# Possibilities of Underground Storage in Salt Cavities in Iraq

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**ABSTRACT**

The occurrence of salt in the geological framework of Iraq is reviewed, with special emphasis on the Miocene Lower Fars formation in the area of the northern city of Kirkuk.

To search for the potential underground storage in salt cavities, an investigation was carried out in the drilled wells on Kirkuk oil-field structure. The choice of location and preliminary decision to drill a test well for the purpose of obtaining full core samples of the salt beds are analyzed. The results of the test well are correlated with the old oil-well data.

A brief discussion of some of the problems involved with the underground storage project in Kirkuk is given.

## INTRODUCTION

In the Republic of Iraq, the subject of underground storage of natural gas and liquid hydrocarbons has been brought up for two main reasons. First, the "Law of Conservation of Petroleum Resources" requires that means must be found to store excess natural gas associated with the production of oil as an alternative to flaring such national wealth. Second, the expanding gas utilization projects necessitate storage of LPG for seasonal fluctuation and peak-shaving purposes.

As far as natural gas storage is concerned, studies have been made to find suitable geologic formations for storage in appropriate structures. Whereas, the storage of LPG and other liquid hydrocarbons has drawn attention to the salt beds as potential cavity storage media.

This paper discusses the salt units which exist in the Middle Miocene Lower Fars Formation. The salt beds of this formation were chosen because of their suitable depth and location.

## GEOLOGIC OCCURRENCE OF SALT

Salt occurs in the geological column of Iraq mainly in the Tertiary and Jurassic. In the Upper Jurassic Gotnia Formation (? Lower Kimeridgian to ? Upper Callovian), salt is encountered in some deep oil wells as "salt-anhydrite series". Other salt indications have been recorded in Lower Jurassic (Pre-Liassic) Adaiyah formation. In the Tertiary, the main salt units appear in the (Middle Miocene) Lower Fars formation and to some extent in the (Lower Miocene) Dhiban Anhydrite.

The occurrence of "salt domes" has not been proven yet, but they cannot be ruled out, since geophysical indications point to the existence of at least one such dome in the south of Iraq on the negative gravity anomoly, SW of Basrah City.

## THE LOWER FARS

The condition under which the Lower Fars "basin" was developed is depicted by its evaporite sections which seem to have been deposited in an almost landlocked basin. These evaporite sections are parts of many repetitions of cyclic sedimentation involving (limestone/dolomite/anhydrite/salt) representing progressively concentrated seawater, followed by marl/siltstone indicating subsequent dilution.

The areal extent of the Lower Fars Basin seems to have been restricted in the south and west by the Arabian Shield and in the east and north by the land swell corresponding roughly to the position of the present Zagros Mountains. However, the extent of the salt units within the Lower Fars is limited to a smaller area of the basin. The rough limits of this "Salt Belt" are shown in Figure 1. Information obtained from wells (drilled for oil) indicates that this belt can be further subdivided into "favorable" and "less favorable" areas.

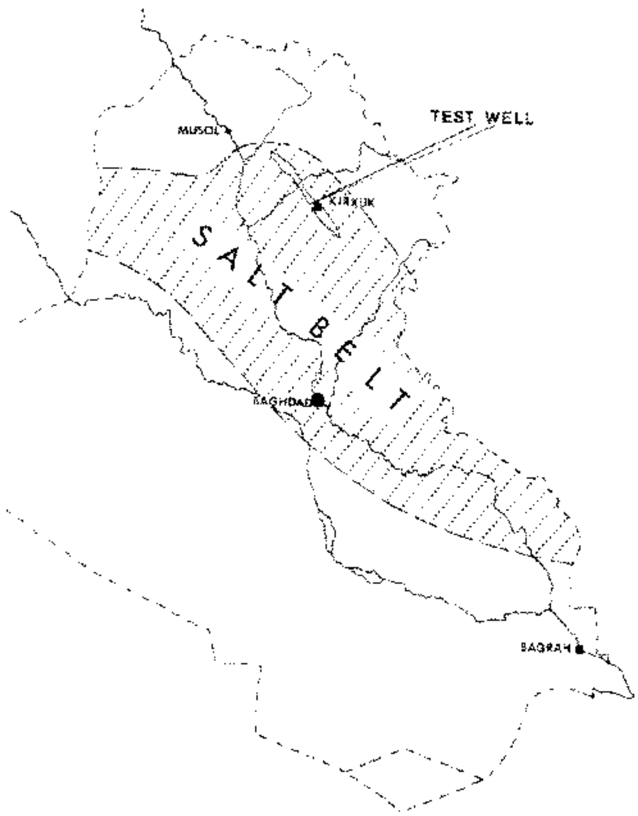


**Figure 1.** Location of the test well near Kirkuk, Iraq.

## SALT UNITS

The Lower Fars Formation consists of the following "Beds" (from top to bottom): Upper Red Beds, Seepage Beds, Saliferous Beds, and Transition Beds. The salt units are confined to the Saliferous Beds, with an unknown original thickness of salt between a thin, limited limestone (Marker X) above, and the first well-developed competent limestone (Marker S-1). The variation in the thickness of the salt is due to tectonic complications. This means that the existing thicknesses of salt units have been governed by the flow of salt under tectonic forces which resulted in the formation of the Kirkuk anticline (Fig. 2).

The following are the results of a very brief study of the salt units in the Saliferous Beds of the Kirkuk structure:

1. All the wells (more than 200) drilled in the Kirkuk structure have shown "pure" salt sections of varying thickness within the Saliferous Beds.
2. It is very difficult to find good correlations among the "pure salt units" encountered in different wells.
3. There are indications that the overall thickness of the pure salt is proportional to the thickness of the Saliferous Beds.

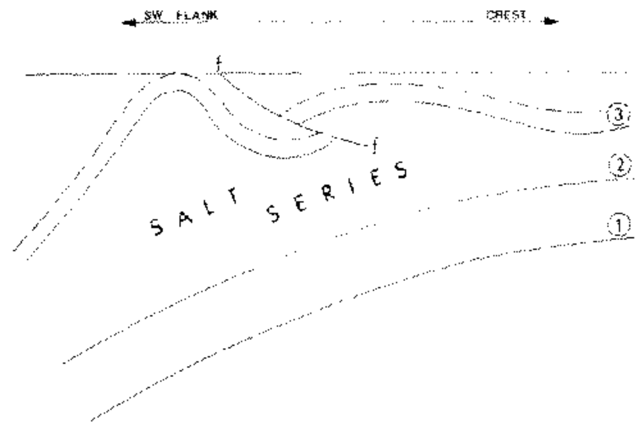


**Figure 2.** Cross section of the Kirkuk anticline. 1 = top of saliferous beds, 2 = top of transition beds, and 3 = top of Main Limestone reservoir.

4. From tectonic point of view, the thickness of salt decreases drastically toward the crest of the structure, and increases in the SW flank where the formations exhibit maximum folding and are cut by thrust faults (Fig. 2).
5. Individual pure salt beds of up to 50 m are likely to be encountered in SW flank at an approximate depth of less than 300 m.

## POSSIBILITIES OF UNDERGROUND STORAGE IN SALT BEDS OF KIRKUK STRUCTURE

From this brief study, it is evident that individual pure salt units in certain areas of Kirkuk can be expected to have a thickness of up to 50 m. This opens the way for further deliberations on the possibilities of storage in cavities made in these salt units.

## CHOICE OF LOCATION

Several factors are involved in choosing a location for the underground storage in salt cavities, among the most important ones were:

1. The proximity of the area to the location of the gas utilization project, where LPG and other liquid hydrocarbons might be stored.
2. The presence of the thickest section of individual pure salt beds (SW flank or Kirkuk field).
3. The relative ease of fresh water supply to the location (a fresh water pipeline passing through the area).
4. The suitability of ground surface (open flat area).
5. The possibility of finding suitable brine disposal facilities (re-injection into the underground).
6. A safe distance from problem areas (such as gas and oil seepages).

Now, the major factor left to shape the decision for an underground storage project in this area was to confirm that the salt beds encountered in the location are of appropriate purity and thickness together with related data which form the basis for the feasibility study of the subject. For this purpose a test well was drilled.

## TEST WELL RESULTS

The test well was located between two wells which have shown the best salt sections in the area according to geological and drilling records. Continuous coring of the salt units (within the Saliferous Beds) was decided upon to obtain suitable samples for analysis. A complete suite of Schlumberger logs were run for correlation. The following geological results were obtained for the Lower Fars Formation (depth from RTKB):

*Upper Red Beds.* (0–34 m); Siltstone and anhydrite (from cuttings samples).

*Seepage Beds.* (34–88 m); Siltstone/marls/limestone/anhydrite (also from cuttings).

*Saliferous Beds.* (88–total depth at 500 m); Brown siltstones/blue marls/white to grey anhydrites/translucent salts/marly limestone.

The following salt section was recorded from cuttings:

107–117 m depth (RTKB) = 10 m.
124–136 m depth (RTKB) = 12 m.

The depth of the first major salt unit was predicted at 250 m. Continuous coring was started at an appropriate depth of 234 m. Pure salt units were recovered (as 4″ cores) as follows:

242.5–245.5 m = 3 m
272.5–314.5 m = 42 m The first major salt
386.0–428.5 m = 42.5 m The second major salt
449.0–459.0 m = 10 m
480.0–485.0 m = 5 m

The S-1 limestone marker, below which no salt occurs in the geological section of this locality, was also cored between 496.0–497.5 m. The well was completed at 500 m total depth.

Therefore, the prospective salt units with underground storage potential are the following two main pure salt units:

1. 42 m thick at a depth of 272.5 m (RTKB) which is overlain by 2.5 m marl followed by 10 m solid anhydrite and underlain by 6 m anhydrite with some salt/anhydrite eutectics followed by siltstone and marls.
2. 42.5 m thick at 286 m depth which is overlain by a thick section of marls and siltstones (about 65 m thick) and underlain by 2 m of anhydrite with eutectics followed by siltstones.

The two salt units are separated by a section of 71 m of mainly fragile and/or plastic siltstone and marls.

Before discussing the correlation of the results obtained from the test well with the nearby wells, it must be explained that this well is the only well in which the salt units have been cored continuously. Information on salt in the other wells consists mainly of the rig geologist's description of cuttings samples which would usually be severely contaminated. Furthermore, few or no Schlumberger logs were run against the salt interval. Therefore, exact correlation will be rather difficult.

However, correlation between the test well and two nearby wells resulted in the following observations (Fig. 3).

Obviously, there is an excellent correlation between the test well (K-214) and the nearest well (K-104) only about 185 m away toward SE. The two major salt units (of just over 40 m each) are repeated, the only difference being that the salt units of the test well are structurally lower by about 34 m.

Correlation with the other, rather distant well (K-139) about 715 m away toward NW shows some variation. The lower major salt unit increases in thickness from 42 m (in the test well) to over 65 m, whereas the upper unit dwindles to a mere 18 m of which less than 10 m consist of pure salt. Structurally, the lower main salt unit in well (K-139) is higher than that of the test well by about 125 m, but the upper one differs only by 40 m in elevation.

The cycle of deposition is confirmed as follows. The salt units are always overlain by marl and siltstone and underlain by anhydrite, indicating that maximum dessication of the "lagoon" was reached by the deposition of salt and then dilution of the seawater occurred with maximum freshness of water being reached by the deposition of siltstone.

Provisional chemical analysis of the salt obtained from the test well show that it consists almost entirely of NaCl. The only difference between the upper and the lower units is in their physical impurities, whereby the lower unit is characterized by its slight marl content (as finely dispersed particles) which give the salt a bluish-grey color.

## POSSIBLE PROBLEMS

It is relevant at this point to mention some problems related to the area adjacent to the location.

**Oil and gas seepages.** It is well known that oil and gas seepages occur at the surface of the Kirkuk structure less than 2 km NE of the location. But no such seepages have been detected within the immediate surroundings of the test well.

The seepages are believed to be related to the main and

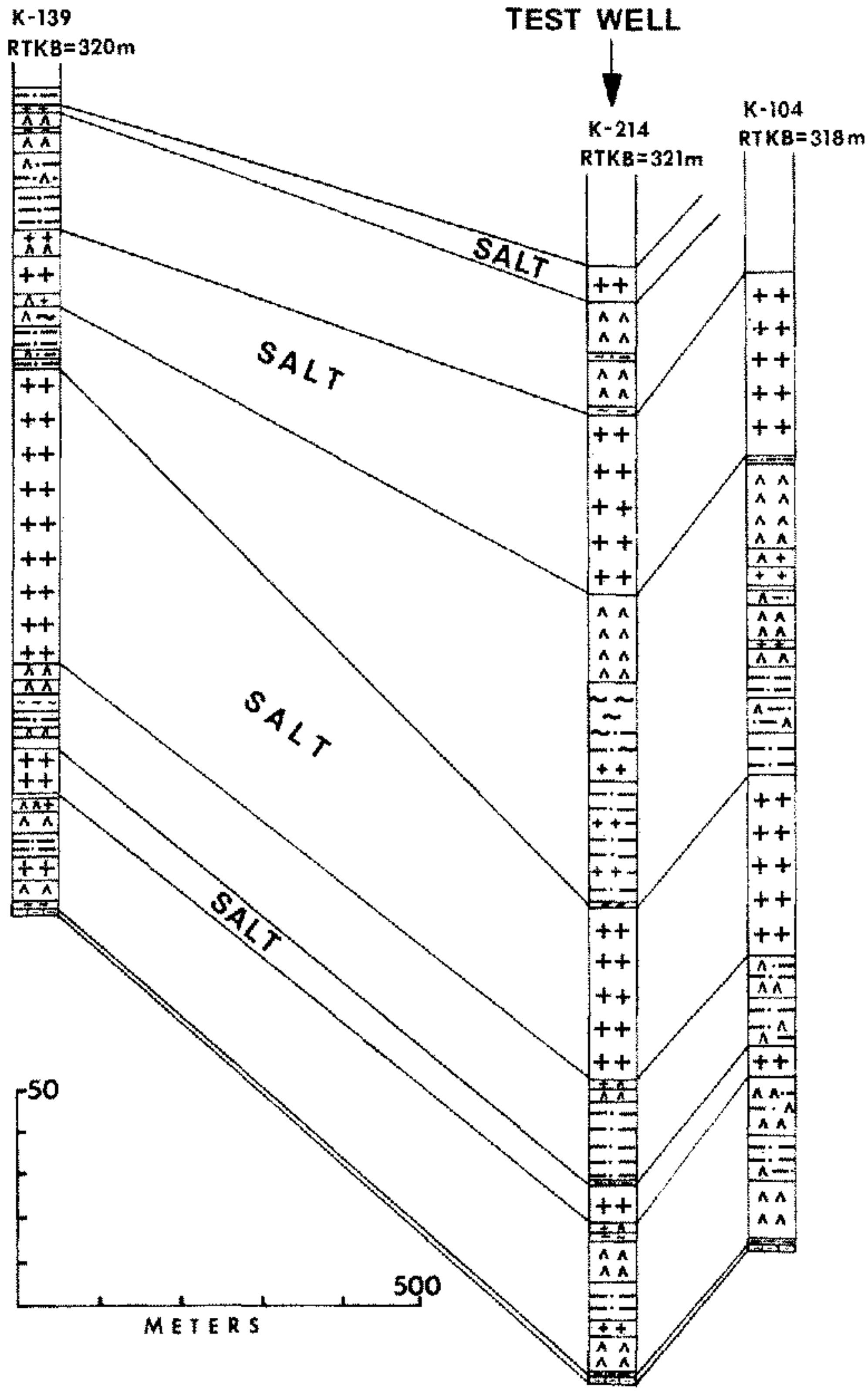


**Figure 3.** Correlation of the test well with other wells on the Kirkuk anticline.

other secondary oil and gas bearing formations through tortious paths connected to the surface.

It is obvious that such phenomena will pose serious problems for underground storage.

**Faults and fractures.** Faulting and fracturing are one of the major features of the main oil reservoir of Kirkuk and the competent formations above it. This can result in problems relating to fluid leakage and mechanical difficulties as far as underground storage is concerned. However, most of the faults indicated by the structure contour maps seem to disappear within the relatively plastic formations above the oil reservoir, especially in the Saliferous Beds which contain the salt units. Also, it is expected that any fracturing will soon be inherently healed within the plastic salt body itself.

**Flow of salt.** Salt flow is known to have caused stuck-pipe problems while drilling through the Saliferous Beds in some of the wells in Kirkuk. This means that the salt unit can flow under differential pressure and, perhaps, with the passage of time.

Nevertheless, no problems of stuck-pipe were experienced in drilling and coring the test well; the main problem being the swelling of marls within the core barrel which necessitated the use of single rather than double core barrels in general.

**Cap rock.** As was seen before, the salt units are, in their cycle, overlain by marls and siltstones which are usually non competent formations. This is particularly significant as far as the lower main salt unit is concerned, where a relatively thick section of siltstones and marls from its cap rock. The upper salt unit, however, is overlain by only a few meters of marls followed by a solid anhydrite section. In this sense the upper salt unit might be regarded as having a better cap rock, although the lower unit shows thickening laterally.

**Underground water.** We have no definite information on the ground water levels in the area. It is obvious that underground waters will create some problems. However, it is hoped that solutions to these problems will be restricted to shutting off of the ground waters by properly cemented casings.

## CONCLUSION

The prospects for underground storage of LPG and other liquid hydrocarbons in salt cavities were indicated by the presence of salt beds of predictably suitable thickness, purity and depth in the area of Kirkuk oil field.

The results of the test well furthered this prospect in as much as they confirmed that individual pure salt beds can have thicknesses of over 40 m at an appropriate depth of 300 m below ground.

Although the thickness of the salt units changes within a relatively short distance, it is fair to believe that within the region allocated for the project such thickness variations will be small. It is also thought that the effect of the problems associated with the underground conditions in the area will be minimal.

A study of the feasibility of underground storage in Kirkuk is presently being conducted. But no results of this study were ready for discussion in this paper. It is hoped, however, that the questions posed by this paper will be answered soon through this feasibility study.