the thalweg. The largest slope occurs in the bisecting plan of both of these orientations, approximately toward the NW. The slope is of about 30°.

An accessory fault, with a very small throw, apparently exists under the buttress No. 12 (the last one, left bank) but was considered of negligible importance.

It is evidently due to the practical difficulty of finding a quarry of homogeneous materials, which also had a good topographic location, that a rock-fill dam was not considered and that the preference was given to multiple-arch construction. The form of this construction does not cause any ground strain other than that resulting from the vertical component of the hydraulic pressure and this component is divided.

From another point of view, the large area of the impounded reservoir, the diversity of the Jurassic layers forming this artificial basin, and the fractured state of most of the beds may endanger the general watertightness. More than any other site, the location of Beni Bahdel should have required, in this respect, a meticulous geological survey of the whole basin and not just the immediate vicinity of the dam site. It can always be hoped that a natural clogging of fractures and permeable beds will take place sooner or later, although the water of this river is exceptionally low in amount of suspended clay.

The capacity of the reservoir is estimated at 41 million cubic meters.

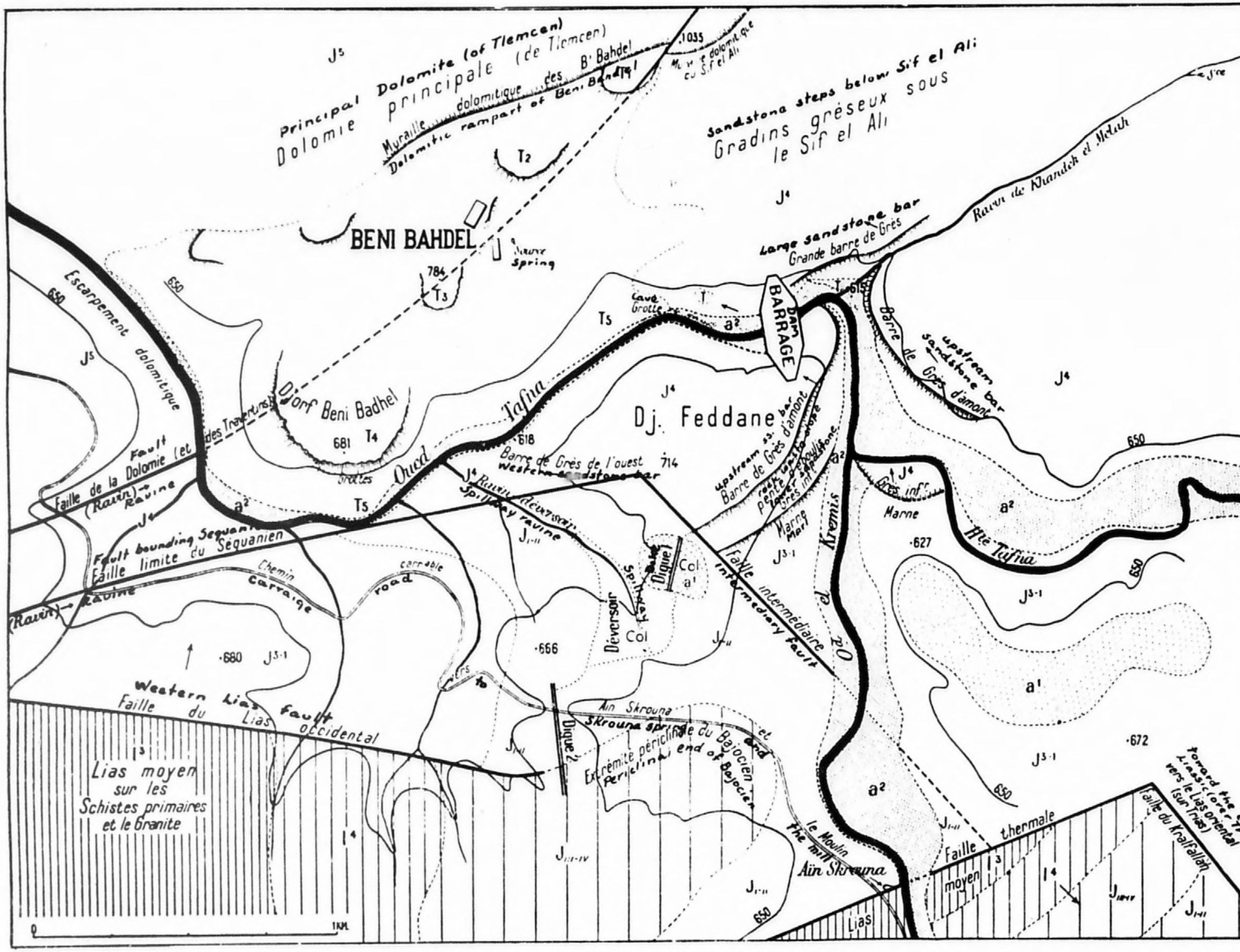


Fig. 10 Geology of BENI BAHDEL (fault zone)

For names of stages, see fig. 9. In addition, J^4 Sequanian; T, T1 to T5 is calcareous travertine

Even though the Beni Bahdel dam was planned for the purpose of irrigating the Middle and Low Tafna, it may also be of great use to the town of Oran in supplying drinking water. It has been established, in fact, that the problem of water supply for this town could not be solved any longer by pumping the "fossil" water of Bredeal, and there is no water-bearing fold in a vast perimeter around Oran which could be used for that purpose.

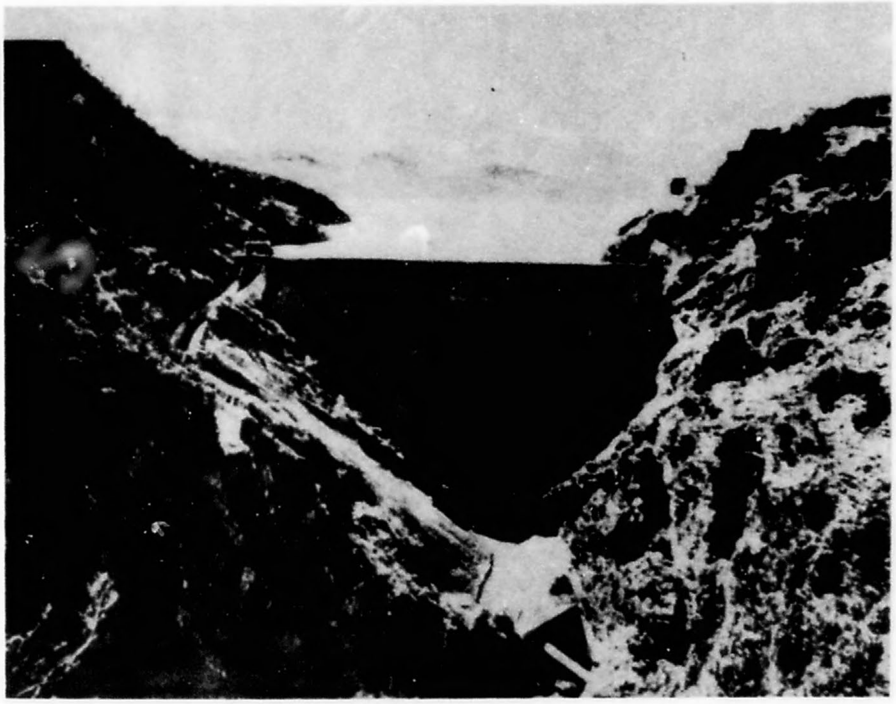
Since projects for supplying water to urban centers have involved the eventual utilization of several dams, it will be noted that the hydrogeologic problems raised by water supply have at all times interested the geologists of this country. Water supply problems of the town of Oran, in particular, led to numerous stratigraphic, tectonic, meteorologic, and even geochemical studies which were all checked by experimental work conducted over a period of years. Here also, the collaboration, even indirect, of the geologist and the engineers was highly profitable to science as well as to humanity, and all the factors of a very complex problem were strictly and finally established.

Vue d'aval du Barrage,

de

L'OUED FODDA

(d'après une phototypie)



View from downstream of the Oued Fodda Dam

In addition to the concrete dam, the artificial lake, already filled, is seen (above) with its frame of mountains. To the left is the open spillway (right bank) destined to eventually form a cascade. Below is the discharge arrangement. To the right, the crevice where the underground spillway emerges (left bank), and the entrance to the road tunnel at the end of the dam crest.

The stratification of the Jurassic limestone, which here is hardly noticeable, dips upstream at an angle of about 30°, (an effect of perspective exaggerates this inclination, the observer being below the strata planes)