MASTER

SCOPING REPORT ON VARIOUS
SALT MINES IN THE UNITED STATES

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Bedded Salts

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Introduction

The information contained in this "Scoping Study" is a matter of personal knowledge or information from my personal files and published documents. Due to the time limitation, no in depth literature search was possible.

The use of cavities, created in salt by either the solution mining or dry mining techniques have been numerous throughout history. Annually the list of cavity uses in salt grows. The Roman's developed a salt mine in the Rumanian's Carpathians which currently is being used as a sanatorium for the treatment of nervous disorders, curing of tobacco and storage of machinery. A portion of a salt mine in Columbia was converted into a church. The salt-potash mines of Germany during World War II were used for the storage of art treasures and the manufacture of V-2 rockets. Currently, Germans are using portions of their salt cavities for the storage of hazardous wastes and compressed air for the peak shaving of power. France is developing numerous huge cavities for the storage of crude oil and other hydrocarbons.

For years salt mines in the United States have been used for such things as storage of documents, records and film; processing of film; as laboratories for numerous

scientific experiments. Currently our mines are being considered as receptacles for a large number of purposes which include cold storage of food; storage of crude oil; growing of mushrooms; the raising of chickens and the storage of various types of waste.

All salt mines in the United States use the room and pillar system of mining. In general, these room and pillar systems extract percentages of salt varying from approximately 75% to slightly less than 50%. In bedded deposits, single level headings have been driven to form the rooms. In dome deposits, the room and pillar system has been modified so that after the heading has been driven, a bench or benches can be created. In the single heading rooms of the bedded deposits, the height of the heading driven usually varies in keeping with the thickness of the salt bed being mined. At Morton Salt Company's Fairport Mine, these headings or rooms are often over 30 feet in height while at the Retsof Mine of International Salt Company, room heights are a minimum of 9 feet. Rooms created in salt domes vary in height from the 65 feet in Morton's Weeks Island Mine to 150 feet in International's Avery Island Mine.

Summary

One of the most important factors in isolating the demonstration waste storage site is an adequate number of shafts to insure proper ventilation. Proper ventilation will require that the air exhausted from the storage area pass directly to the upcast air shaft. Those mines reported by this scoping contract generally conform with the two shafts per mine requirement of M.E.S.A. Three of the mines reported on have more than two shafts. Several of the mines can have additional shafts drilled in time to meet E.R.D.A.'s schedule. Rough drilling costs have been cited in the report.

From an economic standpoint, it is probable that the larger the mine, the greater the economic impact with regard to any dislocation of production that may be required. In some cases, such as the Retsof Mine and the Cayuga Mine, multiple shafts eliminate the probability of dislocation. Those small tonnage mines such as the Kleer at Grand Saline, Texas; the Hockley Mine near Houston and the Lyons Mine of the American Salt Company might be leased or purchased in their entirety.

The following table indicates both the shaft and tonnage aspects of these mines.

<u>Mine</u>	<u>Annual Tonnage</u>	<u># of Shafts</u>
Belle Isle (Cargill)	1,800,000	2
Cote Blanc (Domtar Chemical)	1,250,000	2
Jefferson Isle (Diamond Crystal)	1,600,000	2
Weeks Island (Morton Salt)	1,300,000	2
Avery Island (International Salt)	1,800,000	3
Kleer Mine Grand Saline (Morton Salt)	500,000	2
Hockley Dome (United Salt)	200,000	1
Seneca Lake (Morton Salt)	2,800,000 (Abandoned)	2
Fairport Mine (Morton Salt)	2,300,000	2
Retsof Mine (International Salt)	3,500,000	5
Detroit Mine (International Salt)	1,500,000	2
Cleveland Mine (International Salt)	2,500,000	2
Cayuga Mine (Cargill)	700,000	3
Lyons Mine (American Salt)	500,000 (1976) 150,000 (1968)	2

It is the understanding of the author that the Federal Energy Administration is currently negotiating for the

- 1) Cote Blanc Mine
(Domtar Chemical Co.)
- 2) Weeks Island Mine
(Morton Salt Co.)
- 3) Kleer Mine - Grand Saline
(Morton Salt Co.)

The mines which are acceptable or deserve additional consideration are:

- 1) Weeks Island Mine
(Morton Salt Co.)
- 2) Avery Island Mine
(International Salt Co.)
- 3) Retsof Mine
(International Salt Co.)
- 4) Kleer Mine - Grand Saline
(Morton Salt Co.)
- 5) Detroit Mine
(International Salt Co.)
- 6) Lyons Mine
(American Salt Co.)

Domes

1. Louisiana

a) Weeks Island

Weeks Island is one of the "Five Islands" that form a line across the southern portion of Iberia Parish in Louisiana. The Weeks Island Mine was purchased from the Myles Salt Company in the late 1940's by Morton Salt Company.

The mine consists of two levels separated by a web of salt 124 feet thick. Each of these levels were mined by the room and pillar system including the top level which is now abandoned. This mine is dry and stable from a rock mechanics standpoint. The floor of the current mining level is 758 feet below the surface.

Rooms and pillars are somewhat smaller than they are in other mines housed in dome type deposits being 65 feet in width and of a similar height. In some areas mining was conducted with roof heights of 90 feet. Total volume of the mine openings approximates 500,000,000 cubic feet.

With a domal radius of approximately one mile, it has been found that only about half the dome contains

salt of commercial quality (99.0% NaCl for Louisiana Rock Salt). The other half of the dome is apparently a spine which has been faulted and fragmented during its rise to the earth's surface so that considerable quantities of drag material have been incorporated with the salt. There is no cap rock on the dome.

Conclusions and Recommendations

In the author's opinion, this is one of the better dome type mines in the United States with respect to the possible use as a demonstration site. The dome does contain a few cavities which are a result of solution mining activities, but these operations could be terminated and their existence would not jeopardize mine storage of wastes.

It has been reported that this mine is currently being sought as a storage site for crude oil by the Federal Energy Administration.

Costs

Because the mine is an active mine, a third shaft would be required. If ground conditions are suitable for a bored shaft, this might be accomplished at a

cost of \$1,500 per vertical foot. Assuming a vertical distance of 760 feet and a fully lined shaft, a cost of \$1,140,000 would be incurred. Depending on ground conditions; availability of a competent contractor; availability of supplies and equipment such as steel casing, the drilling and completion of a 48 inch shaft can be accomplished in 4 to 6 months with two months of preparation and design. Driving of a 36 foot tunnel would cost about \$130 to \$140.00/linear foot in dome salt.

Domes

1. Louisiana

b) Cote Blanc

Cote Blanc is one of the "Five Islands" in the chain of domes which occur in southern Iberia Parish. Domtar Chemical Company is the current operator on the property, having assumed the rights of the Carey Salt Company. Carey Salt Company sank the first shaft in 1963 with some degree of difficulty. The contractor using a new modification of an old shaft sinking technique hit a cypress log at a depth of several hundred feet and suffered serious delays.

This 14 foot diameter shaft penetrated the salt to a total depth of 1,400 feet. An 8 foot diameter companion service shaft was drilled to a depth of 1,362 feet. The system of mining is room and pillar. Pillars are 100 foot square with an extraction ratio of about 50%. The faces are undercut 10' 11" with a 2431 Goodman Universal Undercutter so that on each blast 10 feet of linear advance is developed. Rooms are developed with a single 50 foot high heading and no benching. Rooms are 50 feet wide on 150 foot centers. Blast holes are drilled with a twin boom

drill jumbo. The face blasting pattern has 14 rows of 11 holes with 2 additional holes in each upper corner. Ammonium nitrate is used as a blasting agent detonated by non-electric milli-second delay blasting caps.

A 13 ton transloader is used to pick up the salt from the face to the crusher. All crushing and screening is done underground. Hoisting of the screened salt is done with 2 9-1/2 ton skips giving the mine a capacity of about 4,000 tons per shift.

As delineated in the attached structural contour map of the Cote Blanc dome, the 1,000 foot contour on top of salt encompasses less than one-third of the area of the dome. Of the area encircled by the 1,000 foot contour approximately half is in the area of overhang. The current mining operations cover most the area available at the 1,400 foot level.

In negotiating with the Federal Energy Administration for the use of the Cote Blanc dome, Domtar Chemical is advocating building a new mining level at a higher elevation than the 1400 foot elevation currently being

R · 7 · E

R · 8 · E

T · 15 · S

Legend

- oil well
- ◆..... gas well
- ✦..... dry hole
- △..... produced and abandoned
- drilling well
- T.S. top of salt
- B.S. base of salt

T.S.371

new orleans geological society

STRUCTURE MAP
TOP OF SALT AND
BASE OF SALT OVERHANG
COTE BLANCHE ISLAND FIELD
ST. MARY PARISH, LOUISIANA

SCALE

AS OF November 1, 1928

NAME OF DOME Cote Blanche Island PARISH St. Mary

LOCATION Township 15 South, Range 7 East, and Township 15 South, Range 8 East.

MEANS OF DISCOVERY: _____

DISCOVERY WELLS: _____

Salt: Salt produced since 1921

Production: Texas Co. #2 State Lse. 340 (1948)

SHALLOWEST SALT ENCOUNTERED -371' DEEPEST SALT ENCOUNTERED -12,330'

DEEPEST WELL Texas Co. #25, S.L. 340 TO 17,312' T.D.

DEEPEST ZONE PENETRATED Miocene

PRODUCTIVE ZONES Pliocene and Miocene

STRUCTURAL LOCATION (S) OF PRODUCTION Piercement salt dome.

1. SUPERCAP _____ 2. CAP _____ 3. FLANK x

PRINCIPAL OPERATORS: Shell Oil Company and The Texas Company

MARKET OUTLETS: Texas Pipe Line

REMARKS: (Note: if sulphur or salt productive) Salt

PRODUCTION RECORD:

YEAR	OIL			GAS		
	NO. WELLS	PRODUCTION (thousand bbls)	CUMULATIVE	NO. WELLS	PRODUCTION	CUMULATIVE (mmcf)
1955	12*	314.3	1,112.5	12*	511	2,700
1956	16*	728.4	1,830.9	16*	639	3,341
1957	23	855.2	2,686.1	4	806	4,147
1958	32	1,110.3	3,796.4	4	1,124	5,272
1959						

*Both oil and gas wells.

used for salt production. This would seem to indicate that there is some problem such as heat in opening a level below 1,400 feet.

Cote Blanc, as shown on the attached map of the area, has no railroad or highway facilities. Thus, all salt produced and inbound freight must come by barge.

Conclusions and Recommendations

The salt mined at Cote Blanc is extremely pure being consistently in excess of 99% NaCl. Even though the salt is of high purity, the underground openings are stable and the mine free of water, Cote Blanc's handicap is the lack of rail and road facilities. Only a ferry is available for personal cars.

MILEAGE
ETWEEN DOTS 35
IN IN RED

SCHEDULED AIRLINE STOPS
AIRPORTS
AIRPORTS
REST AREAS
SH LINES
DIST. INFORMATION

★ Texaco Service Stations on Major Toll Roads or Adjacent to Non-Toll Federal Interstate Highways and/or Major Limited Access Highways.

For Personalized Routing Service, Write or Visit any
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Los Angeles, Calif. 90005—3350 Wilshire Blvd.
New Orleans, La. 70160—1501 Canal St. or P.O. Box 60252
New York, N.Y. 10017—135 East 42nd St.

Domes

1. Louisiana

c) Avery Island

Avery Island Mine is located near New Iberia, Louisiana and is the second of the "Five Islands" and is operated by the International Salt Company. This mine is the only mine constructed in a dome which has three shafts.

The first mine at Avery Island was started as an open pit from the discovery of rock salt in 1862 until the workings were destroyed by Federal Troops April 17, 1863. In 1867 the first shaft was sunk to a depth of 90 feet and rooms were driven off laterally until they encountered a water filled fault fissure which flooded the mines.

In 1898, the Avery Rock Salt Mining Company was organized and began the sinking of the first shaft of the current mining operation. This shaft was completed to the 500 foot level and the level developed with the room and pillar system. In all cases mining advanced until moisture was observed on the faces. A railroad was built across the swamp to the island in 1886.

Initially, the mine openings were somewhat random in shape and size, but roof spans were confined to less than 65 feet. In about 1900, the progress in a westerly direction was almost completely blocked by faces of wet salt. At this point in time the mining pattern and method was changed. A room and pillar system with 100 foot rooms and 100' x 100' pillars were created. The configuration of these rooms were dictated in part by the purity of the salt. Originally, a 20 foot heading was developed at what was to be the bottom of the room and 80 feet of salt overlying this heading was drilled and blasted down into the heading. This approach was modified in about 1948 so that a 20 foot heading was driven at what was to be the top of the room and two 40' benches were taken to form the 100 foot room.

Due to the fact that all along the north edge of the workings the faces were damp, horizontal drilling was conducted in 1960 through this fault zone. Good salt was found on the north side of the dome and inclined slopes were driven through the fault to the 700 foot level. The reasoning behind driving inclined slopes was that the top of salt on the north side of

ROAD CLASSIFICATION
Medium-duty ——— Light
Unimproved dirt ===

the dome average about 200 feet deeper than the top of salt on the south side.

During this slope driving period, salt to be mined came in short supply. Pillars were instrumented with dilation pins and a bench 35 feet deep and 70 feet wide was excavated. The pillars suffered no harmful effects from increasing the room height from 100 feet to 135 feet. As a result of this favorable experience, management agreed to the creation of rooms which were 150 feet high and 150 feet wide. Again, pillars were increased in size from 100' x 100' to 150' x 150'. These larger size pillars are more stable than the 100' x 100' pillars due to confining pressures.

Due to moisture barriers and dirty salt, mining on the 700 foot level has been phased out. An inclined slope connects to a new third level at an elevation of -880 feet. A new third shaft was designed to service this new 880 foot level. Thus far only headings have been driven with benching scheduled to begin sometime in 1978. Pillars are not superimposed since a sufficient web thickness has been left to insure the stability of the openings. All openings on the 880 foot level are dry and stable.

Recommendations and Conclusions

The most detrimental aspect of the Avery Island Mine is the small quantity of fluid which enters the mine through the primary fault. This fluid is meteoric water which as it enters the mine is a saturated brine. In the immediate past, this fluid has been easily controlled by surface and underground grouting techniques. It is the opinion of the author that all fluid entering the mine (4.5 gpm) can be shut off by surface grouting. All leaks in the mine are in this major fault zone where mine openings on the 700 foot level have penetrated the fluid.

It is the author's opinion that Avery Island is second choice as a possible demonstration site. It has two distinct advantages:

- 1) Mine openings are serviced by 3 shafts.
- 2) The 700 foot level can be completely isolated from the active mining area on the 880 foot level.

It appears possible to drive a drift from the 700 foot level to the bottom of the old hoist shaft. Present mine opening on the northwest side of the

700 foot level could be used or a new drift driven into solid salt to the north. The tunnel from the 700 foot level to the bottom of the Old Hoist Shaft is approximately 1,400 feet. Assuming a drift opening 20 ft. by 20 ft. would cost approximately \$80/linear foot or about \$112,000. Raising into the bottom of the Old Hoist Shaft would cost an estimated \$500.00/vertical foot or \$100,000. This would appear to be the cheapest and fastest approach to a demonstration storage site. Other approaches are possible using the ventilation shaft and isolating the 500 foot level. A complete shut off of the water will cost \$600 to \$700,000. We would recommend that this approach be investigated more fully.

Domes

1. Louisiana

d) Belle Isle

Belle Isle is the last of the "Five Islands". Of all the salt domes containing salt mines, Belle Isle has experienced much more difficulties than all the others. The shaft sunk in 1889 was completed to a depth of 390 feet. A heading was turned off by the Gulf Company who sank the shaft. At a horizontal distance of 340 ft. a fault crevice was encountered and the mine lost. A second shaft was started but never completed. In 1963, Cargil Incorporated sank a shaft to a depth of 1,200 feet. This single shaft opening was used to develop a room and pillar system. In 1968 this shaft was set afire by a welding torch and 21 men were killed. The shaft was rehabilitated and a second shaft was sunk to the workings. Due to improper design, construction and maintenance this shaft was lost a year after its original completion. The ground surrounding the original shaft location was frozen and the shaft reconstituted and currently is near completion. All underground areas have experienced water problems. Attached is a structural contour map of the top of salt.

Recommendations and Conclusions

In view of the fact that Belle Isle is experiencing continued water problems and has no railroad or highway access, it could not be recommended as a demonstration site.

Domes

1. Louisiana

e) Jefferson Island

Jefferson Island is the most northern dome of the "Five Islands" and is operated by the Diamond Crystal Salt Company. The first shaft was started in 1919 when the Jefferson Island Salt Company sank a shaft in the tall isolated spine associated with an adjacent lake.

The author has personally inspected the 800 foot mining level and found the pillars to have been overstressed and the openings in serious difficulty with respect to stability. It was reported that immediately prior to the sale of the mine to Diamond Crystal by Jefferson Island Salt Company, the floor salt on the 800 foot level was benched increasing the height to width ratio and thus weakening the structural strength of the pillars.

Recommendations and Conclusions

It is known that serious rock mechanics problems exist with respect to the mine openings at Jefferson Island. Not only has the operator experienced difficulty with respect to these openings, but the

shafts have been a continual source of trouble.

Domes

2. Texas

a) Kleer Mine

The Kleer Mine at Grand Saline, Texas is owned by the Morton Salt Company. Morton sank the first shaft at Grand Saline in 1930 to a depth of 700 feet. At this depth the room and pillar system was used to develop the mine workings. Production from these workings is relatively small, being approximately 500,000 tons per year. The mine workings are relatively dry and stable. The total volume of salt extracted from the mine was estimated at approximately 18,000,000 tons. It has been estimated that the mine openings comprise less than 270,000,000 ft³. The mine is serviced by both rail and highway transportation.

Recent subsidence on the Grand Saline dome was directly associated with an old brine field which had previously been abandoned. Reportedly, domestic waste water had been injected into the old cavities and the solution of the salt continued after the abandonment of the brine field. Collapse of certain surface structures not related to the mine did occur, but these were removed from the vicinity of the dry mining area.

Recommendations and Conclusions

It is the author's opinion that the Kleer Mine could be used as a demonstration site. Reportedly, the Federal Energy Administration is in active negotiation with Morton Salt Company for the use of this mine as a receptacle for the storage of crude oil.

Domes

2. Texas

b) Hockley Dome

The Hockley Mine is located in the Hockley Dome in Harris County on the outskirts of Houston, Texas. This mine is owned by the United Salt Company who sunk the first shaft in 1932 to a depth of 1,525 feet. Although discussions of plans have been held with respect to the sinking of an additional shaft, this work is understood to be incomplete. No shaft pillar was ever developed.

As the heading of the room and pillar system was developed, the salt remained of low sodium chloride content with relative high percentages of insolubles. This low quality of salt is reflected in the relatively low volume of annual production which approximates 200,000 tons per year. Reportedly, exploration by core drilling has failed to develop any areas of good quality salt on the dome.

Recommendations and Conclusions

Even with the completion of a second shaft, the necessary isolation of a demonstration site from the

active working areas of the mine would be impossible. The only manner in which this mine might be used as a site would be the total and complete acquisition of the mine. Prior to the acquisition of the mine, the proximity of brine wells, oil wells and liquid hydrocarbon storage cavities should be investigated.

The drilling and completion of a 1,525 foot 60" I.D. drilled shaft would take somewhere between 9 and 12 months with 3 months of Design and Procurement.

This time schedule would be dependent upon securing a competent contractor and the availability of supplies and material.

We would not recommend this as a site for a demonstration site unless there was a sizeable lengthening of the time limits and then only after a thorough study.

Part II

Bedded Salts

1. New York

a) Seneca Lake Mine

The Seneca Lake Mine of Morton Salt Company is located on the west shore of Lake Seneca at Himrod, New York. This mine was completed and put into operation in 1972 at a cost of \$37,000,000.

Entrance to the mine was gained through two 18 foot concrete lined shafts equipped with Koepe hoists.

Mining was conducted in a room and pillar system which reportedly required the bolting of the roof. From the writer's personal observations many areas of the roof were so unstable as to require bolting through mesh and bars on much closer centers. After extraction of the salt was complete, large portions of the mine were closed off as a precautionary safety measure. These conditions were brought about primarily due to the faulting of the Salina in southern Finger Lake area. Mining was conducted in a down dip direction to the west - southwest. The bedded salts as delineated in Stratigraphic Log Number

NW GAMMA - RAY LOG CORRELATION

Wells 6701 & 6702

WELL 6701. Drilling floor el. +603.45'
Depth + 53.45' A.S.L.

SE

WELL 6702. Drilling floor el. +583'
Depth -67' B.S.L.

#1 extend from the Retsof Mine area, through the Himrod-Watkins Glen area to Ithaca, New York. During the Appalachian uplift, the tectonic disturbance of the Salina salts took the form of a thrusting action which created both thrust and tear faults within the salt. Subsequently, relaxation of these thrusting forces gave rise to the development of some slip faults. Although severe internal faulting of the Salina beds had occurred in the Himrod area, both the top and bottom of the sequence were relatively flat lying. The Seneca Lake Mine was constructed in the B Unit as depicted in Log #1 at a depth of approximately 2,050 feet.

With a total capacity of about 3,000,000 tons annually, the maximum production that was achieved during the mine's operation was about 1,200,000 tons. Of the total tonnage produced, 1,000,000 tons were in non-marketable fines termed F.C. salt which is particulate matter of a size smaller than 10 mesh.

The mine was closed in the late summer of 1976 due to high mining costs.

Bedded Salts

1. New York

b) Retsof Mine

The Retsof Mine is located about 20 miles south of Rochester, New York at the small village of Greigsville. The Retsof Mine is the world's largest salt mine with an annual capacity of slightly more than 3,500,000 tons and began operations in 1886.

As depicted on the Stratigraphic Log #1, the Retsof Mine is contained by the B3 Subunit termed the Retsof bed. At the Fuller Shaft shown on Sketch #1, the Retsof bed is located at a depth of 1,058 feet below the surface. Workings of the mine extend approximately 6 miles in an east-west direction and 3 miles in a north-south direction. A cross section of the salt bed sequences is shown in Figure 1B. This cross section begins at the Fuller Shaft of the Retsof Mine and extends for a distance of 13.7 miles to the south-southeast.

Mining was conducted with a room and pillar system with the room height varying in thickness from 9 feet to about 16 feet. This thickening and thinning

Sketch #1

Greigsville
Shaft

Isolation
Plug

Fuller Shaft

Retsof
#1 Shaft

Retsof
#2 Shaft

Retsof Mine

NW

SE

FULLER SHAFT
737' A.S.L.

WELL No.5

WELL No.6506

STERLING SHAFT
(CORE HOLE #1)
614' A.S.L.

WELL 6701
603.45' A.S.L.

WELL 6702
583' A.S.L.

No.1 KENNEDY
612' A.S.L.

of the salt is due to the tectonics involved in the thrusting action of the Appalachian uplift. The Load-Haul-Dump concept of mining is employed in the actual extraction of the salt. Here the faces have been undercut with Joy Universal Undercutters; drilled with auger rods tipped with tungsten bits and shot. The broken salt is loaded out with Joy, arm type loaders gathering the salt into shuttle cars. The shuttle cars discharge the salt onto the mainline belt which travels 4.1 miles into the Fuller Shaft bottom. The salt has an average sodium chloride content of 98.3%.

Basically, all shafts in the Fuller Shaft area are dry with only minor amounts of ground water weeping into the shaft at totals of only a few gallons per hour. The rock salt and overlying shale are extremely dry with the salt being a "dusty" salt because of the lack of interstitial moisture. Underlying the B3 Subunit is a soft green shale which in some areas flows plastically from under the pillars causing floor heave. These Vernon shales are interbedded with dolomites and argillaceous anhydrites. No roof problems are experienced and only in areas where continued

occupancy is expected are any roof bolts used.

Only one known fault exists in the Retsof Mine. This fault is not in evidence in the mine workings themselves but rather in a slope which extends down into the B2/4, B2/3 and B2/2 beds (Stratigraphic Log #1). This fault which is the result of a thrusting action has been sealed by the plastic flow of the salt in these beds. The fault exposure is several hundred feet wide and extends for a known distance of 5,000 feet in roughly a north-south direction.

The principal value of the Retsof Mine as a possible demonstration site is shown in Sketch #1. Here is illustrated how the Greigsville Shaft and the mined out area surrounding the shaft can be isolated from the mine workings by the simple installation of a plug in a single entry.

It is evident from the random pillar shape and size that some floor heaving has occurred but the shaft is sufficiently close to virgin salt so that an incline could be driven up into the overlying shale. From a predetermined elevation in the shale,

a horizontal tunnel can be extended over the B3 salt bed. Holes 20 inches in diameter could easily be drilled through the shale and into the salt. Ramping and drifting in this shale to develop headings 24 feet high and 36 feet wide would cost approximately \$200 to \$250,000. This would leave only 10 to 20 feet of salt exposed to the bore of a hole.

A second possible approach would be in the use of the slope which extends down to the B2/2, B2/3 and B2/4. By turning off this slope in the rock above the salt, a tunnel (24 ft. x 36 ft.) can be driven in the dolomites. This would be just above the B2/4 which would expose a full 30 feet plus of salt contained in the B2/4, B2/3 and the B2/2 to the bore of the storage hole.

If this possibility was actually developed, it would be necessary to drive a drift from the slope to the shaft (Greigsville) and raise to the present shaft bottom. Again, we would estimate that a 24 foot by 36 foot tunnel would cost about \$200 to \$250 per linear foot in this ground.

Bedded Salts

1. New York

c). Cayuga Mine

The Cayuga Mine is located on the Portland Point anticline near Ludlowville, New York, some 15 miles north of Ithaca on the east shore of Lake Cayuga.

For many years, the mine was operated by the Cayuga Rock Company who had taken advantage of the salt flowage associated with the anticline and mined the loaf-like lenses of the F Unit of the Salina.

Attached is a "Stratigraphic Section for Well #2 and Well #20. This flowage is illustrated in part by two core holes located north of the mine. Core Hole #1, Well #2 was located some 10,000 feet north of the mine and Well #20 approximately 17,000 feet to the north. Core Hole #1 was drilled in the bottom of an abandoned brine cavity. The thickening and thinning of the salt while directly related to salt flowage, may be in part due to low angle thrust faulting.

Subsequent to the purchase of the mine by Cargill, Inc., incline slopes were driven to the upper bed of the D Unit. In local terminology, this is bed #5.

The original shaft was a 7' x 21' rectangular shaft

STRATIGRAPHIC SECTIONS FOR WELL #2, CORE #1, & WELL #20.
LUDLOWVILLE, NEW YORK

CORE HOLE 1, WELL #2

WELL #20

which was not lined due to the lack of ground water in the area. This 3 compartment shaft still services the mine today and the hoist shaft. Wood timbers, buntons, posts and guides were found to be in excellent condition during a recent visit. Three shafts now service the mine. These are the original shaft, a 60" shaft drilled with cable tools and a recently completed raise bored shaft.

The original mine workings are elongated rooms and pillars. These rooms conformed with the shape of the deposit which consisted of a series of parallel lenticular masses where the salt had been squeezed. Structure Contour Map #1 shows the top of the F-1 salt with the trough axes trending in an east southeast direction. The forces which were applied to this bed of salt cause the thickness to thin to as little as 4 feet in places while developing a trough thickness of over 100 feet. As described in Vol. 53 #1, January 1969 of American Association of Petroleum Geologists, these troughs are cut by a series of peridotite dikes which cut across the troughs at near perpendicular trends. (Magnetometer Survey). Associated with these dikes are sills which cover the area through various bedding planes.

Structural Contour Map #1

MAGNETOMETER SURVEY
OF THE
LUDLOWVILLE AREA
1959

CONTOUR INTERVAL: 10 GAMMAS
SCALE 1:24000

- EXPLANATION -

⊙ SALT WELL

■ CORED MINE SHAFT

◇ MAIN MINE SHAFT

--- INFERRED OUTLINE OF BRINE CAVITY
— OUTLINE OF CAYUGA ROCK SALT CO. MINE
PLOTTED FROM MINE SURVEY MAP OF
1924 & 1935

— DIKE

- - - POSSIBLE DIKE

Only very minor quantities of ground water occur in the area and this mineralized water occurs in the area of the Oriskany sandstone.

Because of the rough and erratic configuration of the mine workings in the F₁ salt, (Mine Map #2) activity in this upper level would be extremely difficult, if not impossible. The lower level which works the D Unit salts is the active mining area. Roof problems have been reported in this lower portion of the mine.

We would not recommend this mine as a demonstration site.

Map #2

COPY OF
CAYUGA ROCK SALT CO INC
MYERS N.Y.
MINE SURVEY OF 1928 LEVEL
SCALE 1" = 400'
BY

SHORE LINE

NOTE:
BROKEN LINES DENOTE SURFACE FEATURES

Bedded Salts

2. Ohio

a) Fairport Mine

The Fairport Mine of the Morton Salt Company is located on the Grand River in Painesville, Ohio. Two 16 foot diameter shafts service the mine. These shafts which are 150 feet apart are concrete lined and equipped with Koepe hoists. The first bedded salt encountered in the Production Shaft was 20 feet thick and 5 feet in the Service Shaft. The second salt bed which houses the mining operation at 1920 feet was 25 feet thick at the Production Shaft and 41 feet thick at the Service Shaft. Reportedly, a major normal fault was encountered in the Production Shaft in the top salt during shaft sinking. This was an open fault which was covered when the concrete liner was poured. "Fairport Mine - Core Hole #1", a copy of which is attached, does not conform with foregoing information.

The mine is a room and pillar system with a production capacity of approximately one million tons per year. Some serious problems were encountered originally with regard to roof stability. This was related to

Fairport Mine
Core Hole #1

the petrofabrics of the rock salt and the direction of the rooms.

The arrangement of the surface facilities is shown on the accompanying sketch.

Conclusions & Recommendations

We can not recommend the Fairport Mine as a demonstration site due to the faulting which has occurred within the salt horizons. Evidence of this faulting has reportedly appeared in the shaft. With regard to roof problems, differences in salt thicknesses between the two shafts and again between the shafts and exploratory core holes indicate possible low angle thrust faulting as a possible cause for mine roof problems. In addition to structural problems within the mine and known tectonic problems within the salt formations of the area. Diamond Shamrock has a huge brine-field several miles in length and several miles in width. Well #18 is the closest old well to the mine shafts, a distance of 4,000 ft. Known surface subsidence is approximately 2,000 ft. from the mine shafts. Thus, it is obvious that the walls of the mine workings and the brine cavity are much closer than the straight line distance between the bore of Well #18 and the centerline of the shafts. The mine is at atmospheric pressure while the wall rock of the brine cavity at the same stratigraphic elevation is roughly 1,100 p.s.i.

LAYOUT SKETCH
MORTON SALT COMPANY
PAINESVILLE OPERATION
FAIRPORT MINE

- A-WAREHOUSE
- B-MEN & MATERIALS SHAFT
- C-COMPRESSOR HOUSE
- D-PERMANENT CHANGE HOUSE
- E-CARPENTER SHOP
- F-MAIN SHAFT
- G-MECHANICAL SHOP
- H-MORTON CONSTRUCTION OFFICE

Bedded Salts

2. Ohio

b) Cleveland Mine

The Cleveland Mine is located on Whiskey Island in downtown Cleveland, Ohio. The mine workings are serviced by two 16 foot in diameter shafts located 600 feet apart. Mining is conducted on the 1770 foot level in the F₂ section of the Salina by the room and pillar method of mining with a capacity of in excess of 2,500,000 tons/year. The bed varies in thickness from 40 to 46 feet with the mine openings averaging about 14 feet. (Cleveland Stratigraphic Column). Underlying this salt strata are a series of thin beds, the largest of these has a thickness of approximately 40 feet. The interbedded layers of insoluble strata are composed of shales, dolomites and anhydrite with the dolomitic materials predominating.

The salt is "dry" with little or no interstitial moisture. As one progresses upward through the stratigraphic column from the mine workings, the only water found before encountering that in the glacial drift is in the Oriskany sandstone at a depth below surface of 1313 feet to 1388 feet. This

75 feet of sandstone contains a saline fluid high in sodium, calcium and magnesium. Analysis of this fluid shows 500 p.p.m. hydrogen sulphide and 400 p.p.m. ammonia.

The accompanying Mine Map #1 shows a fault dividing the mine into two areas where the room and pillar system of mining is conducted. In the area surrounding the shafts on the extreme southern portion of the map only 18% extraction was allowed in order to preserve the shaft stability. The elongated pillars developed by a continuous miner during the early phases of operations were found to be no stronger than their minimum width due to a lack of confinement in the short dimension. After crossing the fault a systematic room and pillar pattern was followed.

Since the commencement of mining operations in 1962, over 700 acres of salt have been mined from this bed with all extraction currently being produced from the area under Lake Erie. Stability of openings can be achieved at the depth of 1770 feet in this salt by limiting extraction to 50%.

Mining is accomplished by the use of the Load-Haul-

Dump concept where the faces are undercut to a depth of 12 feet; 60 holes are drilled and blasted using ammonium nitrate as a blasting agent; payloader using 16 ton rock buckets scoop the salt up after fragmentation and load it into a portable primary crusher. A mainline belt hauls this minus 6" material into the preparation station near the shaft bottom, where secondary and tertiary crushing reduces the material into the four commercial grades of rock salt. Underground storage bunkers with some 30,000 tons of storage capacity give the operation the necessary flexibility with regard to surges.

Conclusions

Because of the near shore location of the two shafts and the off shore location of the mine workings, together with the chemical composition and volume of the Oriskany brine, it is difficult to see how the Cleveland Mine could be used for a demonstration site. A third shaft would be needed in order to provide satisfactory ventilation so that the demonstration site could be isolated. The primary fault is a sharp normal fault with a throw of some 57 ft. A heading could be driven through the east-west trending fault so

that it would be contained within the top salt layer and heaters could be lowered into holes drilled into the current mining level.

Drilling a shaft to the mine level would be difficult only because of the Oriskany sandstone and the fluid and gas it contains. In order to adequately protect the mine workings from intrusion of brine and/or gas special precautions would need to be taken. Numerous means of securing this protection are available, but all would be time consuming and expensive. Some of the steps which might be taken would be:

- 1) Water flood the Oriskany with potable water.
- 2) PregROUT the entire area surrounding the proposed area with massive volumes of formulated cement grout to be followed by special low viscosity chemical grouts.
- 3) Drill a shaft of sufficient diameter to insure a goodly thickness of cement behind the shafts steel liner.
- 4) Use a steel liner capable of withstanding the attack of the chemicals contained in the Oriskany brine.

Recommendations

I recommend against the use of this mine primarily because of the time element involved.

Bedded Salts

3. Michigan

a) Detroit Mine

The Detroit Mine, owned by the International Salt Company, is located in the city of Detroit, near the River Rouge turning basin. The mine is serviced by two shafts which penetrate the Salina formation and afford entrance to the mine workings in the F₂ salt at 1,180 feet.

Page #2 of the "Detroit Mine Stratigraphic Column" depicts the F₂ salt as the B Bed. This is local terminology which has never been eradicated. Shaft #1 was started in 1903 and completed to the A Bed in 1907. The 27 feet of salt that constitutes the A Bed was very impure and operations were moved to the B Bed. The salt of the A-1 Bed was so poor in quality that only recently has it been defined as a salt bed.

In 1937 the present Production Shaft was sunk to the B Bed where all operations have been conducted until the present time. Operations are on a room and pillar system with over 700,000,000 cubic feet of space having been created. The height of rooms

Shalt. Surface Elevation at site 350 ft.

Stratigraphic Column

Riopelle

varies between 18 and 24 feet in keeping with the thickness of the salt bed. Usually, the thickness of salt that remains in the roof for roof control is 42 inches. Above this is a layer of insolubles which are the residual material of a previously dissolved bed of salt. These insolubles have formed an incompetent layer of shale. Above this shale is a hard dolomite which forms the anchorage for any roof bolts which may be installed. Only in cases where personnel and equipment are permanently protected are roof bolts installed.

The salt which composes the bed is uniformly layered throughout the exposed portion of the deposit with relatively few anomalies. Similarly, the chemical composition of the bed is uniformly 97.5% NaCl. Those anomalies which do exist are masses of recrystallized halite which are post depositional. Small quantities of connate water and trapped pockets of methane occasionally occur at the contact between the top of the B Bed and the overlying shale.

Below the B Bed of salt is a bed of anhydritic dolomite which varies in thickness from 4 to 5 feet. Underlying this dolomite is a 50 foot bed of salt,

the F₁ or C Bed as it is locally termed.

Mining is conducted by the room and pillar system of mining with the face of the heading being undercut with a 15 foot bar of a universal under-cutter. The face is drilled with 54 holes that are loaded with ammonia nitrate and detonated. The fragmented salt is loaded into bottom dump trucks which vary in capacity from 50 to 100 tons. The salt is dumped into a 200 ton surge bin which feeds a tooth roll which crushes the salt against a steel plate. The minus 6 inch discharge from the crusher is carried on a conveyor belt to the preparation station where it passes through secondary and tertiary crushers. The material is screened into the four commercial grades.

As delineated on the attached map of the Detroit Mine workings, mining has progressed approximately 4.5 miles west of the shaft locations. Roughly, the east-west direction has been a result of mining salt reserves under the Wabash Railroad. This direction conforms with the strike of the beds. Those reserves still unmined to the west lie under the Ford Motor Company property.

INTERNATIONAL SALT COMPANY

DETROIT MINE

The shaft area of the Detroit Mine can be isolated from the working faces of the active mining area by several different configurations. The shafts, which are 300 feet apart are already isolated from each other in the underground workings. In all cases which the author can envision, a new shaft would need to be constructed in the area of the Ford Motor Company property. Additionally, either of the existing shafts could be isolated, together with sufficient mined space to accommodate a demonstration site.

Conclusions & Recommendations

It is possible that certain areas of the old workings may have room heights which are insufficient, i.e. 22 feet. We believe this could be overcome by shooting down the 3-1/2 feet of roof salt, together with the 4-1/2 feet of incompetent shale. This would expose the structurally strong dolomite. Roof could be

GENERALIZED COLUMNAR SECTION OF MICHIGAN

MICHIGAN GEOLOGICAL SURVEY DIVISION

SYSTEM. SERIES	FORMATION. GROUP	THICKNESS
RECENT		
PLEISTOCENE	GLACIAL DRIFT	0-1000
"PERMO-CARBONIFEROUS"	"RED-BEDS"	
	GRAND RIVER	80-95
PENNSYLVANIAN	SAGINAW	20-535
MISSISSIPPIAN	BAY PORT	2-100
	MICHIGAN	0-500
	"MICHIGAN STRAY"	0-80
	MARSHALL	100-400
	COLDWATER	500-1100
	SUNBURY	0-140
	BEREA-BEDFORD	0-325
	ELLSWORTH-ANTRIM	100-950
DEVONIAN	TRAVERSE	100-800
	BELL	0-80
	ROGERS CITY-DUNDEE	0-475
	DETROIT RIVER	150-1400
	SYLVANIA	0-550
	BOIS BLANC	0-1000
SILURIAN	BASS ISLANDS	50-570
	SALINA	50-4000
	NIAGARAN (Guelph-Lockport-Engadine) (Manistique-Burnt Bluff) (Cataract)	150-800
ORDOVICIAN	CINCINNATIAN (Richmond) (Mayville-Eden)	250-800
	TRENTON-BLACK RIVER	200-1000
	ST. PETER	0-150
OZARKIAN OR CANADIAN	PRAIRIE DU CHIEN	0-410
	HERMANVILLE	15-500
CAMBRIAN	LAKE SUPERIOR (Munising) (Jacobsville)	500-2000
ALGONKIAN	KEWEENAW (Copper formations)	9800-35000
	KILLARNEY GRANITE	
	HURONIAN (Iron formations)	2000+
ARCHEAN	LAURENTIAN	
	KEEWATIN	

CHARACTERISTIC
GAMMA RAY CURVE IN
SALINA SALT SECTION

NOT TO SCALE

"G" UNIT
F UNIT
E UNIT
D UNIT
C UNIT
B EVAPORITE
A-2 CARBONATE
A-2 EVAPORITE
A-1 CARBONATE
A-1 EVAPORITE

NIAGARAN

"CLINTON"

bolted, meshed and guniting in order to furnish any additional protection which might be required.

The Detroit Mine would appear to be a good site prospect.

Bedded Salts

4. Kansas

a) American Mine

It has recently been reported that the American Mine was offered for sale by the owner at a price of \$2,000,000. The American Mine is located immediately south of the town of Lyons, Kansas. The location and configuration of the mine is shown on Map #1.

In 1968 the Lyons Mine of the American Salt Company gave the general impression that they were producing salt at a cost approximating \$1.00 to \$1.25 per ton. Safety and maintenance were poor. About 1960 the general condition of the mine and surface structures reached a low ebb. Since that time, considerable money and effort has been expended in revitalizing facilities. These general impressions are based on the following observations which were made by the author:

1. A single 12' by 24', 3 compartment shaft, penetrating the minable salt at a depth of 1,000 feet was sunk in 1918.

Map #1

2. A 70 second cycle or 45 hoists per hour lifted a cage and one 1,000 pound car per cycle to the surface.
3. Each car was loaded with two tons of salt.
4. The hoist was a Nordberg with a single drum counter-balanced skip using a 1-1/4" cable.
5. The headframe was wooden and in an exceptionally poor state of repair, as were the thimbles, bails, guide shoes and guides.
6. Plans call for an immediate installation of a new headframe together with regular skip hoisting of aluminum skips. They will shut down for two weeks during the coming summer to install this prefabricated headframe.
7. Salt is hauled from the primary crushing station to the shaft bottom in standard 2 ton western style steel ore cars.
8. Maximum production occurs during the winter months when the regular crew of 10 men work 6-12 hour shifts per week. During the slack summer months, they work 2 to 3 eight hour days per week.

9. Underground mining equipment consists of:

- 2 - Joy 60E battery operated shuttle cars.
- 2 - 12 A.A. short-wall Goodman undercutters.
- 2 - 11 BU Loaders.
- 1 - Drill - Long Airdox (single drill).

Only one of the 11 BU Loaders is in operation at any one time.

10. The ten operating personnel were distributed as follows:

- 1 - Hoist Operator
- 1 - Skip Tender at bottom
- 1 - Motorman
- 1 - Car Loader
- 2 - Shuttle Car Operators
- 1 - Driller
- 1 - Joy Loader Operator
- 1 - Utility and Powderman
- 1 - Foreman

11. Average wage is \$2.47 per hour.

12. The union is the Chemical Workers.

13. The battery operated shuttle cars were exceptionally slow. Reportedly, they did last a 12 hour shift without recharging. Maintenance is high.
14. All mine maintenance except major overhauls is accomplished by the equipment operators. Where major repair work is required, surface maintenance personnel from the mill and evaporating plant are used.
15. The pattern of drill holes consists of 3 lines of 11 holes in the 9 foot by 42 foot face.
16. Holes are 1-5/8" diameter, 9 feet deep.
17. Ammonium nitrate fuel oil is used with a collar priming of 1-1/4" x 8" A.N. dynamite and electric delay caps.
18. The faces are undercut to a depth of 8 feet. Approximately 220 to 240 tons of salt is broken per face blasted. Regular tungsten carbide insert bits are used.
19. Although the pillars which are 50 feet x 50 feet with 42 foot faces result in a low 70.5% extraction, they exhibit spalling that, in some cases, approaches a crushed condition.

20. Roofs in working areas appear to be dangerous. No roof bolts are used.
21. In work areas an extra 5 to 6 feet of salt had been shot down. This exposed a thin clay shale parting that appeared to aerate and hydrate on exposure to air, causing a separation at this point.
22. Considerable floor heave is encountered. A sharp salt shale contact approximately 9" below the undercut together with a flowage factor gave rise to this condition.
23. Electric current taken underground close to the mine face was 2,300 volts. This was converted to 440 V current.
24. Loading and transporting from the mine face was very inefficient. Due to the slow tramming speeds and the use of only two shuttle cars, not only were the shuttle car operators producing a low tonnage per man-hour, but the loader-operator was less than 50% employed. It was also my impression that the equipment operators were poorly trained.
25. Trains of 15 to 20, 2 ton ore cars are hauled

from the primary crusher to the shaft bottom by battery operated electric motors. Studies are currently underway to convert this system to a trolley system, or possibly belts. The rails were 60 pound 42 inch gauge road.

26. The primary crushing station was very interesting. The shuttle cars emptied onto a slat-type chain conveyor which fed a pick-point Blake type modified jaw crusher. Instead of crushing against the customary solid steel jaw, the pick-point-studded jaw crushed against a series of serrated bars. This gave a very uniform minus 6" feed for the secondary crusher. During the winter period of high production, what appeared to be minus 8 mesh material was screened out and stored. During the summer this material was reclaimed. The entire underground plant could be disassembled, moved and reassembled in 40 hours with the present work force.

27. A new mill building designed by Allen Garcia had been constructed in about 1960. This building was exceptionally well designed. The ore cars were dumped into a 200 ton bin that fed a crusher which discharged to screens with the

oversize going to secondary crushers which in turn fed screens. The screened product was fed into partitioned bins. These parabolic shaped bins had bottoms constructed of "stacked" two-by-four's held in shape by steel framing. These bins could feed to bulk rail cars on one side of the building, bulk trucks on the other or to bagging machines. Bags were picked up by a conveyor and carried about 500 feet to the center of a warehouse where again, trucks were serviced on one side of the building and rail cars on the other. Rock salt was bagged in 100 lb. bags, 50's and 25's. The design of this building facilitated good house-keeping, easy maintenance and good working conditions.

28. Annual production: 500,000 tons.