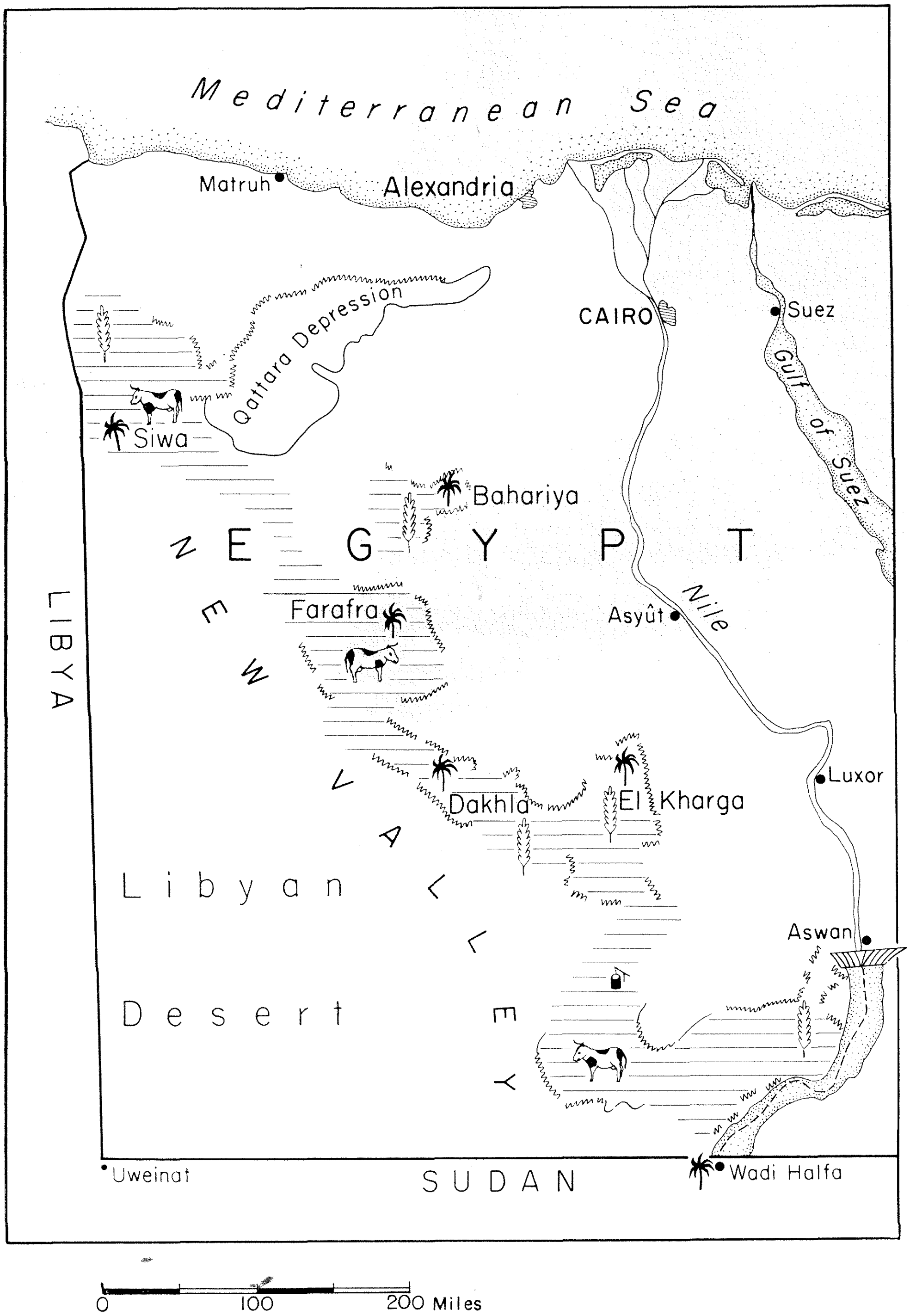


The hatched portions in this map of the Egyptian desert show the areas that are now, or will be, irrigated by artesian water in Project New Valley, a long range plan which will bring from 10 to 15 million people to this arid area.

Project New Valley

by Egon T. Degens

In the spring of 1960, a geologist, a physicist, and a geochemist landed at Cairo airport. Their visit, which was sponsored by UNESCO, the Federal Republic of Germany, and the Egyptian Government, concerned the water problem of the Western Egyptian Desert.

It was the time of Ramadan (which literally means "hot month") when strict fasting is practiced during daylight hours, until the Great Bairam, the highest Mohammedan festival, ends the fasting. Actually, it seems that a great percentage of the Egyptian people

Αριστον μέν ὕδωρ

"Water is the best of all things"—Pindar (475 B.C.)

practice Ramadan more or less permanently, for many of them live on only one or two cupfuls of hot beans a day.

One may ask why these people cannot make a decent living in a Nile Valley which often looks like the Garden of Eden. The answer is quite simple. Egypt covers an area of about 400,000 square miles and has a population of about 26 million; that means 65 people per square mile—a population density very much like that of California. But the inhabitants of Egypt are concentrated in the small valley of the Upper Nile and delta region—an area which embraces only 14,000 square miles. In other words, there are 1,800 people per square mile here, making this one of the most densely populated spots on our planet. The rest of Egypt is just plain desert, with here and there an oasis; but only a couple of thousand people call such oases home.

The population of Egypt increases by more than 500,000 per year. A few years ago, people all over the world realized that something had to be done immediately to forestall even more serious famine, and the erection of a high dam near Aswan was planned. This would make possible the development of some industry and the irrigation of an additional few thousand square miles of desert.

Because of the external political situation, the construction of the Aswan Dam is now in progress under Russian management and will be completed in 8 to 10 years. The succeeding irrigation program will provide subsistence to about 5 million people—but, since this is precisely the expected increase in population over the coming decade, it is somewhat unrealistic to regard the Aswan Dam as the final solution to Egypt's problems.

Ancient history

Not long ago, in the period of about 100,000 to 10,000 B.C., the Western Egyptian Desert, which is a part of the Libyan Desert, was a center of culture and civilization. Since that time human beings have gradually disappeared from this region. The population has declined from an estimated few million people in the Mesolithic era to just a few thousand fellaheen today.

In Mesolithic times, which cover the period from about 50,000 to 10,000 B.C., huge fresh water lakes developed naturally in the Western Egyptian Desert. They were fed by streams which branched from the old Nile near Wadi Halfa and then flowed northwesterly along the line of the so-called desert depressions—in which the oases Kharga, Dakhla, Farafra, Bahariya, and Siwa are located—to end ultimately in the Mediterranean.

This picture, as outlined, is like a mirage seen across the sands of time, for today one sees only growing sand dunes, dry lakes, and a precipitation of less than one inch in 25 years.

The past — key to the future

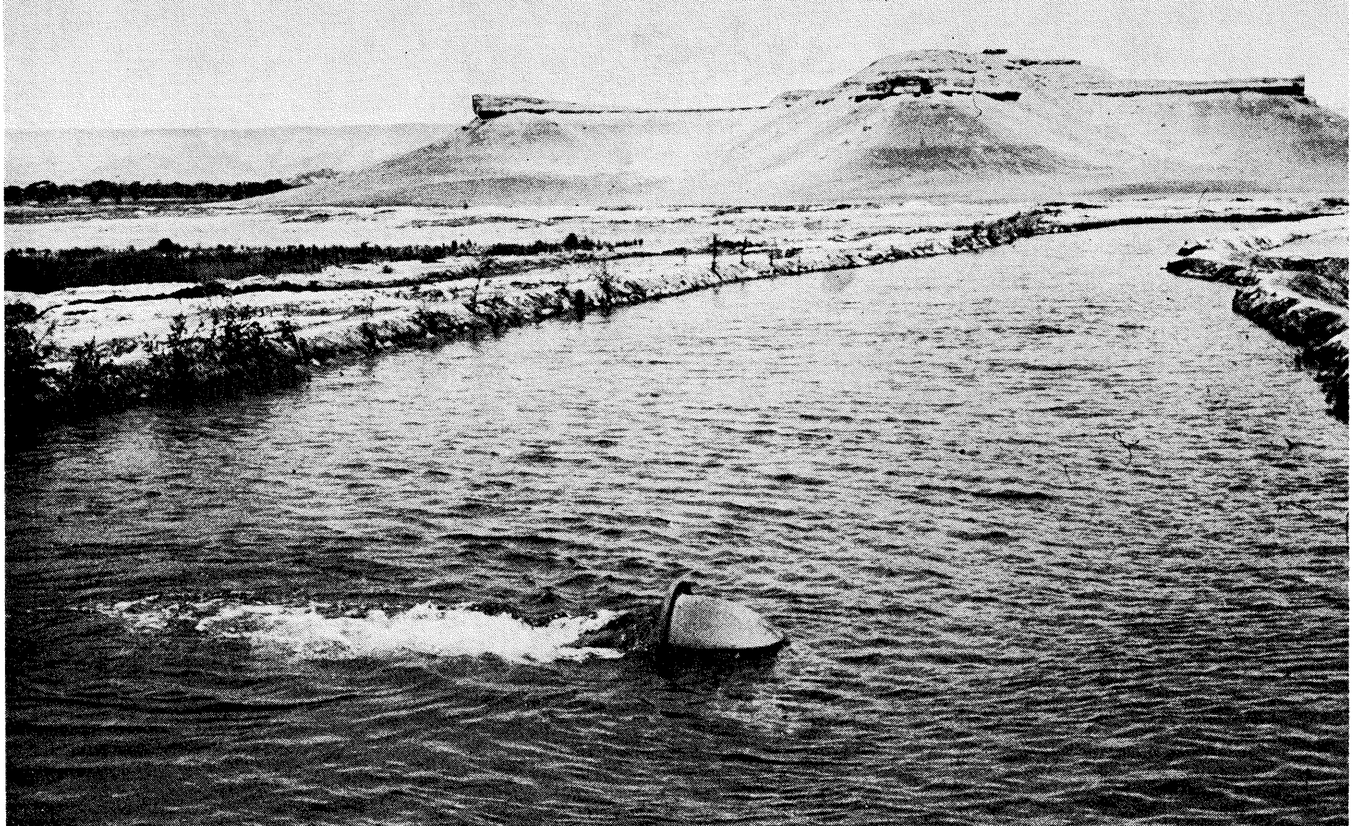
Oases are located sporadically throughout the Libyan Desert, and it is a common belief that they have unlimited water resources at depth. It is further assumed, without adequate basis, that this water reservoir is continuously recharged from the south (Abyssinia-Sudan) and southwest (Equatorial Africa) where precipitation is abundant.

This belief is based largely on the fact that the oases have stayed as a bastion in the desert for at least the last few thousand years, and that during this period the water supply has not changed significantly.

The water is mostly artesian—brought to the surface by natural water or gas pressure. It is stored at depths from 100 to 3,000 feet below the present surface. It is well established by geological studies that there is subsurface water intercommunication between some of the oases, which could mean that water reservoirs of larger dimensions are developed at greater depth beneath the Libyan Desert.

This assortment of facts and vague hypotheses has led to one of the most fantastic cultivation programs the world has ever known—Project New Valley. Although this program will change the economy and the face of Egypt in a profound manner, little is known about the ultimate goal of the project outside of Egypt. Basically, the project intends to irrigate land now occupied by desert by means of subsurface waters, supplied from hundreds of bore holes to be drilled in the depressions of the Western Egyptian Desert. Some additional water will be furnished from the Aswan High Dam reservoir along an artificial river flowing through the New Valley.

The area under consideration is hatched in the map at the left. This is the very same area where prehistoric man lived, and the aim of Project New Valley is, therefore, the recultivation of ancient farmland which has gradually developed into desert over the last 5 to 10 thousand years. As an indication of how



Project New Valley produces irrigation water at a rate of about 300,000 cubic meters a day at the oasis of Dakhla. Pipes like that above bring artesian water from hundreds of feet below the surface. At present the water is overflowing and evaporating, leaving thick layers of salts on the newly developed acres.

the project will affect the population structure of Egypt, approximately 10 to 15 million Egyptians are expected to settle in this area within the next 10 to 15 years.

New Valley is an outgrowth of the General Organization for the Rehabilitation of Deserts which was founded at Cairo about 10 years ago. One of the first activities of this organization was to drill a great number of bore holes across the desert depressions, hoping for unlimited water resources beneath the desert.

The project is only a few years old and still in its initial stage, yet millions of cubic meters of water are being continuously extracted from the subsurface reservoir. At Dakhla, a small community of less than 1,000 people, the daily outflow of water is about 300,000 cubic meters, a quantity sufficient to supply a town of 1-2 million inhabitants. At present, the water is just running down from the slope to evaporate at the rate of about one inch a day, leaving layers of salts up to a half inch in thickness on the newly developed acres.

One important necessity for the success of Project New Valley is that the extraction rate of the water be matched by an influx rate of comparable magnitude. However, there are convincing reports that such a sound water balance does not exist. For instance, a significant decrease in gas pressure and water outflow rate has already been registered in the first five years of the project. This might be an indication that the water resources are not as plentiful as generally assumed.

This was the situation when our three-man research team landed at Cairo airport to study the origin, source, and distribution of the artesian waters in the Western Egyptian Desert. Over a period of three weeks we collected water samples from various places in the desert depressions, the location site of New Valley, to be analyzed later in our laboratories at home. A two-engine Ilyushin aircraft, furnished by the Egyptian Government, made this rapid collecting of the water specimens possible.

The group was headed by Dr. Georg Knetsch, director of the Geological Institute at Wuerzburg University in Germany. Dr. Knetsch has spent many years in Africa doing temporary work as head of the Department of Earth Sciences at Cairo University. He is unanimously regarded as the outstanding European expert on African geology. His profound knowledge of Egyptian geology was the scientific backbone of our whole investigation.

The physicist, Dr. Karl Otto Munnich, senior research associate at the Physical Institute of Heidelberg University, working with Dr. John Vogel, associate professor at the Physical Institute of Groningen University, determined the age of the waters by means of carbon-14 analysis.

As geochemist, I investigated the chemistry and stable isotope distribution of the waters and the sediments.

During our trip, we were associated with two Egyptian geologists, Dr. A. Shata and Dr. M. Shazly, both staff members at the Desert Institute in Cairo.

Geological background

To understand the water situation and the future of Project New Valley, it is necessary to have some idea of the geological setup of Egypt.

The oldest rocks exposed in Egypt are crystalline rocks of Precambrian age. They cover a small strip of about 30 to 80 miles wide along the west coast of the Red Sea. They are also present in Sinai. Westward from the Red Sea, these Precambrian or basement rocks are overlaid by sediments belonging to the so-called Nubian Series which dip gently to the west.

Spots of Precambrian rocks also crop out in the Libyan Desert, close to the border of the Sudan. These crystalline "islands" are oriented along an east-westerly line starting from about Aswan and moving westward to Uweinat, a small place located in the northeast corner of the Sudan. This is the surface manifestation of the Aswan-Uweinat Uplift, a gigantic subsurface rock dome which lifted crystalline rocks to, or close to, the present surface and has served as an effective impermeable barrier to the movement of ground water.

North of this uplift, the crystalline basement dips northward and is covered by sediments of the Nubian Series which are gently inclined to the north. The Nubian rocks represent stratigraphically all sediments from at least the Cambrian up to the Cretaceous and sometimes the Eocene, a time period covering about 400 million years of earth history. In the north, Upper Cretaceous and Tertiary limestones and clays rest upon the Nubian Series.

These features indicate that Egypt is surrounded on the east and on the south by a girdle of crystalline rocks; to the west extends the Sahara Desert, and on the north the country is bounded by the Mediterranean. Inside Egypt, moving from the Aswan-Uweinat Uplift in the south toward the Mediterranean, only Nubian and younger sediments are exposed, resting on the Precambrian basement. Toward the north, these sediment layers increase steadily in thickness from zero to about 10,000 feet. They hold the waters on which the success of Project New Valley largely depends.

"Tales Sunt Aquae . . ."

"Waters take their nature from the strata through which they flow." This statement by Plinius (23-79 A.D.) carries a profound meaning. Practically all matter found in the earth's crust is to some degree soluble in natural waters. Natural waters act as decomposing agents and solvents in the earth's crust. In turn, the waters cannot remain unchanged in their chemical composition as long as they migrate through rocks. The proportion and type of soluble matter taken up from the strata depends on a number of factors such as the chemical nature of the rocks, the purity and temperature of the water, the ease of circulation of water through the rocks, the overhead pressure, and the velocity of water flow.

In applying these fundamental hydrochemical laws to the Egyptian water problem, all the systematic variation in the chemistry of the waters can be explained in a simple fashion. Our data show that waters taken from oases in the south, close to the Aswan-Uweinat Uplift, have about 10 times less solutes than waters obtained from oases in the north, located near the Mediterranean. In other words, there is an increase in salinity toward the north, and this increase is solely caused by contributions of chlorine, sulfate, and sodium ions to the water solutes. The remainder of the ions show no significant fluctuations over hundreds of miles.

Experimental leaching studies on the Nubian Series, which serve as aquifers or water-carrying strata, reveal that chlorine, sulfate, and sodium are, in fact, the only ions that can be extracted in significant quantities from the Nubian wall rock. This feature suggests a cause-effect relationship between sediment and associated water in a manner which confirms that "Tales sunt aquae, qualis terra per quam fluunt."

Isotope analysis

Although the chemistry of the water changes consistently from south to north as a result of migration and storage mechanisms, the ratio of the two stable isotopes of oxygen (0^{18} and 0^{16}) in this water does not change and, further, the amount of the heavy 0^{18} is abnormally low.

From other studies it is known that the amount of 0^{18} in natural waters is controlled primarily by the temperature at which such waters precipitated from the atmosphere. Precipitation occurring under cold conditions is relatively deficient in 0^{18}. The fact that the Egyptian ground waters are abnormally low in 0^{18} gives a clue as to the climatic conditions under which such water fell to earth and seeped into the ground to be stored in the safe-deposit box of the Egyptian water basin.

Analyses of the carbonates of the waters made it even more possible to determine the precise age of the water. At Kharga, the age is about 25,000 years, and at Siwa, 30,000 years. The ages of the other oases fall in between, gradually increasing from south to north.

The history of the water

All geochemical, geological, and physical information indicates that the water fell in Pluvial periods of the Mesolithic era about 25,000 to 30,000 years ago and was transported in surface drainage systems from

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Abyssinia and the Sudan into the Western Egyptian Desert in the Nile drainage system of that time. A significant *sub*surface migration of former rain waters from Central or East Africa into Egypt can be completely ruled out, since the Aswan-Uweinat Uplift, which once had lifted the crystalline basement to, or close to, the present surface, operated as an extremely effective water barrier, preventing a significant subcutane influx of water from the Sudan, Abyssinia, or the region of Equatorial Africa. The infiltration of present Nile water, a hypothesis formerly suggested, can be excluded for various geological and geochemical reasons.

Prehistoric lakes

The large supply of water from outside into the center of the desert depressions in prehistoric times resulted in the formation of extensive fresh water lakes full of fish, in which sediments were deposited. These unobtrusive sediments are the only clues to the former existence of the lakes, and their present distribution makes it possible to reconstruct the ancient shore lines. Embedded in the sediments, besides prehistoric artifacts, are small gastropod shells, whose isotope ratios are consistent with ratios that would be expected if the shells were formed in isotopic equilibrium with the desert water and its dissolved carbonate.

It is even possible to calculate, from the oxygen isotope data of the desert water and the shell carbonate, the mean annual temperature of the lake environment at the time the shell creature lived. The prehistoric water had a mean annual temperature of about 15-16°C, which is appreciably lower than the present mean temperature of the Nile. This is not surprising since there was a glacial stage at about that time.

The Nubian sediments, in which shales, sandstones, and conglomerates alternate, are quite favorable for the storage and transportation of the water. Aquifers are provided by sandstones and conglomerates, which are enclosed by relatively impervious shales. In those days the lake and river water oozed rapidly into the underlying Nubian Series or was carried by surface drainage systems into the Mediterranean along the line from Kharga to Siwa.

Evaporation from the lakes that existed in prehistoric times certainly caused precipitation and affected the general climate considerably. It has to be emphasized, however, that the overwhelming part of the present subsurface water was derived from the same geographical intake area as that of the present Nile, whose chemistry is identical with that of the desert waters which have been stored in the most southern oases for the last 25,000 years.

Water is never at rest. The Egyptian water migrated slowly from an intake area bounded by the Aswan-Uweinat Uplift in the south toward the Mediterranean, picking up more and more salts from the surrounding rocks during transportation. On the basis of carbon-14 data, it has been estimated that the velocity of flow is roughly 15 miles in 100 years. The solutes of the water increase by about two milligrams per liter during one mile of transportation. The low salt concentrations in the southern oases support our inference that the water did not migrate the long distance of about 1,000 to 1,500 miles through rocks from Abyssinia to the Sudan.

Waters from greater depths rise to the surface by pressure of gases. The origin of these gases is not fully known. The most likely hypothesis is that the gas phase, which is mostly air, became entrapped in the sediments contemporaneously with the water. During storage and migration, the gases were separated from the water, and the shales, operating as a shield, prevented their escape. Just as compressed gas billows force oil to the surface in some petroleum deposits, waters present in the Nubian Series may similarly be expelled to the outside.

Future prospects

The success of a project of such fantastic dimensions as New Valley is dubious. Waters in the Libyan Desert are with great probability fossil, which means that no significant recharge from outside takes place. In addition, the water reservoirs are more or less restricted to small sediment basins below the desert depressions and do not extend over the entire Libyan Desert. Finally, the waters are presently being wasted in an irresponsible manner. There is of course no simple way to calculate the total water reserves, but the decrease in outflow in some of the oases should make people suspicious.

Under these circumstances it is advisable to stop the enormous consumption of irrigation water immediately. This can easily be done by switching from a flooding to a sprinkling technique, which would simultaneously prevent the development of salt crusts on the newly developed acres. It should also be possible to irrigate the desert on a somewhat smaller scale during the final stage of the cultivation program.

Under these conditions, the future of the many fellaheen who will eventually settle in the desert will be more secure, perhaps for the next hundred years or two.

I can already visualize a small stream, branching from the water reservoir of the Aswan High Dam into the Western Egyptian Desert and sending, as in prehistoric times, Nile water to the New Valley. More water will come from the ancient water reservoirs beneath the desert depressions. The climate will become more favorable and the New Valley will be transformed into a flourishing Garden of Eden.

This vision is the same as the one Egypt has been dreaming of ever since those seven meager years recorded in the first book of Moses.