

Dow Canada Brine Field at Sarnia, Ontario

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ABSTRACT

Salt underlies southwestern Ontario and forms part of the Michigan and Appalachian basins. The deepest aggregate beds are located in the Sarnia-Goderich area.

Dow Chemical of Canada, Limited, has carried out brining operations for the past fifteen years. During this time various methods such as washing, detonation, low and high angle directional drilling, and hydraulic fracturing have been used to communicate wells. Hydraulic fracturing has proven to be the most successful and fastest method although there is evidence by sonar surveys that the directions of fractures have not proceeded as expected.

Neutron surveys of several wells in the same field provide reasonably accurate correlation with cores and neutron surveys taken from one well. The information is useful in fracturing operations and for the cementing of casing.

INTRODUCTION

During the past fifteen years Dow Chemical of Canada, Limited, has been engaged in extracting salt from underground deposits by brining operations for its chemical processes. In order to maintain and improve the continuity of brine for these processes it has become important to study the formations and the methods for connecting and developing wells in greater detail.

This presentation deals with the various methods used in attempting to achieve this purpose.

GEOGRAPHY

Geographically, Sarnia is located in southwestern Ontario at the southern tip of Lake Huron. It also borders on the eastern side of the State of Michigan and is some sixty miles north of the border cities of Detroit, Michigan, and Windsor, Ontario.

GEOLOGY

In southwestern Ontario there are three main areas underlain with salt of the Silurian Age -- the Windsor area, the Chatham area, and the Sarnia-Goderich area. The salt beds in the Windsor and Sarnia-Goderich areas form the eastern margin of the Michigan salt basin while those beds in the Chatham area probably join the Appalachian salt basin beneath Lake Erie. These areas are shown in Figure 1.

RESERVES AND PRODUCTION

The estimated reserves of salt present in the Salina formation in the Sarnia-Goderich area are estimated to exceed two million tons. The annual salt production in Ontario according

DISTRIBUTION OF SALT IN SOUTHWESTERN ONTARIO

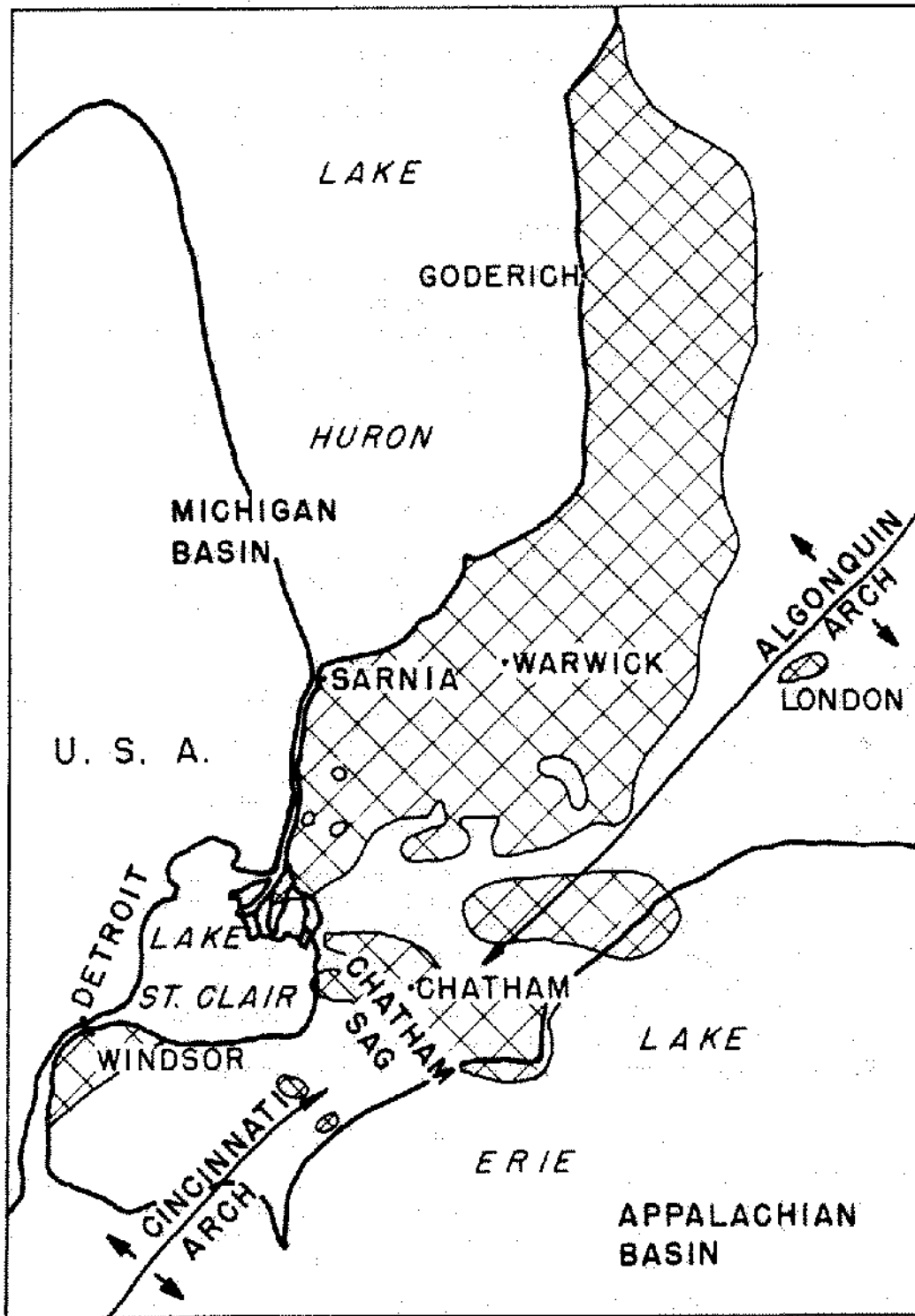


FIGURE 1

to the Ontario Department of Mines statistics (1) has increased during the last fifty years from approximately 84,000 tons to over 3,000,000 tons. In 1959, Dow Chemical of Canada, Limited, and two other companies which produce brine wholly for chemical purposes accounted for 52% of the total Ontario output.

LITHOLOGY OF SARNIA AREAS

In Sarnia, salt beds occur, as shown in Figure 2, in the A2, B, D and F units of the Salina formation, cyclically interspersed with beds of limestone, dolomite and anhydrite. The upper salt beds have an aggregate thickness of over 500 feet and are poor in quality being banded with layers ranging from 1/10 inch to 20 feet thick of limestone, dolomite or anhydrite. The lower salt beds are much purer, having no thin layers dispersed in them, and attain a thickness of 140 feet. The total salt available is about 700 feet. The A2, F and D salt thin out and disappear 40 miles east of Sarnia.

BRINE FIELDS

Dow Chemical of Canada, Limited, has two brine fields as shown in Figures 3 and 4. The first field, which was developed during its initial chemical operations, is located on the works site. It contains 10 wells of which 6 have been retired and the remainder are being held as reserves for the second brine system comprising of 9 wells located three miles southeast of the works site. The base of the Salina formation in the two fields is located at 2670 feet and 2527 feet respectively, indicating the rise in the Michigan basin and a resulting thinning out of the salt toward the east.

LOCATION OF CASING AND TUBING

Figure 5 shows three typical arrangements of setting casing and tubing in our wells. Arrangement "A" shows, the 16 inch surface casing set and cemented into the Kettle Point Formation approximately 130-170 feet below the surface, the 10 3/4 inch casing is set and cemented into the C unit of the Salina formation approximately 1700-1900 feet below the surface and the 8 5/8 inch tubing hung into the A2 salt of the Salina formation approximately 2425-2650 feet below the surface. Arrangement "B" is similar to Arrangement "A" for the 16 inch casing and 8 5/8 inch tubing except that the 10 3/4 inch casing is set and cemented in the A unit of the Salina formation approximately 2460 feet below the surface. Arrangement "C" is similar to Arrangement "A" for the 16 inch casing except that the 10 3/4 inch or 8 5/8 inch casing is set and cemented into the A2 formation and 8 5/8 inch or 5 1/2 inch tubing is either omitted or hung through the 10 3/4 inch or 8 5/8 inch casing into the A2 formation.

The full advantages or disadvantages of the forementioned arrangements have yet to be realized as brining operations continue. It may be said however that Arrangement "A," while providing the greatest exposure of the salt beds and capable of producing saturated brine in excess of 1,000 g. p. m. by top injection creates a greater hazard to failure, loss of pipe and costly work-over jobs. On the other hand, while the other extreme, Arrangement "C," exposes less and purer salt and produces lower flow rates of saturated brine, maximum consumption of salt is being derived because of first developing the lowest bed of salt. The upper beds can be consumed in turn by plugging and milling out the casing at the appropriate elevations.

METHOD OF COMMUNICATING WELLS

Referring again to Figure 3, wells number 1 and 2 were drilled on the works site 50 feet apart by the cable tool method and were operated as single wells until they joined some 14 months later. In the process of drilling number 3 well, in line with and 50 feet from number 1 well, the tools dropped into the cavity created under number 1 and 2 wells.

Wells number 4 and 5 were drilled by the rotary method 40 feet apart and 2060 feet from the number 1, 2 and 3 system. Number 5 was directionally drilled towards number 4 well by whipstocking 7 degrees every 40-50 feet. These two wells were not joined by directional drilling and subsequent surveys showed that a 7 foot partition of salt separated them at their closest point.

SUBDIVISION OF THE SALINA FORMATION

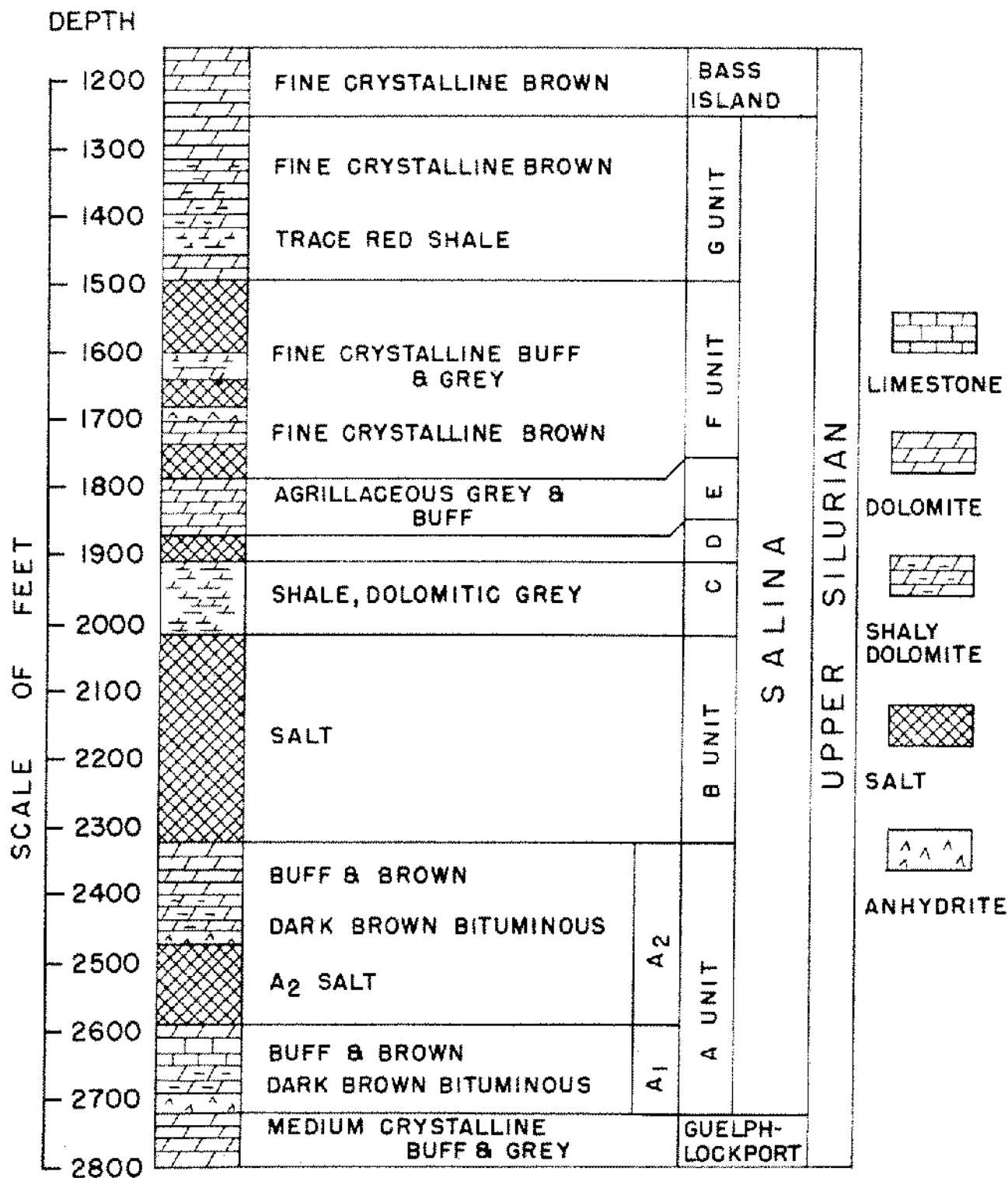


FIGURE 2

BRINE SYSTEM ON WORKS SITE

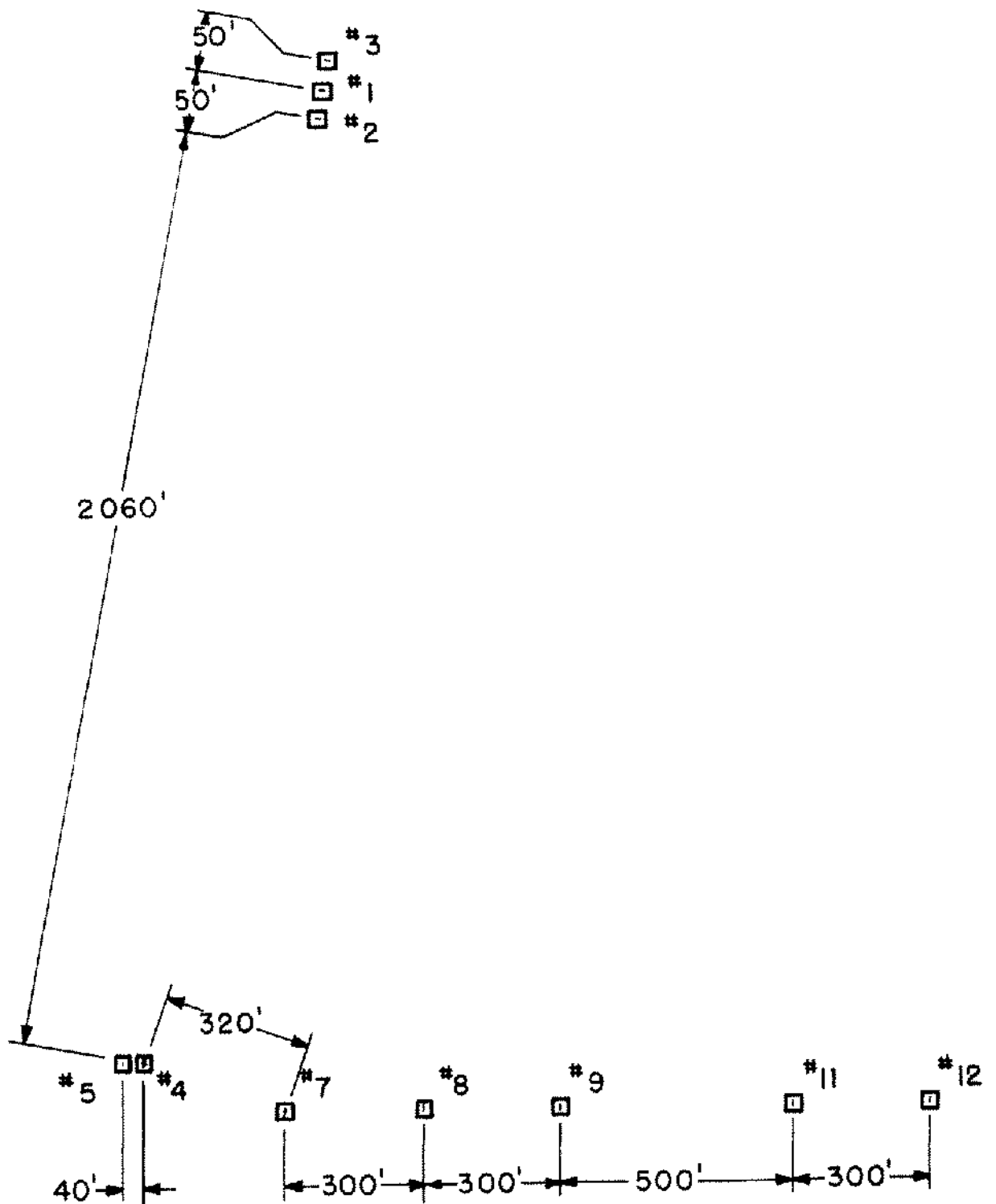


FIGURE 3

NEW BRINE FIELD

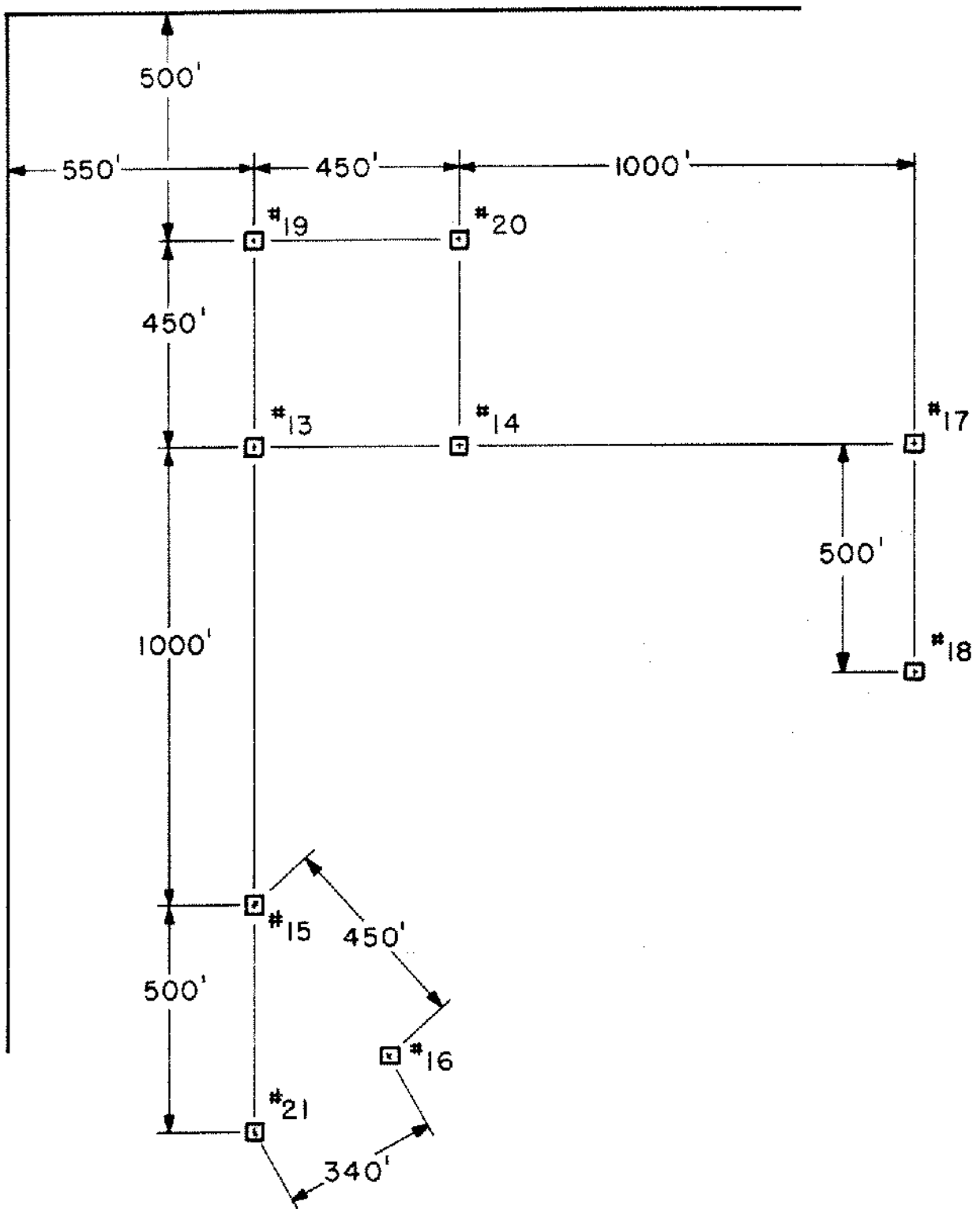


FIGURE 4

TYPICAL CEMENTING DEPTHS

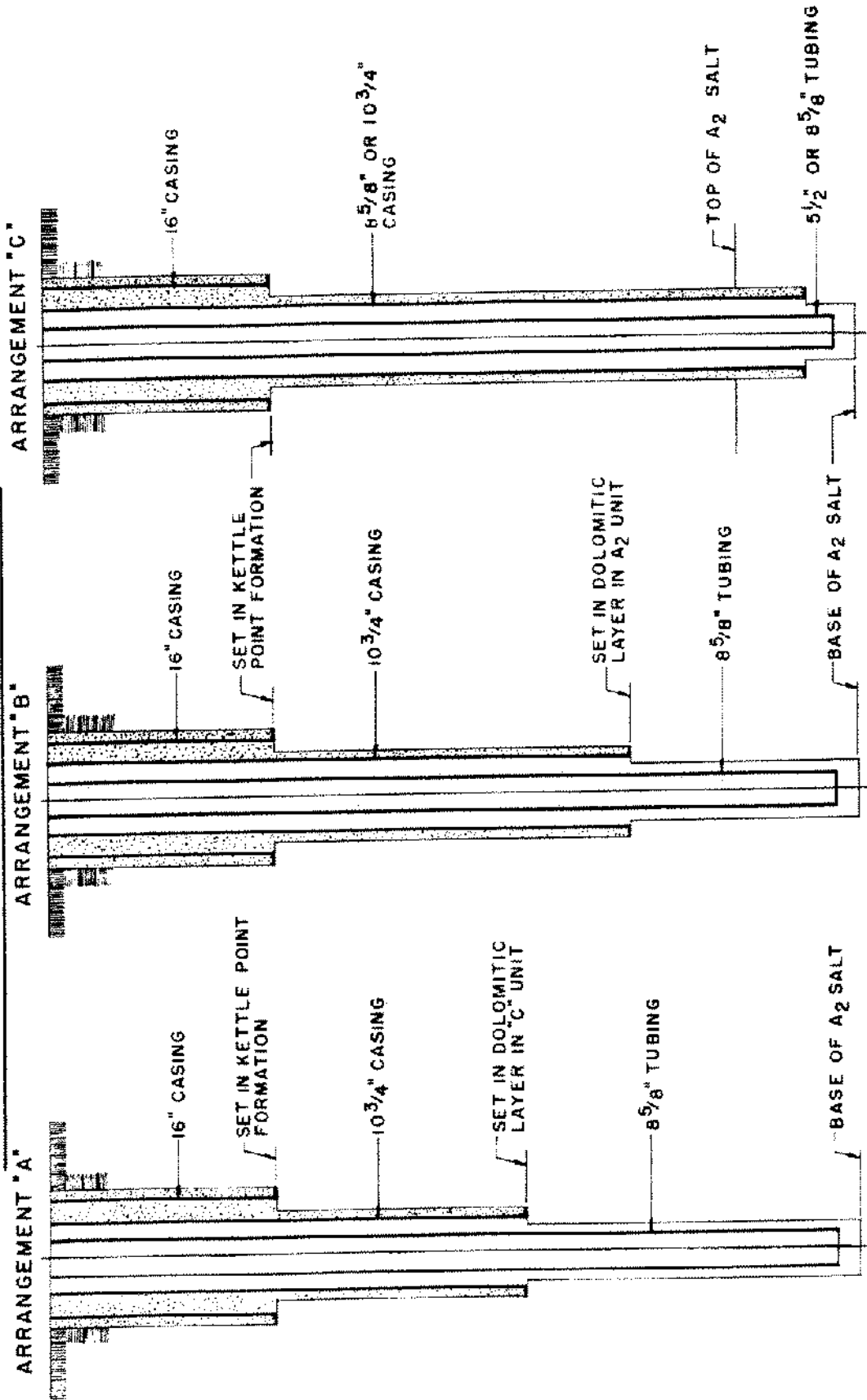


FIGURE 5

In order to join them, one well was bailed dry while into the second well, which was maintained full of brine, was introduced 120 quarts of nitroglycerin. The explosive force generated when the nitroglycerin was detonated was not sufficient to break through the 7 feet of salt. These wells were finally joined several months later by operating them as single wells until they washed into one another.

Number 7 well was drilled 300 feet from the number 4 and 5 well system. In consultation with representatives of the Dowell Division of the Dow Chemical Company it was decided to hydraulically fracture the salt formation in the expectation that communication would be made with another well, number 8, which was drilled 300 feet away. In this case, as shown in Figure 6, the 10 3/4 inch casing was cemented into a dolomite layer above the A2 salt formation. An easily drillable pipe 5 inches in diameter was hung in number 7 well from a point 90 feet inside the 10 3/4 inch casing into the A2 formation and cemented. A notch was cut in the salt below the bottom of the 5 inch pipe and the hole was continued to the base of the A2 formation. Under high pressure, water was injected into the formation through a 3 inch tubing held by a packer in the 5 inch pipe. A fracture was created which successfully extended into the cavity of the number 4 and 5 well-system. It is believed that these wells were the first joined by this method. Some months were required, after communication was made, to reduce the pressure in the fracture to plant operating pressures. It is believed that the fracture had very likely travelled through the insoluble limestone of the Guelph formation, located at the base of the A2 salt, which had created the pressure drop.

Having successfully joined wells by hydraulic fracturing it was decided to extend the gallery system by attempting to fracture number 8 well which was constructed similar to number 7 well. Unfortunately number 7 and 8 wells were not joined after pumping into the fracture for several days. The venture was not yet abandoned and sand was injected into the well for the purpose of diverting the old fracture in a new direction. This also failed as did a final attempt when the 5 1/2 inch pipe above the old fracturing zone was plugged and perforated and fracturing was tried again at a slightly higher elevation.

When a new well, number 9, was drilled some 300 feet away from number 8 well, it was decided to employ a company which had developed high angle tools capable of turning through a right angle in a distance of 40 feet to see whether communication could be made with number 8 well in this manner. Some problems were encountered when the tools were "gummed up" in an anhydrite layer and it was necessary to offset the tools at a new elevation. Drilling was continued and when the tools had reached a distance of 35 feet they fell into a cavity which was evidently created by the previous fracturing of number 8 well.

Number 11 and 12 wells were also drilled 300 feet apart and 500 feet from number 9 well system. An interesting point has been the short period of 20 minutes to join the wells after fracturing pressure was reached.

Wells 13-21 inclusive, shown in Figure 4, were drilled in the new brine field of 300 acres approximately 3 miles south-east of the works. This particular field has been projected to be drilled on a grid system, with wells on roughly 500 foot centers.

Wells 13 and 14 and 15 and 16 were drilled and fractured successfully as pairs using the previously mentioned method for number 7 well.

Number 17 and 18 wells were also fractured as a system. In these wells the easily drillable and expensive pipe was not used. Instead the 10 3/4 inch casing was set and cemented near the base of the A2 salt formation in each well as shown in Arrangement "C," Figure 5. Fracture was accomplished through perforations made in the salt below the 10 3/4 inch casing.

Since the 13 and 14 well system was placed in semi-retirement due to roof failures a few years ago, number 19 well was drilled and fractured below the casing as in the 17-18 well system. The fracture failed to communicate with the 13-14 system. However, evidence of the fracture having advanced some 1700 feet was obtained by a pressure rise in the 17-18 system when it was closed in. No attempt was made to produce a three well system and 19 well has operated as a single well.

No further fracturing has been attempted. Wells 20 and 21 have been drilled and are operating as single wells for the purpose of washing them into previous systems.

TYPICAL PIPE ARRANGEMENT
FOR FRACTURING

TYPICAL METHOD OF CEMENTING
EXPENDABLE LINER

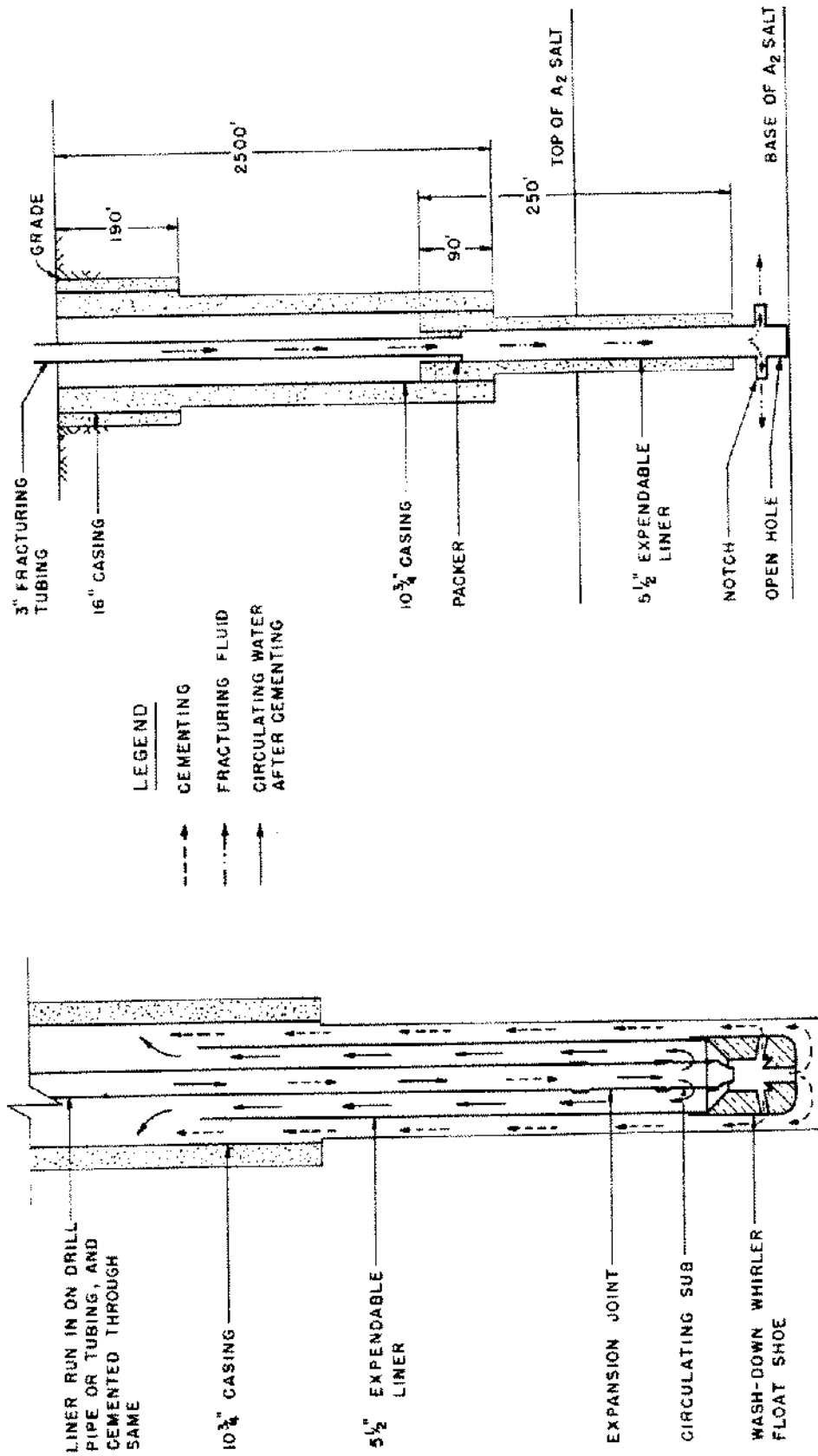


FIGURE 6

INTERPRETATIONS OF RESULTS

It is not to be construed that joining wells is as simple a matter as has been described. On the contrary much apprehension, ingenuity and perseverance go into the venture. Fortunately, our successes have far exceeded the failures.

In the case of using explosives to join wells, this method does not warrant any justification for future attempts.

Washing single wells to form a system can be time consuming particularly if the wells are some distance apart.

Well systems produced by hydraulic fracturing can be regarded as possessing a high degree of success. However, it is recognized that the operator has no control of the direction a fracture will take and has knowledge only that the fracture is proceeding along contacts of least resistance. It is also reasonable to assume that a fracture emanating from one well, which fails to enter the second well, may have been due to (a) the existence of an anticline between the wells whereby the fracture will travel in a gallery fashion perpendicular to the dip, (b) entering a formation below the opening of the second well or (c) entering a formation above the opening of the second well. Coring or electric logging of former wells in the area can possibly indicate the feasibility of fracturing wells drilled on either side of an anticline. When the possibility of a fracture circumventing either above or below the open hole of the second well exists, each well should be fractured in turn at the same elevation and, if necessary, alternately several times. As a further aid to joining wells it may be desirable to apply near to fracturing pressures on the second well while fracturing the first well. This scheme develops some lift or weakness in the formation around the second well and assists in the communication of the fracture from the first well.

Wells can be more easily joined when the fracture is initiated along weaknesses of two formations such as the contact zone between salt and limestone or anhydrite.

Attempts to alter the direction of fractures by plugging the formation with sand have not met with success. The sand evidently does not close the fracture and very likely assists in keeping it open.

Every effort should be made to assure a good cementing job around the pipe where a fracture is to take place. Structurally unsound cement and uncentralized casing can allow the fracture to rise between the casing and the formation and make communications with the second well more difficult to achieve.

Directional drilling is a method which deserves further investigation. In order for directional drilling to achieve success it is necessary that the tools are capable of turning through a right angle in the shortest possible distance at or near the base of the salt. The tools should also be self supporting so that they do not slip in the relatively soft salt and that they remain on "target" with the second well.

CORING AND LOGGING WELLS

The geological structure of our brine fields is determined from the drillers' samples and more precisely by coring. It is necessary in either case to use a very carefully controlled saturated brine drilling mud to prevent dissolving the salt.

From the cores the physical characteristics such as fractures, crystallinity of the salt, weakness zones, etc., can be obtained. This information can lead to the most desirable location of setting casing and for fracturing.

Additional information has been obtained through the use of electric logging. The various surveys conducted on our wells are calipering, micrologging, laterologging and gamma ray-neutron logging. Of these most use is made of the caliper log to determine washouts during drilling and for cementing casing and the neutron log which is compared with the neutron log of the cored wells for cementing and fracturing purposes. Such comparison of neutron logs with the core are shown in Figure 7. Another log is also shown in Figure 7 which represents the drilling time through the formations. This drilling log gives reasonably good comparison with the neutron logs and core.

COMPARISON OF COLUMNAR SECTION OF CORE WITH LOGS

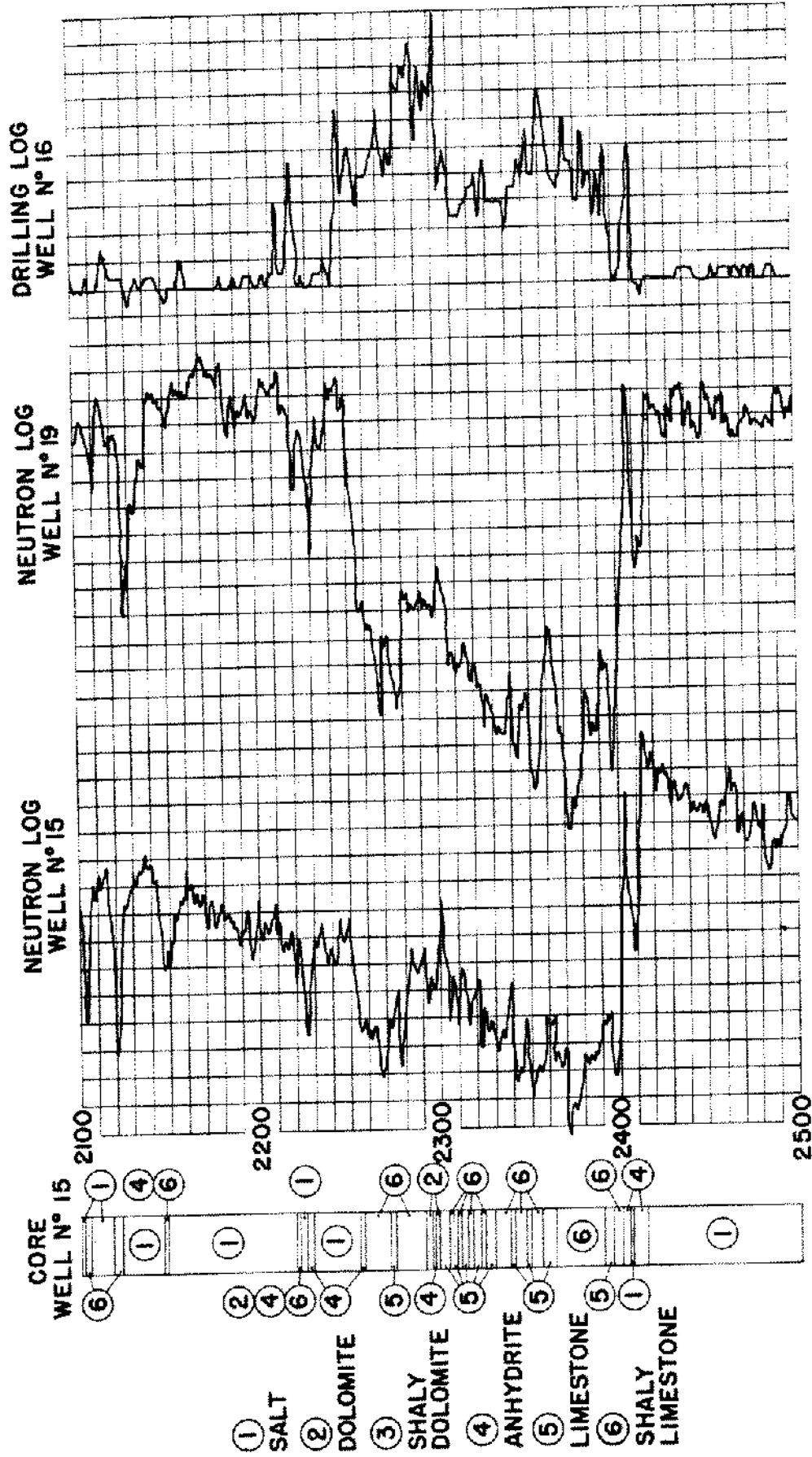


FIGURE 7

DELINEATION OF WELL CAVITIES

In the fracturing and/or the development of any well system the operator is, of course, very anxious to know what has occurred. We have used the services of the Dowell Division of the Dow Chemical Company which has developed a tool called "sonar" for the delineation of well cavities. We believe it is an excellent piece of equipment for determining the shape of the cavity and the level at which the fracture has taken place.

As the instrument operates on the emission and reception of sound waves through 360 degrees the configuration of the cavity is obtained at any level. By taking measurements at a number of elevations the cavity can be surveyed through its entire depth. Usually sufficient information of the cavity shape can be obtained by taking readings at 5 foot intervals. Sonar must be conducted in an open hole and is not capable of obtaining the shape of the cavity around corners or below the rubble pile.

We have made several sonar surveys of our wells. An interesting survey, shown as a model in Figure 8 (2), indicates that fractures from each well were initiated in directions parallel to each other along the base of the salt formation. Since sonar is not capable of going around corners the interconnecting portion between the initial fractures is assumed to follow the path indicated by the light portions of the model. Other surveys have indicated that fractures have travelled across the top of the formation. Surveys of single wells show agreement within 10 per cent of the actual quantity of salt dissolved.

REFERENCES

1. Ontario Department of Mines, Industrial Mineral Report No. 6, Salt in Ontario by D. F. Hewitt, 1962.
2. Photograph by Dowell Division of the Dow Chemical Company.

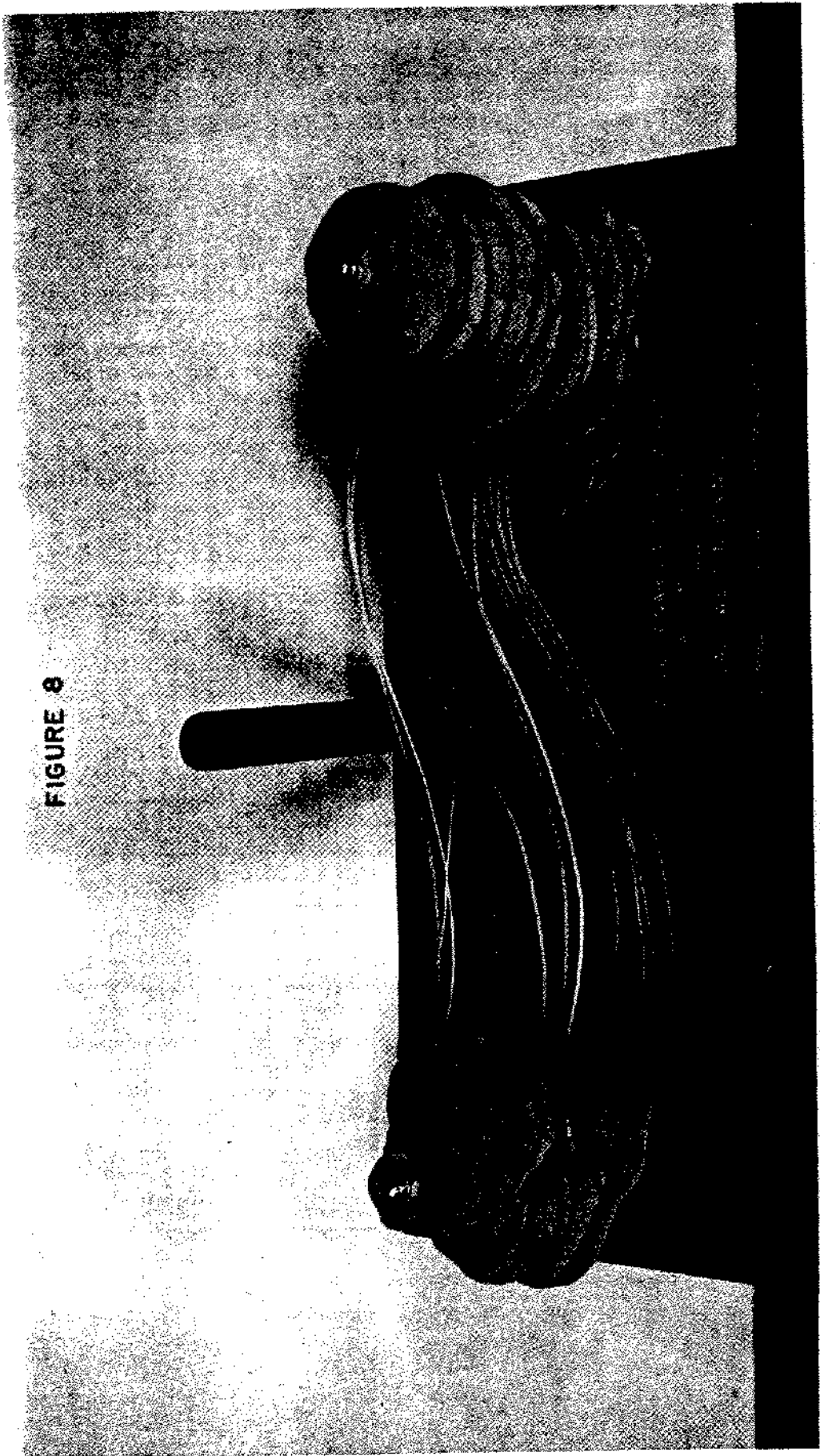


FIGURE 8