Sea Salt Production at Torrevieja, La Mata, Pinoso, Spain

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ABSTRACT

The plant at Torrevieja-La Mata was described at the Second Symposium on Salt. Subsequently, modifications have been made to enlarge its production capacity, which now exceeds 1,200,000 tons a year. These improvements have been obtained by regulating the feed to the Torrevieja lagoon (1,400 hectares surface area) from three different sources. The first source is the seawater. The second is the concentrated brine coming from the evaporation of seawater in the contiguous lagoon of La Mata (surface area 700 hectares). The third is the brine which is nearly saturated and is derived from the dissolution of rock salt of the Pinoso bed by water injection at high pressure. The water injected into independent chambers, with previous decantation, is carried to the Torrevieja lagoon through a 450 mm diameter pipeline 53.7 km long. The line drops from an elevation of 780 m to the 20 m level at Torrevieja.

The advantage of transporting the Pinoso brine to the Torrevieja lagoon is that this source smooths out irregularities in the lagoon productivity because it greatly reduces the influence of rainfall. It also reduces the difficulty one has in the total extraction of salt from seawater without also producing a proportional amount of the other salts contained in seawater.

The addition of the salt from the Pinoso bed is justified by a number of tables. The technological development of the Pinoso bed and its incorporation as a source into the saltworks plant at Torrevieja is also described.

INTRODUCTION

The salt production in Spain is undergoing an extraordinary increase, as is shown in Table 1, it is mainly in connection with the production of chlorine and caustic soda.

This article studies the increase of production capacity in the Torrevieja saltworks, due to the addition of rock salt brines from the Pinoso deposit, as well as the reasons for and consequences of these additions.

We shall omit any description of the salt harvesting in the Torrevieja lagoon, as this was fully dealt with in the Second Symposium (1), and its technology has not undergone any subsequent important modifications, except those that were required by the production increase shown in the aforementioned table.

The irregularity in the production of the Torrevieja saltworks is chiefly due to the variability of the climatological conditions and, specifically, to the variability of the rainfalls.

The rainfall effect on the production is so important that we consider it requires some comments. Table 2, which tabulates the total rainfall in the Torrevieja lagoon from the year 1960, does not give an exact idea of the relationship between rainfall and production. To appreciate the effect caused by the rainfall intensity over the lagoon preparation and salt extraction on the production of each season, we assume that the supplies of seawater and brines from the La Mata lagoon took place in ideal quantities and at ideal times, and that the evaporation intensity can be regarded roughly constant, as may be deduced from Table 3.

Table 4 gives a breakdown by months of the rainfall registered and of the dragged water brought into the Torrevieja lagoon during the years 1962 to 1976.

TABLE 1

Salt Production in Thousands of Metric Tons

Year	Spain	Torrevieja
1960	1.391	409
1961	1.599	452
1962	1.640	475
1963	1.699	521
1964	1.924	597
1965	1.857	477
1966	1.754	412
1967	1.771	380
1968	1.844	419
1969	1.862	376
1970	2.080	464
1971	1.979	327
1972	1.866	267
1973	2.385	302
1974	2.257	204
1975	3.132	862
1976	3.158	722
...	...	...
1980	3.900	1.200
1985	5.000	1.200
1990	7.400	1.200

TABLE 2

Rain Water Introduced into the Torrevieja Lagoon
In Liters Per Square Meter

Year	Direct Rain	Dragged* Water	Total
1960	158	18	176
1961	67	3	70
1962	214	25	239
1963	100	30	130
1964	191	30	221
1965	281	139	420
1966	137	56	193
1967	287	69	356
1968	268	60	328
1969	264	65	329
1970	151	—	151
1971	392	116	508
1972	517	150	667
1973	309	107	416
1974	376	91	467
1975	198	—	198
1976	178	—	178

*Dragged Water means the waters coming into the lagoon, when the rain fell in the surroundings has been extraordinarily heavy.

It is to be noted that the rainfall effect on the production depends on the time of the year in which the rain falls so that rain in July/August affects practically the whole of the harvest, while rain in December, for example, only affects the sixth part of the harvest, this being the approximate proportion which remains to be gathered at that time; consequently, in order to obtain the true effect on production, corrective coefficients are applied as follows, according to the different months:

Month	Fraction of total rain registered
July	6/6
August	5/6
September	4/6
October	3/6
November	2/6
December	1/6

During the months when the harvest is being prepared, all rain is taken into account, because it is the time when the bottom of the lagoon does not contain any salt from the previous season.

By applying these coefficients to the rainfalls registered by the pluviometer and to the water that was dragged each month during the years 1962 to 1974, and adding the twelve figures for each year, we obtain what we will call "SEASONAL RAINFALL INDEX". In Figure 1 we have shown the inverse of these coefficients value in function of the production of each season according to Table 5. A good idea can be obtained of the relationship between the rainfall and production variation up to the year 1974 as it was in the middle of 1973 when the brines addition from the Pinoso deposit began.

The relationship which previously existed between the inverse of the "SEASONAL RAINFALL INDEX" and the figure attained in the corresponding harvest continues to apply, but a correcting factor will need to be applied, and we shall be able to ascertain this factor when we have the figures for 5 or 6 seasons.

TABLE 3

Water Evaporation in Torrevieja
In mm, Deducting Direct Rain and Dragged Water

Year	Distilled	Salty	Coefficient
1960	3.395	1.025	0,302
1961	3.727	1.068	0,286
1962	3.231	926	0,286
1963	3.479	851	0,245
1964	3.399	974	0,286
1965	3.093	938	0,303
1966	2.996	957	0,319
1967	2.561	866	0,338
1968	2.751	979	0,356
1969	2.659	942	0,354
1970	2.726	1.030	0,378
1971	2.254	875	0,388
1972	2.217	740	0,334
1973	1.902	888	0,467
1974	1.736	866	0,499
1975	1.839	928	0,505
1976	2.071	783	0,378

TABLE 4

Rain Water Introduced Each Month into the Torrevieja Lagoon During the Years 1962 to 1976, in Liters Per Square Meter

Years	January	February	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total
1962	2,9	46,5	22,1	11,7	16,7	11,7	0,5	—	2,2	87,4	27,7	9,7	239,1
1963	13,8	4,7	—	8,6	4,0	1,0	—	0,9	65,8	—	2,6	29,1	130,5
1964	21,8	2,6	10,5	21,5	—	5,7	3,0	8,3	—	2,4	4,5	140,4	220,7
1965	19,2	23,0	1,0	7,6	1,9	63,4	—	1,0	—	151,8	35,4	116,1	420,4
1966	1,7	3,4	0,8	9,6	2,0	12,1	5,3	2,1	20,9	135,2	—	—	193,1
1967	9,8	32,1	9,0	117,0	8,4	36,9	—	3,0	97,2	—	42,3	—	355,7
1968	183,8	23,2	30,7	8,0	35,5	20,6	—	—	3,8	—	11,5	11,0	328,1
1969	7,0	14,6	11,4	17,2	1,7	10,7	—	2,8	46,9	183,8	27,9	5,2	329,2
1970	18,3	—	15,0	5,9	11,8	16,9	—	5,6	—	24,5	—	52,9	150,9
1971	9,9	5,0	78,0	34,2	17,7	1,3	1,1	0,3	101,0	62,5	69,4	127,6	508,0
1972	11,9	4,6	39,9	47,6	5,0	6,8	—	8,1	86,3	339,9	109,7	7,2	667,0
1973	2,7	2,5	9,2	6,9	—	38,4	—	—	36,5	107,1	107,0	106,1	416,4
1974	4,2	90,5	55,0	71,6	7,7	3,6	2,3	54,0	—	161,8	15,3	0,6	466,6
1975	41,2	2,8	14,9	24,0	41,1	10,6	—	4,0	1,9	8,8	4,7	44,1	198,1
1976	8,2	13,9	0,6	42,2	39,7	0,8	—	16,4	9,0	16,0	1,3	29,5	177,6

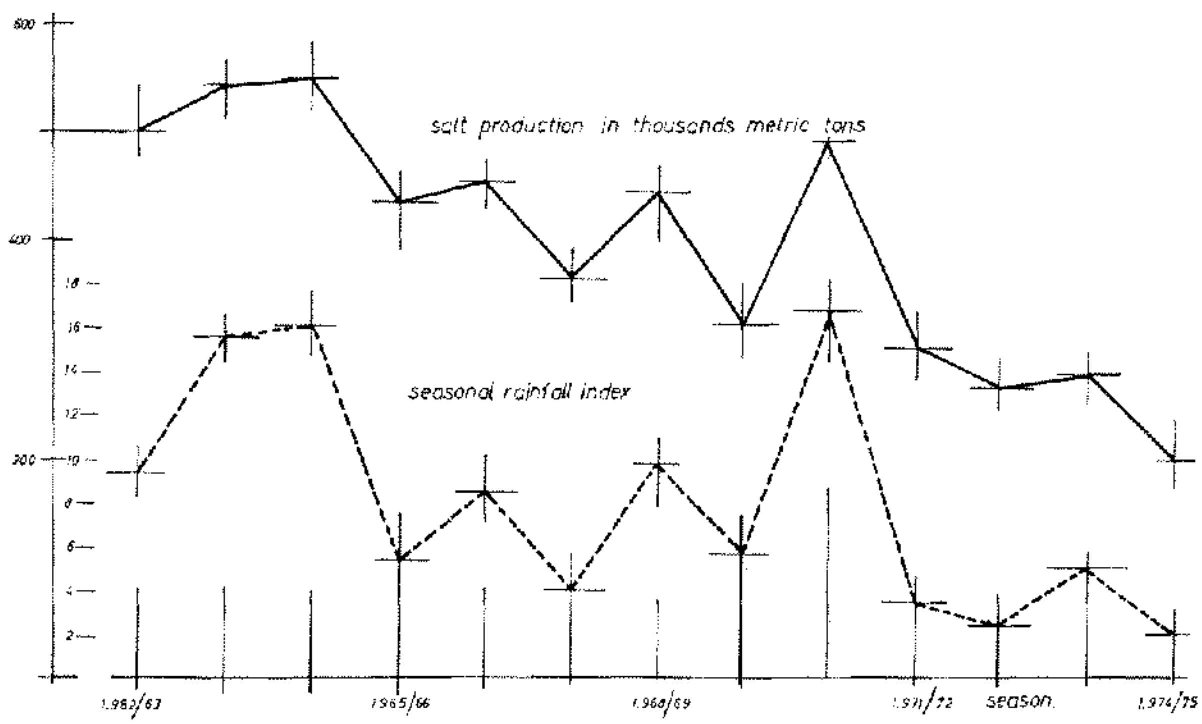

Figure 1. Relationship between seasonal rainfall index and salt production at Torrevieja.

From the foregoing it will be seen that any attempt to increase substantially the production of the Torrevieja salt-works had to be based on the establishment of alternative processes to counter the effect of the meteorological factors, so we have the idea of adding concentrated brines from some salt deposit, thus increasing the salt crystallization capacity by evaporating the same amount of water.

Furthermore, by doing this we could avoid the serious drawback inherent in the massive salt extraction from the lagoon without the proportion of other salts which are found together with sodium chloride in seawater, thus increasing the proportion of impurities in the brines, and causing a corresponding increase of concentration at the beginning of sodium chloride crystallization, and hence a corresponding decrease in the whole quantity of precipitated salt. In the Mediterranean seawater, the crystallization of sodium chloride begins at 26,0° Bé, as will be realized from Table 6. On the contrary in the brines of the Torrevieja lagoon this

TABLE 5

Salt Extraction in the Torrevieja Lagoon

Season	Thousands of Metric Tons
1962/1963	500
1963/1964	541
1964/1965	543
1965/1966	436
1966/1967	454
1967/1968	365
1968/1969	444
1969/1970	325
1970/1971	490
1971/1972	302
1972/1973	267
1973/1974	302
1974/1975	204
1975/1976	1.006
1976/1977	820

density was increasing gradually up to 26,8° Bé at the beginning of crystallization in the years 1969 to 1973, with contents of sodium chloride which were much less than those in the concentrations from seawater, as is shown in Table 7. The effect of the massive brines supply from the Pinoso deposit is demonstrated explicitly in the composition of the brine for the "setting" of 1975; setting in matters of salt production, means the concentration at which the crystallization of sodium chloride begins.

Up to the end of 1977 the Torrevieja lagoon will have received more than three and a half million tons of sodium chloride from the rock salt deposit of Pinoso, in the form of concentrated brines, without any significant quantities of magnesium. If this salt had been brought in as seawater, it would not have been possible to bring it in such a large quantity and, moreover, it would have contained the corresponding portion of magnesium salts, as well as generally speaking the other salts which are present in seawater. Another important result of the massive salt addition from the Pinoso deposit has been that the lagoons, which were impoverished after several years of adverse climatic conditions, would have recuperated much more slowly if they had been supplied only with seawater, owing to the dilution which would inevitably have taken place.

In the last salt harvesting seasons, not only were no significant quantities of magnesium added, but it became necessary to drain the Torrevieja lagoon into the sea to reduce the high contents of magnesium salts, as had been

TABLE 6

Composition of the Mediterranean Sea Water Concentrates in Torrevieja, in Grams Per Liter

	Sea Water								
Grade Bé	4,1	8,4	15,8	23,5	26,0	26,5	27,0	28,1	29,8
Density	1,0293	1,0624	1,1229	1,1951	1,2194	1,2245	1,2305	1,2415	1,2604
CO_3	0,082	0,14	0,10	0,14	0,17	0,20	0.31	0,37	0,50
SO_4	3,036	6,70	12,52	16,96	19,06	23,29	29,86	40,96	59,68
Ca	0,474	1,01	1,43	0,60	0,58	0.55	0,49	0,21	0,10
Mg	1,462	3,22	6,73	11,26	12,78	16,05	20,82	28,86	42,66
K	0,401	0,88	1,84	3,10	3,50	4,42	5,68	7,72	10,15
Br	0.069	0,15	0,31	0,54	0,63	0,78	1,00	1,34	1,84
Na	12,011	26,43	54,74	92,94	105,00	101,07	94,56	81,69	62,83
Cl	21,609	47,55	98,70	167,07	188,81	189,85	189,68	186,23	185,20
Total	39,144	86,08	176,37	292,61	330,53	336,21	342,40	347,38	362,96
Na_2CO_3	0,033	—	—	0,25	0,30	0,35	0,54	0,66	0,89
$CaCO_3$	0,113	0,23	0,17	—	—	—	—	—	—
$CaSO_4$	1,454	3,10	4,62	2,03	1,99	1,87	1,67	0,72	0,34
$MgSO_4$	2,519	5,65	11,61	19,46	22,12	27,53	35,95	50,69	74,48
$MgCl_2$	3,732	8,15	17,16	28,70	32,54	41,08	53,10	72,94	108,16
KCl	0,762	1,68	3,51	5,90	6,67	8.43	10,84	14,72	19,35
NaCl	30,442	67,08	138,90	235,58	266,09	255.94	239,02	205,92	157,37
NaBr	0,089	0,19	0,40	0,69	0,82	1,01	1,28	1,73	2,37
Total Salts	39,144	86,08	176,37	292,61	330,53	336.21	342,40	347,38	362,96
H_2O	990,156	976,32	946,53	902,49	888,87	888,29	888,10	894,12	897,44
Total	1.029,3	1.062,4	1.122,9	1.195,1	1.219,4	1.224,5	1.230,5	1.241,5	1.260,4
Relation NaCl: Total Salts	0,778	0,779	0,787	0,805	0,805	0,761	0,698	0,593	0,433
NaCl:Mg	20,8	20,8	20,6	20,9	20,8	15,9	11,5	7,1	3,7
Cl:Mg	14,8	14,8	14,7	14,8	14,8	11,8	9,1	6,5	4,3
Cl:K	53,9	54,–	53,6	53,9	53,9	42,9	33,4	24.1	18,2
Cl:Br	313,–	317,–	318,–	309,4	299,7	243,4	189,7	139,–	100,6
Na:K	30,–	30,–	29,7	30,0	30,–	22,8	16,6	10,6	6,2

TABLE 7

Brines Composition in the Torrevieja Lagoon at the Moment of "Setting"
In Grams Per Liter of Brine

Year	1961	1965	1969	1973	1975
Date of Setting	1/6	24/4	16/5	5/7	4/4
Density	1,2220	1,2242	1,2285	1,2267	1,2205
Grade Bé	26,2	26,4	26,8	26,8	26,2
$Mg(OH)_2$	0,10	0,17	—	—	—
$MgCO_3$	0,45	0,35	0,41	0,67	0,36
$Mg(CO_3H)_2$	—	—	0,72	—	0,08
$CaSO_4$	0,30	0,17	0,71	1,02	1,09
$MgSO_4$	40,97	42,50	44,74	39,19	27,09
$MgBr_2$	1,36	1,55	1,52	1,42	0,96
$MgCl_2$	61,48	73,50	73,38	65,63	44,21
KCl	13,12	14,53	15,87	13,23	8,05
NaCl	205,77	198,59	197,24	214,94	243,43
Salts	323,55	331,36	334,59	336,10	325,27
H_2O	898,45	892,84	893,91	890,60	895,23
	1.222,00	1.224,20	1.228,50	1.226,70	1.220,50
Relation NaCl:Total Salts	0,64	0,60	0,59	0,64	0,75
NaCl:Mg	8,46	7,16	6,99	8,58	14,3
Cl:Mg	7,27	6,56	6,44	7,40	10,8
Cl:K	25,70	23,88	21,85	26,7	43,7
Cl:Br	149,86	134,88	137,75	150,84	222,2
Na:K	11,76	10,25	9,32	12,18	22,7

done in previous years; it should be specially noted that, while making a considerable reduction of the proportion of magnesium salts, important quantities of sodium chloride were also thrown back into the sea.

From the foregoing considerations it will be understood how necessary it was to try to secure massive additions of sodium chloride for Torrevieja lagoon, for which purpose the prospects used were as follows.

The Pinoso deposit of rock salt. In order to find a saline deposit, which would supply the Torrevieja lagoon with brines saturated with sodium chloride, an intense mineral research campaign was started in the second half of the year 1967 in a zone of approximately 800.000 hectares in the neighborhood of Torrevieja.

This research was carried out in the three classical steps of:

1. Study of the region.
2. Mineral resources estimation.
3. Deposits evaluation.

As the object of this research was to find out a salt deposit suitable of fulfilling the objective in view, the survey which was carried out in the zone was neither complete nor exhaustive, but, on the contrary, left open considerable possibilities in areas which were considered suitable for future evaluations.

From the study of the region, the conclusion was reached that the area which had the best possibilities of containing important salt resources were the triassic outcrops of the Pre-Betic Mountain System, which covers the north-eastern part of the zone surveyed.

These triassic islands are generally small and dispersed, without any apparent relationship between each other. They are generally aligned in an east-northeast, west-southwest direction corresponding with the Pre-Betic structures. They may be classified into three types:

1. Extensive outcrops which do not conform with the structures in which they are situated (Villena, Elda, etc.).
2. Small islands which occur along fractures (Ibi).
3. Individual and completely diapiric outcrops (Pinoso, De la Rosa, etc.).

The studies concerning the calculation of mining potential of each of the zones marked by the regional study, selected only the outcrops showing a neatly diapiric origin as being interesting for deserving to be applied to the phase of mining evaluation, and among which are those located at Yecla, Castalla, Casas de Blazquez, Jumilla, Casas del Puerto and Pinoso. Of all them, those resulting specially interesting are the ones located at Casas del Puerto and Pinoso, named Cabezo de la Rosa and Cabezo de la Sal respectively.

In view of the exceptional conditions which co-existed at "Cabezo de Pinoso", efforts were made to buy this deposit which were concluded satisfactorily.

As a result of the foregoing, the third step of the research that is to say the deposits evaluation was confined to the survey of "Cabezo de Pinoso".

The outcrops of salt in various places of "Cabezo de Pinoso" gave rise, at different times in the past, to mineral and exploration surveys being carried out on them.

The most important of these was the mine "Segunda Terrible", which penetrates about 60 meters into the salt diapir, and whose vault reaches a maximum height of about 25 meters.

The research of the deposit was effected by geophysical survey and mechanical drilling. Seventeen boreholes were drilled the total length of perforation being 5.598 meters.

The Pinoso deposit consists of a dome or diapir with confirmed reserves cautiously evaluated at about 600 million tons, in the classical shape of a mushroom (Fig. 2), the central zone being the best one. It is covered by a cap of marls and anhydrite, whose thickness there is from 50 to 250 meters according to the zone, both the deposit and the cap being highly mineralized, the cap containing dolines and chasms which are extremely deep and make it difficult to site operation drills.

Water reserve in the zone. As the consumption of water to exploit this deposit by dissolution needed to be something like 4 million cubic meters per year, it was necessary to carry out a thorough study of the hydrological conditions of the region, to ensure that the necessary quantities of water could be extracted. Fortunately, at the foot of the Cabezo itself, a phreatic layer was discovered which was very important and too saline to be employed in agriculture; this permitted the "Pinoso Project" (as it was called) to be carried out, to supply the Torrevieja lagoon with brines containing 275 grams of NaCl per liter of solution, 4–5 grams of calcium sulphate and practically no other salts, especially magnesium, by drilling independent wells to produce brine at "Cabezo de Pinoso", and constructing a pipeline 54 Km long which, starting from Cabezo itself, crosses the mountainous zone called "Sierra de Crevillente" and leads to receiving station situated on the communicating channel between the lagoons of Torrevieja and La Mata, so that the brine can be supplied into either one of the two lagoons as required.

Mining operation. The system used to obtain the brine consists of drilling a borehole until it reaches the case of the saliferous deposit. The zone of the cap rock as well as the part of the zone of salt, is protected with cemented casing of 13⅜" in diameter. A second casing of 9⅝", which is concentric with the above mentioned one, is introduced into the borehole, and is sunk to a depth which is estimated in accordance with the initial volume which it is desired to obtain from the well. The length of this casing (9⅝") greater than that of the cemented pipe, is progressively shortened by being raised, as required by the process which is used to form the cavity. The space between the inside surface of the casing 13⅜" and the outside surface of the casing 9⅝", continued by the space between the wall of the borehole drilled into the salt and the lower part of the casing 9⅝", is filled with a protective hydrocarbon operating as seal fluid. As a result the height of the dissolution is limited at its higher end by the situation of the string or extreme lower end of the casing 9⅝".

Concentric with these casings and penetrating to the bottom of the drill hole, a tubing of 5½" is placed. Through this

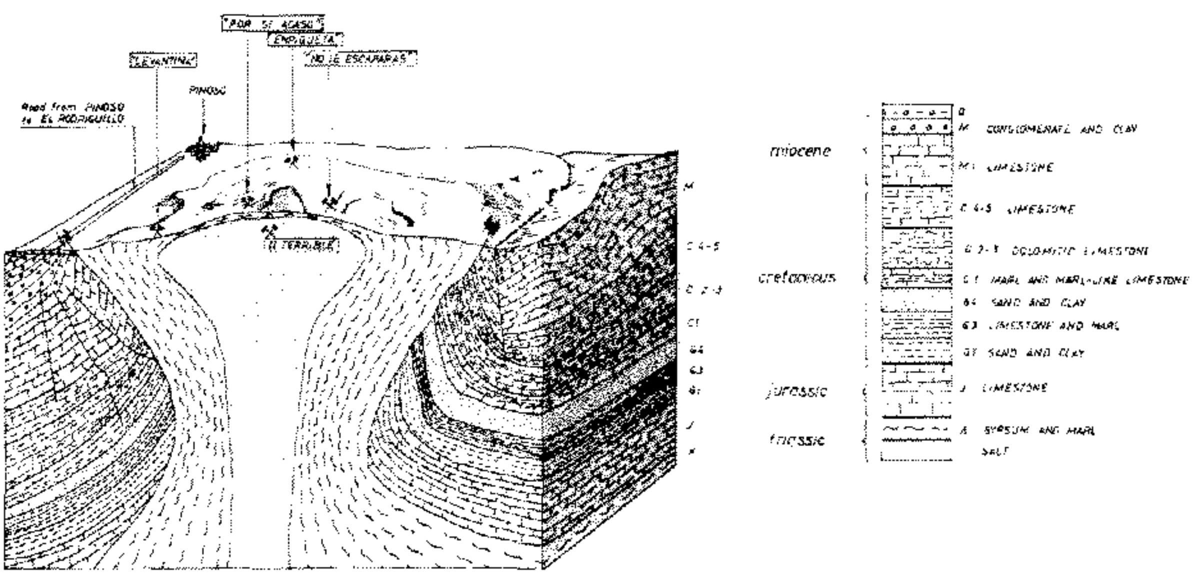

Figure 2. Idealized structural diagram of the "Cabezo de Pinoso" showing the interpretation of the diapiric salt extrusion.

central tubing is inserted the dissolving water, so that the brine comes out through the annular space between this tubing and the inside surface of the intermediate casing thus avoiding the space which is protected by the hydrocarbon. In the operation of the well the following pressures are very important: The pressure of the injection of the dissolving water, as it is necessary to overcome the losses of head caused by the piping, and to permit the brine to come out; also that of the seal fluid, which is measured by a manometer at the head of the well, and is related to the pressure at the 13⅜" cemented seal string. The pressure at this latter point must not be greater than the geostatic pressure, as otherwise it would cause the fracturation of the well.

The necessary water supply is obtained from three wells in the hill side of the dome, at 520 m level. These wells work with deep well pumps, which are driven by electric motors at a voltage of 500 V, developing 335 HP, and 175 meters of total head with flows of 300 m^3/h. This first pumping brings the water to a steel collecting tank from which a pipe gives admission to the second pumping station, consisting of three centrifugal horizontal pumps placed at the 520 m level; these are driven by electric motors at a voltage of 500 V, developing 270 HP (1) and 544 HP (2), and flows of 150 and 300 m^3/h respectively, with a total head of 284 meters. The steel tank referred to above has two depth gauges, one at maximum level and the other at minimum level, so that the deep well pumps act automatically. They are started by means of liquid resistances, which make a much smoother start.

This second pumping operation raises the water to a reservoir constructed on the ground at the 780 m level, lined with butyl rubber, with a capacity of 3.000 m^3. This tank acts as a receptacle for the output of the third pumping station, which is placed at the 780 m level and has three pumps driven by motors at a voltage of 500 V, developing 270, 680 and 750 HP respectively, with flows of 150 m^3/h for the first and 300 m^3/h for the last two, and with a manometric height of 320 meters.

The second pumping station and the tank referred to above are connected by a piping with a diameter of 400 mm and a total length for the three wells of 456 meters. From the second pumping station to the rubber receptacle there is a piping 450 mm in diameter, of a length of 3.813 meters.

The main discharge pipe of the third pumping station carries the water to the cavity through a central pipe with a diameter of 450 mm, with branches from the central pipe to each cavity. The brine from these cavities is brought back to a main pipe 936 meters long and 350 mm in diameter, which carries the brine to four cylindrical thickeners, each 22 meters in diameter, where the insoluble matter is decanted. The first decantation of these insolubles has already taken place in the inside of the cavity as the speed of ascent is calculated so as not to cause massive dragging of the insoluble matter which form a part of the deposit.

From these thickeners a pipe 880 meters long and 400 mm in diameter carries the clarified brine to a reservoir lined with neoprene, which has a capacity of 3.000 m^3, and from which starts the pipeline which carries the brine to Torrevieja lagoon over a distance of about 53 Km. The way to Torrevieja is carried out by gravity, and up to the crossing of the "Sierra de Crevillente", which is known as "Cuerda de la Murada", there is a drop of 480 meters over a length of 11 Km. To avoid the pressure on arrival at the plane being too high, three decompression chambers have been intermediated during the descent at the levels 484, 270 and 110, and by these means the brine arrives at the crossing of the national highway nr 340 from Barcelona to Cádiz at a pressure of 13 Kg., which permits to proceed across the irrigated plane with a length of 26 km, and to cross the numerous channels, canals, trenches and the Rio Segura, totaling more than 50. This pressure compensates for the pressure drop which all these obstacles would cause, until it arrives at the spot where it discharges into the connecting channel between the two lagoons, with a pressure of 8 kg/cm^2.

A basic feature of the dissolution process is the control of the working cavities in regard to flow and injection pressure and also the seal fluid pressure. These data can be seen clearly in the place of each cavity, and also in the panel control which shows the data for all the cavities. In this way, any abnormality is detected automatically.

Before starting up a cavity it is necessary to test its watertightness by hydrostatic tests. To do this it is submitted to pressure by the injection of brine, until the testing pressure is reached, the variations being measured by manometric scales. When these variations are stabilized at a set figure per hour, the test is completed.

Another basic feature in the wells operation is the knowledge of how they evolve in regard to shape and volume. For this purpose the cavities are tested periodically by sonar measurements.

By these measurements we ascertain the volume occupied by the brine, which figure, when properly corrected, taking into account the average of insoluble matter content in the salt and the swelling coefficient of these when they have been decanted, allows us to check the volume obtained by the injection of known flows of water.

The sonar is carried out approximately each ten or twelve months, during which time the injected flow will have caused a considerable increase in the cavity; the chief reason which makes it necessary is that it permits us to ascertain the progress of the cavity shape, and to study its conditions of stability, in accordance with which the appropriate flow variations can be carried out, and the placing of the casing and tubing can be corrected, so as to arrange for the exploitation of the cavity to last longer. In the case of Pinoso the insoluble matter is distributed uniformly in the salt, and if there are layers of insolubles they are not normally either horizontal or continuous.

This is shown by the fact that the average vertical sections of the cavities are not irregular, so that the invariability of the coefficient of dissolution leads to the creation of cylindrical cavities with diameters which grow progressively from one sonar measurement to another.

Figure 3 shows a typical example of the progress of a Pinoso cavity.

The main drawback in the conditions of dissolution in the case of this deposit is that the diameter of the roof normally increases at the same rate as that of the average zone of the cavity, which makes necessary frequent sonar measurements in order to maneuver the casing 9⅝" correctly; the

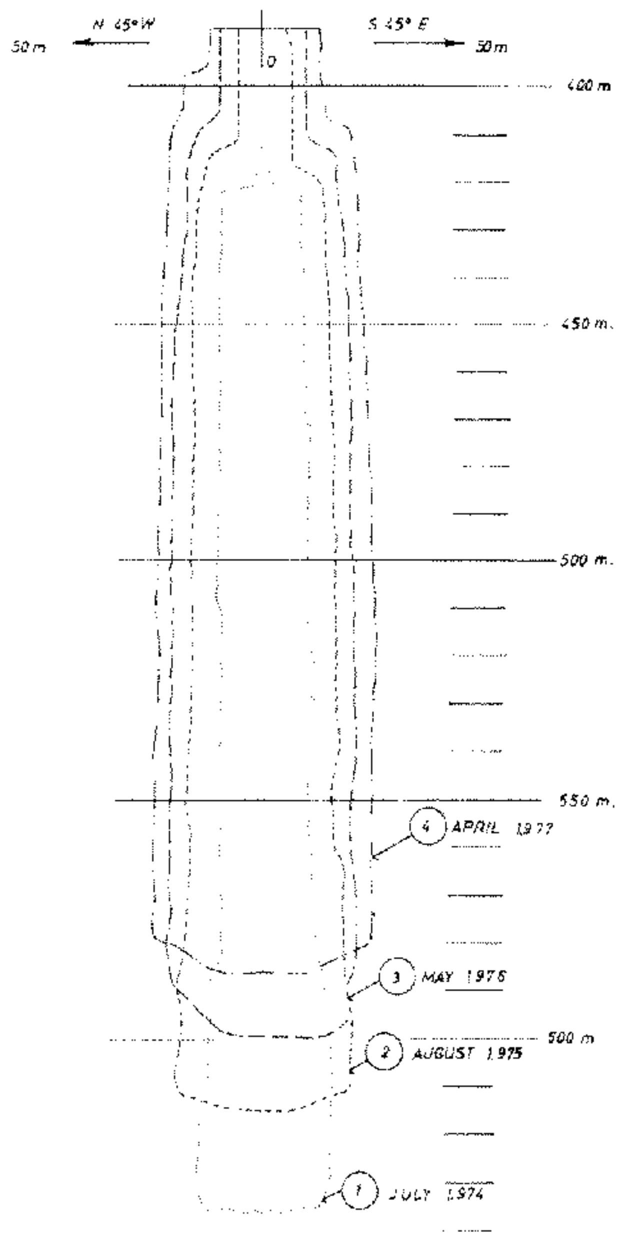

Figure 3. Vertical profile of a Pinoso well from sonar measurements of cavity shape and its progression (echo-log).

ideal is when the roof takes the form of a dome, which indicates greater stability.

If the diameter of the roof is too great, there is a risk that it will not be completely protected by the hydrocarbon, with the possibility of divergent preferential dissolutions being caused, called digitations, which, being above the level of the cemented casing string, would need the work being carried on with a reduced flow and maximum density, and in an extreme case would need the abandonment of the cavity to avoid its collapse and the consequent repercussion on neighboring cavities.

Torrevieja lagoon supply. Before the Pinoso deposit was incorporated into the system, the industrial cycle normally began during the month of January with a supply of seawater to dissolve the remaining salt, without it being gathered on the shore.

The beginning of the salt crystallization took place each year on a different date, along the second quarterly, according to the climatic conditions. The harvesting commencing when the thickness layer was more than 50 mm, although the crystallization process continues during July, August and eventually September and October, the layer thickness being about 120 mm by the middle of September.

Independently, La Mata lagoon, with a surface of about 700 hectares, used to supply Torrevieja lagoon, with a surface of about 1.400 hectares, with brines of medium concentration.

The lagoons of Torrevieja and La Mata were intercommunicated by a channel which was constructed in 1929, and they then started working in serie with the object of increasing as much as possible the output from the former; in view of the production figures reached in Torrevieja, the brines concentration from La Mata were reduced progressively, in order to achieve the greatest possible evaporation of seawater.

As Torrevieja lagoon now has a direct input of seawater, an input of brines of low concentration from La Mata lagoon, and an input of highly concentrated brines from the deposit of Pinoso, its production capacity has been raised to one million two hundred thousand tons, and it is possible in practice to control the composition of the salt as a result of having eliminated the input of seawater and drastically reduced the input of its concentrates with the object of approximating at will the relationship between the sodium chloride and the other components of seawater to that which is normal in its concentrates.

The homogenous composition of the salt, which was referred to in the last paragraph, can be specially appreciated by the constant figure of its contents of sodium chloride (Tables 8 and 9), as well as by a slight increase in the average content of calcium sulphate, and the consequently lesser content of magnesium oxide. Under the special conditions which we are confident will be obtained regularly but profitably, considerably smaller percentages are obtained both of calcium sulphate and of magnesium salts.

TABLE 8

"Raw" Salt Composition from Torrevieja Lagoon

	Average 1960/1970	1972	1975	1976
$CaSO_4$	1,310	1,312	1,677	1,552
$MgSO_4$	0,598	0,466	0,360	0,362
$MgCl_2$	1,015	0,803	0,516	0,532
NaCl	96,872	97,189	97,060	97,269
Insoluble matter in water	0,205	0,230	0,387	0,285
	100,000	100,000	100,000	100,000
Humidity	6,717	6,287	5,961	4,811
MgO	0,629	0,495	0,339	0,346

TABLE 9

Salt Composition in the Stockpile After Three Months Harvesting

	Average 1960/1970	1972	1975	1976
$CaSO_4$	0,204	0,242	0,262	0,302
$MgSO_4$	0,176	0,134	0,122	0,093
$MgCl_2$	0,290	0,221	0,183	0,147
NaCl	99,301	99,381	99,395	99,413
Insoluble matter in water	0,029	0,022	0,038	0,045
	100,000	100,000	100,000	100,000
Humidity	2,879	3,479	2,559	2,627
MgO	0,182	0,138	0,118	0,092

REFERENCE

Rocamora, J. and Rafols, J.M. 1966. Salt plants at Torrevieja (Spain) and their operation. Second Symposium on Salt, Northern Ohio Geol. Soc., Cleveland, Ohio, 2:140–151.