History of Solution Mining at Hauterives, France

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ABSTRACT

The geological characteristics of the brinefield (bedded salt deposit) are briefly described for the Valence Oligocene Basin as a whole, the Rhône-Progil concession, and the Salines du Sud Est Exploitation site at Hauterives. Then follows the mining techniques with some details about hydraulic fracturings, well connections, and solution mining methods with fresh water and non-saturated brine. Balance sheet of the leaching as of March 1, 1973, is discussed with interesting observations on the shape and dimension of the existing and anticipated cavities. Finally, there is the last chapter about existing storage cavities which are located on and outside the concession. The present and future mining and storage possibilities for the exploitation will be found in conclusion.

INTRODUCTION

RHONE-PROGIL (RHONE-POULENC Group) has two centers in France for the exploitation of rock salt by underground solution mining and will have very soon a third (Fig. 1). The oldest exploitation center is located in La Madeleine, near Nancy, in the east of France, where the salt lies at a depth of 400 m. (1300 ft.).

The most recent exploitation, in operation since 1965, is located in Hauterives, near the Alpes, between Valence and Grenoble, where the salt beds lie between 1100 m. (3600 ft.) and 1700 m. (5500 ft.). The third center of exploitation is located in southern France, in Vauvert near Nimes, where the deposit is located at an approximate depth of 1700 m. (5500 ft.) to 2500 m. (8200 ft.). The latter is presently being studied and equipped and does not produce any brine as yet.

The solution mining method applied for the two first cases and anticipated for the third case is underground circulation between wells previously connected by hydrofracturing. The saturated brine produced is sent by brineline to chlorine and soda producing units which directly process it by electrolysis, or sent to Na_2CO_3 producing units.

The purpose of this paper is to discuss the site at Hauterives and to briefly characterize features of the solution mining exploitation.

OBJECTIVES OF HAUTERIVES ROCK SALT EXPLOITATION

In Hauterives, RHONE-PROGIL holds a 23 Km^2 (8.92 sq mi) concession on the salt deposit of the Valence Basin, located along the Rhône valley, south of Lyon, on the Paris-Marseille axis. RHONE-PROGIL has entrusted the exploitation of this concession to its subsidiary Salines du Sud Est. 80 Km. (50 miles) east of Hauterives, near Grenoble, the Pont-de-Claix (RHONE-PROGIL) and Jarrie (Pechiney – Ugine-Kuhlmann) plants have long been producing chlorine and soda in their electrolytic plants.

In 1965, there was a drastic change in the supply source. Prior to 1965, those electrolytic plants were supplied by halite from the Mediterranean salt marshes, 300 Km. (187 miles) away. There were several major disadvantages to this procedure, particularly because, from the economic point of view, the large expenses of handling and transportation of solid salt heavily increased the cost price of manufactured products, and furthermore because the supply was not satisfactorily guaranteed due to the increasing needs.

In addition, the use of diaphragm cells in the electrolytic plants would allow the direct utilization of saturated brine, and consequently the application of optimum conditions for the brine supply to those cells from another source.

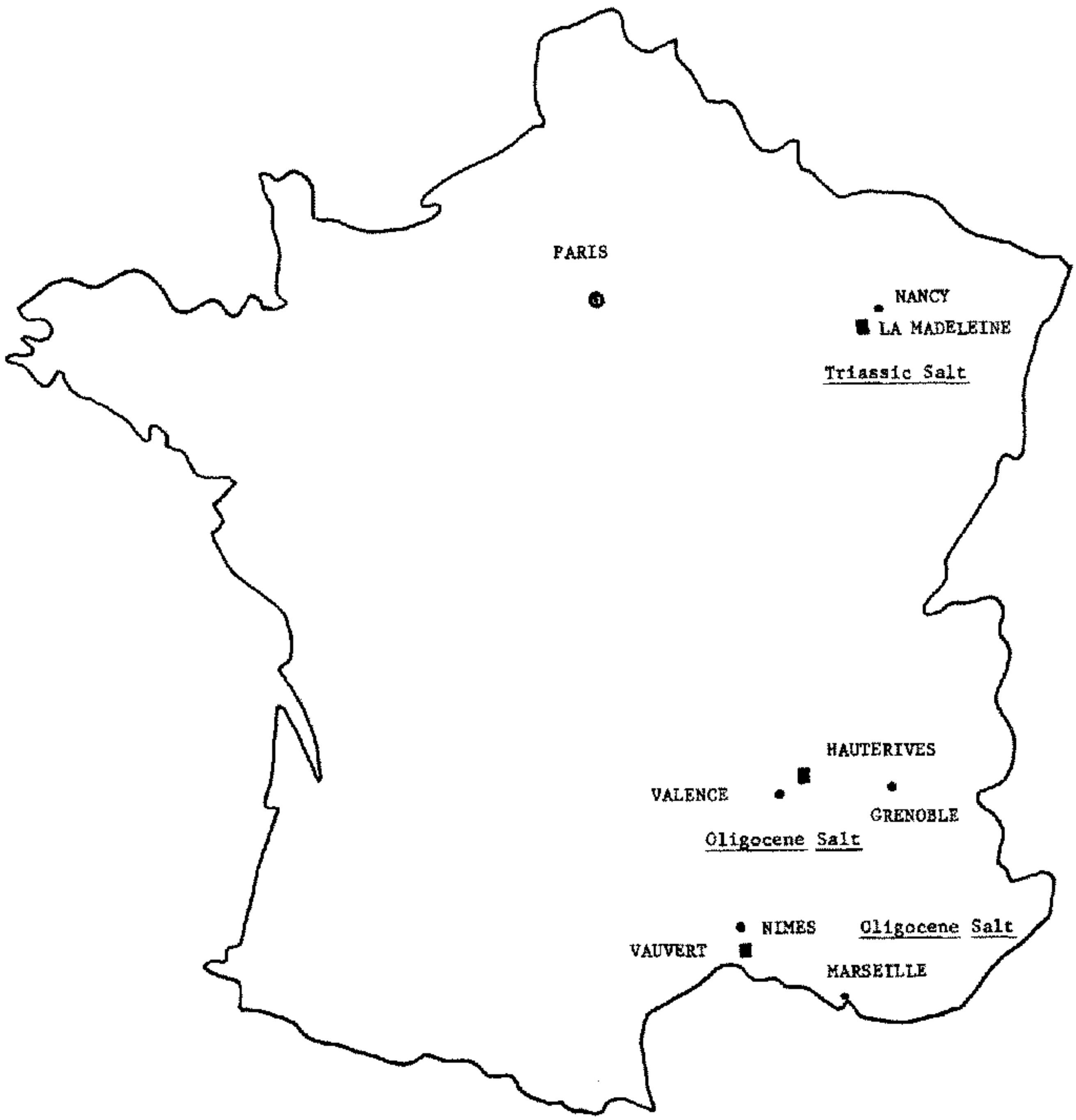

Figure 1. RHONE PROGIL salt concessions. Location of the Hauterives concession.

The increase in chlorine production, the limitations imposed by an outside supply source, and finally the effort to bring down the manufacturing cost of chlorine and soda, led us to look for another salt supply source. As a result, since 1965, and after the discovery of rock salt in the Valence Basin, the Hauterives solution mining provides the electrolytic units with saturated brine which is fed continuously to the Pont-de-Claix plants by a 80 Km. (50 miles) brine pipe. Further advantages are that the existing installations make it possible to make and to operate underground storage cavities, with a priority for the specific needs of the chemical industrial group (presently propylene storage).

GEOLOGY

The basin as a whole

The Valence Basin salt is an Oligocene salt. The basin is entirely located east of the Rhône valley. Although explored by geophysics (telluric, gravimetric, reflection seismograph) and by sonic deep borings, this basin is not well known and it is not possible to give here a clear and accurate description of it. It is thought that the Tertiary filling is in a complex graben structure, and that the deposits lie above a secondary syncline (Triassic, Jurassic, Cretaceous). This "graben" is limited on the east side by the fringe of the folded alpine structures of the Grenoble area, and on the west side by the granitic base of the Massif Central. The basin's longitudinal axis is directed NNE-SSW.

The evaporite area is located on part of the Oligocene basin and is approximately 60 Km. (37 miles) long and 20 Km. (12 miles) wide, but the clearly salty area is smallest and has the probable dimensions of 40 Km. (25 miles) in length and 10 to 15 Km. (6 to 9 miles) in width. The thickness of the saliferous series varies between the extremities of the basin, whereas it is negligible on the fringe as thick as 500 m. (1650 ft.) in the known axial parts. The reserves amount to several tens, perhaps several hundred billions of tons of salt. The French yearly consumption is about 6 million tons.

Setting of the RHONE-PROGIL concession

Location in relation to the whole basin. The concession is located in the northern part of the Oligocene basin and along the Galaure River valley. The 23 Km^2 (9.92 sq mi) concession is 10 Km. (6.2 miles) long and 3 Km. (1.87 miles) wide. The location of the concession in the northern part of the saliferous basin has not been chosen in terms of geological criteria but for technical and economic reasons which are linked to the length and to the limitations in the location of the brine line. Further the location of the concession along the Galaure River valley is linked to the more favourable conditions of fresh water supply offered by the groundwater tables of this valley and to the ready road access. This explains why the longitudinal axis of the concession obliquely crosses the geological structural directions of the basin which are directed NNE-SSW.

Location within the concession. The maximal gravity anomaly axis of the Oligocene basin crosses the concession at its mid-point. The WSW extremity of the concession corresponds probably to a clear limit of the saliferous basin with steep dips locally. The ENE extremity is near east limit which is poorly defined and where the various low-dipped beds become progressively thinner and finally disappear one after the other. Reflection shooting profiles were not sufficiently numerous to make it possible to distinguish geologic structures whose existence is most important for the positioning of exploitation drilling or the creation of underground storage cavities.

Location of the presently exploited area. The present site of exploitation is very close to the village of Hauterives. The saliferous series under the site of exploitation is located at a depth of approximately 1100 to 1700 m. (3600 to 5600 ft.). The overall geological series is shown in Table I.

TABLE I

Depth	Lithology	Geological Stage
0 to 580 m. (0 to 1900 ft.)	Alternating sand, sandstone and clay	Helvetian, Aquitanian, beginning of Chattian.
580 to 1100 m. (1900 to 3600 ft.)	Clay and marl (some anhydrite)	Chattian and Sannoisian
1100 to 1330 m. (3600 to 4300 ft.)	Salt (some anhydrite)	Sannoisian
1330 to 1500 m. (4300 to 4900 ft.)	Salt and mostly clay (some anhydrite)	Sannoisian
1500 to 1630 m. (4900 to 5300 ft.)	Salt (some anhydrite)	Sannoisian
1630 to 1670 m. (5300 to 5450 ft.) at least	Clay mostly and salt (some anhydrite)	Sannoisian

Consequently, there are in fact two clearly saliferous series separated by an intermediate clayey series which contains some salt:

1. Upper series, 230 m. (750 ft.) thick, at a depth of approximately 1110 to 1330 m. (3600 to 4300 ft.).
2. Lower series, 130 m. (400 ft.) thick, at a depth of approximately 1500 to 1630 m. (4900 to 5300 ft.).

In both these series, the average ratio of insoluble substances is between 10% and 20%. The dip of the lower saliferous series is about 5 to 10°. The 1100 m. (3600 ft.) overlying the salt deposits and located between the surface and the salt provide good protection for the exploitation cavities and the storage cavities. The first 600 m. (1900 ft.) contain only a few sand beds more or less indurated and aquiferous; the rest is clayey. The last 500 m. (1700 ft.) located above the upper saliferous series are only clayey, and are consequently impermeable. The average reserves characterizing the deposit in the area now being exploited exceed 6 million tons of salt per hectare (1550 million tons of salt per sq mi or 2.45 M tons/acre).

Means of study. Besides the geophysical surveying of general exploration (telluric, gravimetric, seismic) which were used to study the basin as a whole and to detect the presence of salt, RHONE-PROGIL may use reflection shooting, if there is a problem in choosing a drilling site. This method is relatively accurate and gives at least the direction of the dip and makes it possible to distinguish the main geologic structures which divides the territory of the concession into compartments.

During drillings, the usual electrical, sonic and nuclear logs are run in order to locate accurately the succession of beds, their nature, quality, thickness, exact position and dip. These data are correlated from one well to the other and provide a careful choice of sites for future wells, a choice of fraĉ level to get the mining started by establishing a connection between the wells, and then allow one to follow the development of the solution cavities.

SOLUTION MINING TECHNIQUES

Method and well equipment

Carl Bays recommended the solution mining method to be used in two wells that had been previously connected. The method allows the production of saturated salt brine directly for the diaphragm cells of the electrolytic plants. The connection is established first by hydrofracturing a level chosen beforehand near the base of the saliferous series. At Hauterives, the fracture level was chosen, for the present, at about 30 m. (100 ft.) above the base of the lower saliferous series. First Carl Bays, then Donald Richner chose the fracture level and presided over the hydrofracturing and the establishment of the connection among each of the groups of mining wells. At the present time, there are three groups of wells for seven wells.

Each well is drilled to a depth slightly above that of the salt base of the lower series. The average depth of the wells is 1700 m. (5600 ft.). The distance between two wells of the same group varies from one group to the next (120 m, 170 m or 250 m) (400 ft, 560 ft or 820 ft). The well equipment is shown in Table II.

Before running production casing, the level to be fractured must be chosen after a careful examination of various geophysical logs. A widening of the drilling hole is done locally at this level by notching with abrasive jets which create a notch in the wall. Precise positioning of the tool is done by nuclear diagraphic marking through a drill pipe.

Cementing of the casings must be done carefully, especially for the production casing which is checked several times before hydraulic fracturing is started. Prior to hydraulic fracturing, the fracture level is again located through the casing of each well with nuclear logging. Next each casing is perforated with jet charges within the previously-notched area of the hole.

TABLE II

Depth		Drilling	Tubing	Tubing
–0 ft	0 m			
2300 ft	700 m	ϕ 17" 1/2	Protection casing ϕ 13" 3/8	Exploitation casing ϕ 9" 5/8
–5600 ft	1700 m	ϕ 12" 1/2		

The hydraulic fracturing, the connection and the leaching

The basic principles and procedures of hydraulic fracturing, as used at Hauterives, were initially developed by Carl A. Bays Associates, and subsequently modified and improved by Donald R. Richner of Terraneers, Limited. Certain details of a proprietary nature are omitted from this report.

In practice, a high-pressure fluid pad was created along the selected frac-horizon of the up-dip well—the main objectives being to (1) create and extend a fracture in tension, (2) remove the foci of stress concentration away from the well bore and (3) present a larger target to the fluid traveling up-dip from the downdip well.

After the fluid pad had been emplaced, the up-dip well was shut-in to observe both the pressure and the pressure decline rate (if any) of the fluid in the well head.

Fluid was then injected into the down-dip well—first creating a bedding plane fracture (in tension) around the well bore, then extending this fracture up-dip until it penetrated the previously formed fluid pad around the up-dip well.

Special test procedures have been developed whereby the presence or absence of a fluid connection between wells can be readily determined. After a low-pressure connection between wells has clearly been established, the high-pressure fluid within the frac system must be carefully withdrawn to the point of normal operating pressure. Well head back pressures must be maintained at each well, and balanced between wells, in order that "bridging" does not occur within the fracture. Principle parameters of the hydraulic fracturing projects at Hauterives are summarized within Table III.

A comparative examination of these results shows that the power that had been installed when the first operation took place was by-and-large sufficient. This was the first time that any hydraulic fracturing had been done at this depth in this basin. The data in Table III also show that the experience that is acquired with any given operation is conducive to a better understanding of the various parameters that come into play and consequently to a better adaptation of the method for the following operation.

TABLE III

	Group 1			Group 2		Group 3	
	HA 1	HA 2	HA 3	HA 4	HA 5	HA 6	HA 7
Description	February 1965			October 1967		April 1970	
Power in "situ" (hydraulic HP)*	4100			3600		3450	
Frac pressure on well head (psi) (Kg/cm2)	3530 248	3190 275	4270 300	3410 240	3850 270	3700 260	3770 365
Support pressure on well head (psi) (Kg/cm2)	3060 215	3190 224	3420 240	3135 220	3135 220	3135 220	3135 220
Maximum rate of injection in down-dip well (bbl/mn) (m3/h)	25 250			20 200		18 180	
Time required (after frace of down-dip well) to establish fluid connection between wells	90 h			32 h		16 h	
Total duration of procedure	6 days			3,5 days		1 day, 6 h	

*Note: The power "in situ" that has been installed also includes the emergency units at rest (stand by).

Once the low-pressure connection is established, the leaching is begun with the pumping equipment used in the mining process at a growing flow rate of 20 to 60 m^3/h (2 to 6 barrels per minute) during the first year. This is increased progressively to 80, 100, 120 m^3/h (8, 10, 12 bbl/mn) the following years, depending on the existing needs for saturated brine. It is quite obvious that if, for any reason pertaining to the group of wells (for instance, the risk of the connection being clogged) one is momentarily forced to produce non-saturated brine by increasing the flow rate, the former can be stored in order to be recycled afterwards.

Solution mining method used in Hauterives

General. The direction of fluid circulation is almost always the same. Each well within a group performs either as an up dip injection well or as a down dip production well. Dissolution of salt is thus mainly restricted to the area up dip of the injection well; the down dip well cavity and it original up dip extension to the up dip well should always contain saturated brine. The production rate of saturated brine and the stability of the underground openings are both enhanced by following this procedure.

Occasionally, because of increased pressure resulting from crystallization around the perforations or the head of the production well, reverse circulation is required. A volume of 500 m^3 (3,150 barrels) of fresh water is considered adequate to dissolve all the deposits. The frequency of the reversals depends above all on the temperature of the brine, which in turn depends on several factors, mostly related to the production rate or the size of the cavity. Normally, this reversal takes place every 15 to 30 days.

Fresh-water leaching. Fresh water is pumped from the water-table of the Galaure River Valley and is then sent to each of the injection wells. The manometric readings regularly taken on each group make it possible to follow the progressive increase of pressure due to crystallization and to decide when the reversal should take place.

A good knowledge of these pressure changes also makes it possible to distinguish between normal and abnormal increases of pressure, the latter being caused by clogging of the perforations or of the connection, or by a squeezing of the casing.

Non-saturated brine leaching. Non-saturated brine, injected in the leaching circuit to produce saturated brine, may have various origins. It may result from:

1. periods of reverse circulation on production wells,
2. the construction of a storage cavity leached by only one well,
3. the operation of a storage cavity during the period in which a cavity is filled with hydrocarbon.

Here again the evolution of the manometric pressures on the well heads is closely examined, more especially as the interpretations of the various changes are more difficult than those made on the fresh-water leaching. Indeed, under normal circulation conditions and with equal flow rates in both cases, the injection pressures on the well heads are half as high as in the case of injection of non-saturated brine with a concentration of 200 to 250 grams per liter.

Variations in concentration and density of the injected brine, cause variations of injection pressure. These variations are irregular and unavoidable because of the non-homogeneity of the brine being used, even after it has gone through pools of buffer storage. It is therefore indispensable to know constantly the density of the injected brine in order to interpret the variations of pressure and to distinguish normal changes from the abnormal changes as defined in the preceding paragraph.

The non-saturated brine leaching demands greater care on the part of the personnel involved in the exploitation. In some instances, certain distinct but simultaneous phenomena may hide each other because the visible result of the addition of their consequences is null. This is the case, for instance, when there is an increased restriction by crystallization in the exit well, while the concentration of the injected increases. The first phenomenon itself would generate increasing pressure losses, thus requiring higher injection pressure, while the second phenomenon itself would generate a decrease of the injection pressure. If there is simultaneity and compensation of these opposite variations, the increases of the pressures on the well heads appear very late and the risks of clogging taking place become much greater. Only the expertise and the experience of the personnel involved in the exploitation can alleviate these risks.

For the next ten years, the solution mining center of Hauterives will receive without stop non-saturated brine originating from creation of gas storage cavities.

PRESENT STAGE OF EXPLOITATION

A diagram of the surface installations would be of no value in a paper of this type. The purpose of this section is to give some general ideas on the quantities and the qualities of the fluids in circulation, not on the capacities of the equipment (pumps, pipes, etc . . .).

Number of exploitation units in service and geological position of the leaching

The production of brine is supplied by the three following groups of wells, ordered according to their opening date.

Group 1, including three wells, HA 1, HA 2 and HA 3, set up in a triangle, 117 to 180 m. (384 to 590 ft.) from each other. Opening date: 1965.

Group 2, including two wells, HA 4 and HA 5, 250 m. (820 ft.) from each other. Opening date: 1967.

Group 3, including two wells, HA 6 and HA 7, 250 m. (820 ft.) from each other. Opening date: 1970.

The dissolution cavities are currently being developed in the lower saliferous series. The top of the cavities related to group 1 (HA 2) and to group 2 (HA 4) reaches, at the present time, the base of the intercalary series which has very little salt. Group 3 is the youngest and not quite developed yet.

Balance sheet of the leaching as of March 1, 1973, and present exploitation rate

The total volume of the dissolution cavity, calculated from leaching records is distributed as follows, as of March 1, 1973:

Group 1	=	4,090,000 barrels	=	649.083 m^3
Group 2	=	2,870,000 barrels	=	455.598 m^3
Group 3	=	1,110,000 barrels	=	176.928 m^3
Total volume of all cavities	=	8,070,000 barrels	=	1.281.609 m^3

This corresponds to a total tonnage of 2,875,283 metric tons of salt extracted from these cavities since the beginning of the exploitation.

On the basis of these calculated results, the following measured elements are found which define the volume of the circulations since the beginning of the exploitation until March 1, 1973:

Total amount of fresh water injected= 41,700,000 barrels
= 6.621.899 m^3

Total amount of non-saturated brine injected = 18,600,000 barrels
= 2.950.880 m^3

Total amount of saturated brine produced = 60,000,000 barrels
= 9.544.086 m^3

In 1972, 556,000 metric tons of salt were extracted. The average flow rate for the months of January, February and March of 1973 was 260 m^3/h (26 bbl/mn). This is close to the average hourly rate based on 350 working days per year which is at the present time of 240 m^3/h (24 bbl/mn).

Quality of the extracted brine

NaCl = 315 g/l	$SO4^{--}$/NaCl = 12×10^{-3}
CaSO4 = 5 to 6 g/l	Ca^{++}/NaCl = 5×10^{-3}
Mg = negligible	Mg^{++}/NaCl = 8×10^{-5}

The temperature in the bottom was originally of approximately 65° C (150° F). The brine that is presently coming out of each group has a fluctuating temperature, linked to the temperature of the injected fluid, to the size of each cavity, to the flow rate of leaching, and to the exploitation pace of each group. At the end of March 1973, for example, the following temperatures were taken for the outcoming brine:

Group 1: temperature = 100° F = 38° C
Group 2: temperature = 82° F = 28° C
Group 3: temperature = 60° F = 16° C

CONTROL OF EXPLOITATION

Control of cavities by sonar

The development of cavities is supervised by investigation with a sonar instrument introduced in each cavity. Echo logs are regularly made each year and make it possible to follow in each cavity the rise of the top, the development in height and in all directions, the accumulation of the insoluble residues on the bottom, and the dimensions of the connection at its limits.

Measurements every 15° horizontally and every 6° vertically make it possible to draw 24 oriented vertical cross-sections, from which horizontal cross-sections can be made. The volume of each cavity is calculated from these cross-sections; consequently, it is in fact a volume observed by sonar.

Volumetric and bulk density control of the dissolution

Fluid characteristics are continuously monitored at each well head and on the main injection and production pipe lines servicing each group of wells. Fluid measurements include flow rate, pressure, density, temperature and salinity, and a material balance is constantly maintained. This information, in combination with sonar and well log data, provides a current "picture" of the solution-mining operation both below and above ground. It also provides a sound basis for forecasting solution-mining "problems"—thus allowing time for planning and preparation in advance.

Casings control

The development of a cavity is accompanied by the progressive deterioration of the casing. This casing, wherever it is no longer held by the ground, hangs freely, swings, and breaks. It can also be affected by the falling of insoluble blocks from the top of the cavity. It is interesting to know the position of the base of the last hanging tube. It is the loose opening for the fresh water exit in the large cavity of the injection well, or it is the opening for the saturated brine entering into the casing of the small cavity of the exit well.

In the main cavity of the injection well, we know that, for an adequate exploitation flow rate, the height of the wall affected by the dissolution is included, approximately, between the casing base and the cavity top. To avoid a fast rise of the cavity top to the detriment of the development in width, it is desirable to avoid the early rupture of the casing and the fall of the loose tubes. The knowledge of the position of the opening (or base) of the casing makes it possible to adapt the flow rate in accordance with the desired result.

In the small cavity of the exit well, the problems are different, but it is also interesting to have some data concerning the condition of the casing, particularly for a better interpretation of certain obstruction phenomena. The casing collar logs (C.C.L.) are regularly done, in particular with sonar measurements (echo logs).

Observations on the shape and dimension of the cavities

Practical consequences. As mentioned above, the frequency of the sonar measurements taken up to date allow one to follow and study the development of Hauterives cavities. In this case, we are interested in the development of a main cavity corresponding to an injection well.

Shape. In all the cavities observed, we note that the shapes are very similar and that the direction of the development depends closely on the direction of the dip. Indeed one observes that (Figs. 2 and 3):

1. the horizontal section is ellipsoidal
2. the large horizontal extension axis is parallel to the direction of the dip.
3. the progression of the extension is in the updip direction.
4. the development in height occurs together with a widening and a lengthening of the cavity.
5. the vertical cross-section which is perpendicular to the direction of the dip is symmetrical about the drilling axis.
6. the vertical cross-section which is parallel to the direction of the dip is asymmetrical about the drilling axis and clearly deformed in the updip direction.

Dimensions. As an indication, the main dimensions of the HA 4 at the beginning of 1972 were:

Height:	120 m. = 400 ft.
Maximum long horizontal axis:	90 m. = 300 ft.
Maximum short horizontal axis:	60 m. = 200 ft.

The volume was then approximately 280.000 m^3 (1,760,000 barrels). For a same development, the dimensions of the other cavities are very close to these.

Practical consequences. We know now that large regular-shaped cavities, with guarantee of stability, can be "fabricated" at the site of Hauterives, by using the previously mentioned solution mining method.

When evaluating stability by finite element studies the geometry of such a cavity is simulated as a symmetrical object (solid of revolution around an axis). This symmetry axis is different from the drilling axis and positioned parallel to it, on the same dip line and updip.

This simulation is made possible by the slight asymmetry of the cavity in the direction of its horizontal extension and by the small difference in dimension between the length and the width.

Considering the small amount of insolubles, the relatively regular shape of each cavity, of its stability and tightness quality, it is possible that in the future some of

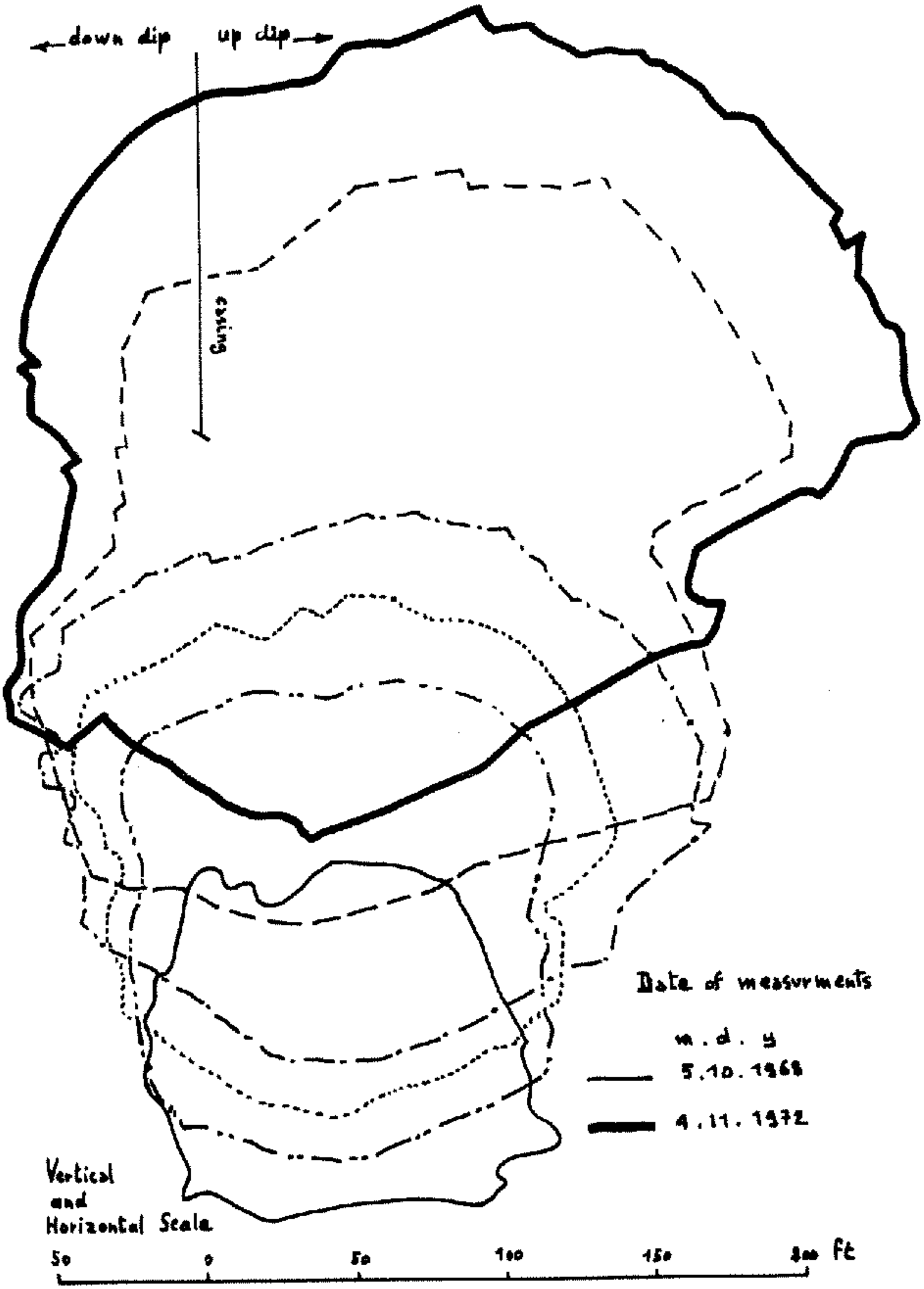

Figure 2. Vertical cross section of HA 4 wells cavity. Sonar measurements (echo log).

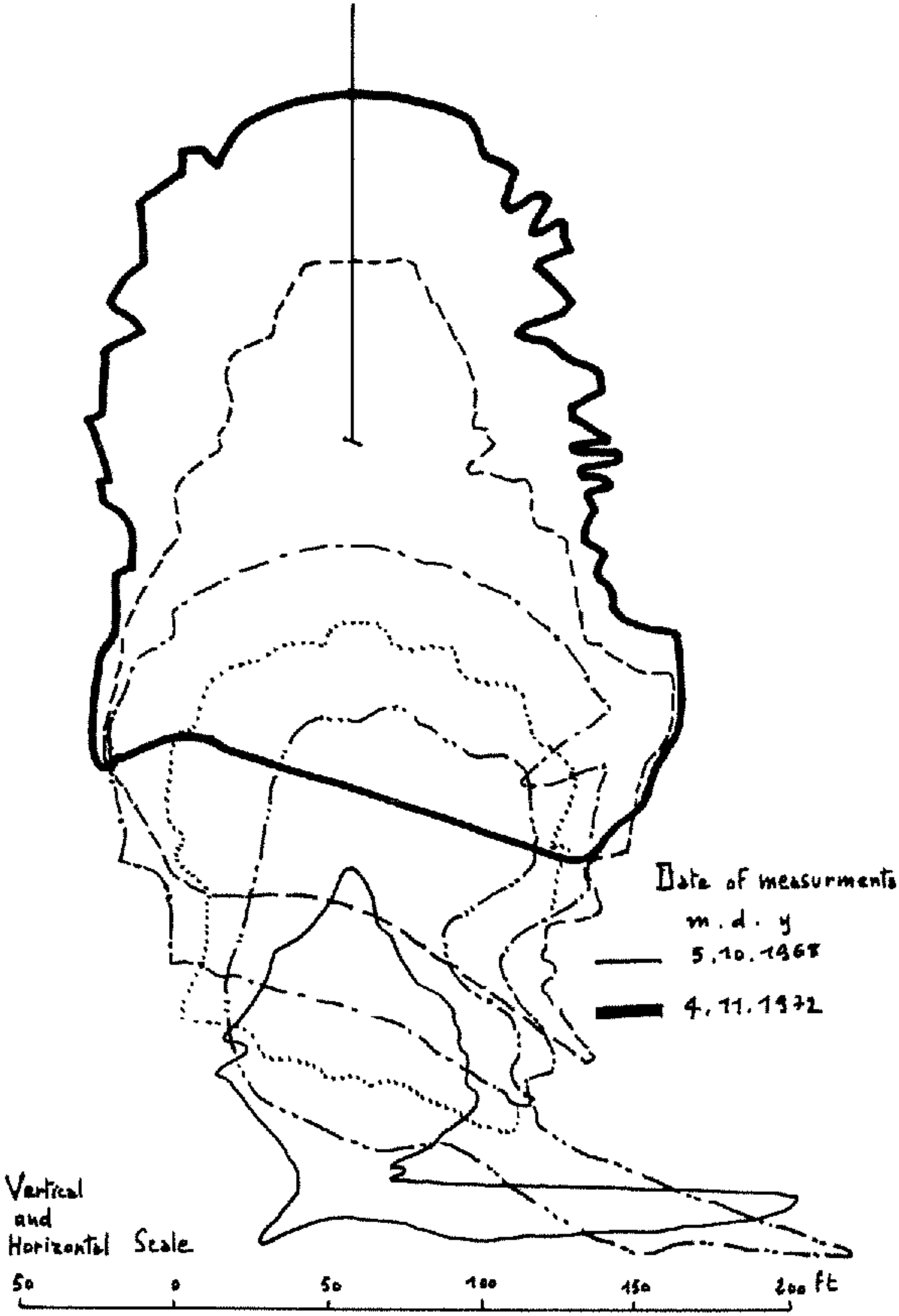

Figure 3. Vertical cross section of HA 4 wells cavity (perpendicular to the direction of the dip). Sonar measurements (echo log).

them will be equipped and used for the storage of hydrocarbon. A project for the creation of such storage cavities was studied recently. It is anticipated that the following average dimensions for each cavity can be obtained:

1. cavity created in the lower saliferous series:
- height: 328 to 425 ft. = 100 to 130 m.
- maximum long horizontal axis: 328 ft. = 100 m.
- maximum short horizontal axis: 213 ft. = 65 m.
- height of insolubles fallen in: 164 ft. = 50 m.

2. cavity created in the upper saliferous series:
- height: 590 to 655 ft. = 180 to 200 m.
- maximum long horizontal axis: 394 ft. = 120 m.
- maximum short horizontal axis: 230 ft. = 70 m.
- height of insolubles fallen in: 164 ft. = 60 m.

These dimensions correspond approximately to minimum capacities of 330.000 m^3 (2,075,000 barrels) in the lower series, and of 650.000 m^3 (4,100,000 barrels) in the upper series, with the understanding that the useful storage capacities to be considered are smaller than those figures for various reasons.

The studies related to this type of project are being carried on particularly the technical studies concerning the stability of a group of cavities.

EXISTING STORAGE CAVITIES

Underground storage perimeter located on the concession

The storage perimeter of the Grand Serre is located on the territory of the RHONE-PROGIL concession, at its eastern extremity. It is a propylene storage unit. There is only one cavity in operation now. It is a "bottle-shaped" cavity, located in the upper saliferous series, and has a capacity of 70.000 m^3 (440,000 barrels). The shape of this cavity is regular and symmetrical about the drilling axis, it was created by a single well, using the method of controlled leaching by means of a fuel-oil "buffer-top," whose height can be adjusted.

The non-saturated brine produced by this leaching was sent back to the exploitation site, for reinjection into the groups of saturated brine producing wells. The exhaust brine-pipe at the exploitation site of Hauterives is now operating in both directions, as a function of the periods of filling and emptying of propylene, which requires the recovering or the supplying of brine.

The equipment of this cavity, the top of which is 1294 m. (4250 ft.) deep and the bottom 1342 m. (4400 ft.) deep, is standard (Table IV).

The tightness tests on the bore hole and on the exploitation casing shoe have been performed with a test pressure gradient of 1.8 Kg./cm^2/m. (782 psi/100 ft.).

Other cavities of the same type are anticipated for the coming years within the Grand Serre perimeter.

TABLE IV

Position	Casing and Tubing	Diameter	Depth of Shoe
Above the cavity	Protection casing	13" 3/8	0–328 ft. 0–700 m.
	Exploitation casing (propylene in annular 9" 5/8-7")	9" 5/8	0–4010 ft. 0–1252 m.
At the cavity level	Tubing (dilution fresh water in annular 7"-4")	7"	0–4400 ft. 0–1340 m.
	Brine tubing	4" 1/2	0–4397 ft. 0–1339 m.

Underground storage perimeter located outside the concession

A few Kms. southwest of Hauterives, in Tersanne, the State company "Gaz de France" owns an underground gas storage perimeter in which there are several cavities created by single well, with controlled leaching by means of a fuel-oil buffer top. A new program of creation of cavities is starting.

The non-saturated brine produced is sent by brine-pipe to the RHONE-PROGIL exploitation site in Hauterives, which reinjects it in its groups of saturated brine-producing wells.

FUTURE POSSIBILITIES FOR THE EXPLOITATION

The utilization of a variable and non negligible flow of non-saturated brine from outside is compelling for the exploitation. These non-saturated brines of various origins, of different concentrations and variable in time, require not only a permanent and careful checking of densities, pressures, temperatures, etc . . . , but also a great operational flexibility, because the operation of the system must be adjusted at all times by the flow of electrolytic plants, which is located at the very end of the circuit, 80 Km. (50 miles) from Hauterives.

It is estimated, however, that the increase of needed saturated brine necessary for the manufacture of chlorine in Pont-de-Claix makes it possible to consider the accepting a large flow of non-saturated brine at Hauterives in the following years, and consequently the possibility of creating around Hauterives storage cavities by single well (propylene storage of the Grand Serre—gas storage of

Tersanne). In that context, the Hauterives exploitation cavities which will continue being leached with non-saturated brine, will develop slowly as compared with those that will be leached with fresh water.

Moreover, the possibility of rapidly creating cavities suitable for the storage of hydrocarbons by fresh water leaching between wells connected by hydrofracturing (consequently by leaching directly producing saturated brine) is now being seriously considered and studied, as indicated above.

Thus, the development of the needs for storage cavities gives to the Hauterives exploitation of rock salt by dissolution an increasing importance and determines its present and future double mission to be the production of saturated brine and the creation of cavities for storage near to the exploitation site and on the site itself.